A MULTIVARIATE AND GEOSPATIAL ANALYSIS OF ICT UTILIZATION AND THE DIGITAL DIVIDE IN AFRICAN NATIONS

James Pick, School of Business, University of Redlands, 1200 E. Colton Avenue, Redlands, CA 92373, 909-748-8781, james_pick@redlands.edu
Avijit Sarkar, School of Business, University of Redlands, 1200 E. Colton Avenue, Redlands, CA 92373, 909-748-8783, avijit_sarkar@redlands.edu
Jeremy Johnson, School of Business, University of Redlands, 1200 E. Colton Avenue, Redlands, CA 92373, jeremy_johnson@redlands.edu

ABSTRACT

This exploratory empirical study examines the extent of differences in information and communication technology (ICT) utilization and enhances understanding of factors that impact ICT utilization and the digital divide in African countries. In our conceptual model of ICT utilization, five dependent indicators of ICT that include social media technologies 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. Laws that relate to the use of ICTs are a dominant predictor of all forms of ICT utilization, a novel finding. The effectiveness of a national parliament as a lawmaking institution is significantly associated with modern (broadband) as well as legacy forms (fixed telephones) of ICT. Gross national income per capita is determined to a dominant predictor for three ICTs and mobile tariff is negatively associated with mobile cellular subscribers.

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 determine factors that impact ICT adoption and usage in the African nations. According to the UN, Africa is the second largest continent behind Asia in terms population (estimated to be 1.03 billion in 2010). However, a large majority of nations in the African continent, especially nations in sub-Saharan Africa are classified as low income or lower middle income nations [1]. Exceptions are Algeria, Libya, South Africa, Botswana and Namibia. African nations also fare poorly in terms of social, health, and economic indicators such as life expectancy, undernourishment, participation in education, unemployment, poverty, etc.

ICT adoption and utilization in many African nations have lagged behind those of their more industrialized counterparts in other continents. 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 [2]. 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 [2]. In 2005, Africa with an estimated 14% of the world's total population accounted for less than 2% of the world's internet usage. However this has improved noticeably, and at present, Africa with an estimated 15.3% of the world population accounts for 7% of the world's internet users. Africa's internet penetration rate is 15.6% (of total population) in 2012 [3], lagging behind the worldwide rate of 34.3%

and far behind the rates of North America (78.6%), Europe (63.2%), and Latin America/Caribbean (42.9%).

This 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 level. (2) Unlike typical digital divide studies that concentrate on one particular ICT, we consider five different forms or indicators of ICT – broadband, fixed/landline telephones, mobile phones, internet, and virtual social networks. (3) In addition to standard multivariate analysis of the predictors of Africa's ICT adoption and utilization, we employ spatial analysis of the predictors 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 helps us determine if regression findings are spatially biased and help explain such results based upon spatial agglomerations of the ICT dependent variable. The research questions are: (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?

LITERATURE REVIEW

Literature on ICT availability, adoption, and diffusion, and the digital divide is vast, including empirical literature that attempts to understand influences of various factors on ICT adoption and utilization. Sometimes this literature adopts frameworks of social reproduction [4] and institutional factors [5] as theoretical foundations. Most empirical studies have found that income, education, and infrastructure are key determinants of ICT penetration. In more specific contexts, for example for developing economies, or for specific ICTs such as PC 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.

Empirical studies that have examined the influence of factors on ICT utilization in Africa are rather limited. The effect of economic, human development, political, and population conditions on ICT capacity in African nations was investigated in [6]; the study 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, expenditures per student, and health expenses as percent of GDP. The association of internet diffusion in sub-Saharan Africa with human capital, telecom infrastructure investment, PC density, telephone density, presence of internet hosts, and economic wealth estimated by GDP per capita as independent predictors was examined by [7] which 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. Another investigation [8], examined the influence of economic development, 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 and determined that presence of English as an official language, monopoly ISP market structure, overall economic development, and the amount of international bandwidth are the strongest predictors of internet subscription. A study [9], 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. The study determined that openness of the economy is the sole significant predictor of the extent of digitization as measured by the IT index and rationalized 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 are located along the oceanic coastlines with unfettered access to the global economy and trade flows.

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 investment in ICTs especially in telecom to build infrastructure, (ii) deregulate telecom markets to encourage competition, (iii) simplify licensing regimes, (iv) provide state support for infrastructure development in areas where private operators will be hesitant to invest, (v) encourage use of ICT at elementary and secondary levels of education, (vi) specifically use PCs at the individual level as well as organizational level at educational institutions, small businesses, and governmental organizations to build human capacity, (vii) support growth of internet hosts, preferably in the native-language, and (viii) expand international internet bandwidth.

CONCEPTUAL MODEL

Based on prior literature and authors' inductive reasoning, a conceptual model is proposed and justified. A stream of theoretical study that relates the present study of Africa is World Systems Theory. This theory considers the developed and developing nations of the world as a set of interdependent societies that tend to strengthen world stability. The world is viewed as a global economic system that includes a division of labor. Groups of nations are viewed as dominant or dependent for periods of time, 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 [10]. In the present study, world systems theory forms a theoretical basis to understand evolving relationships within the continent of Africa, which traditionally was regarded as entirely peripheral. 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 nations within Africa, and the relationships between them.

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 relate together 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 detailed conceptual model has justifications from prior studies.

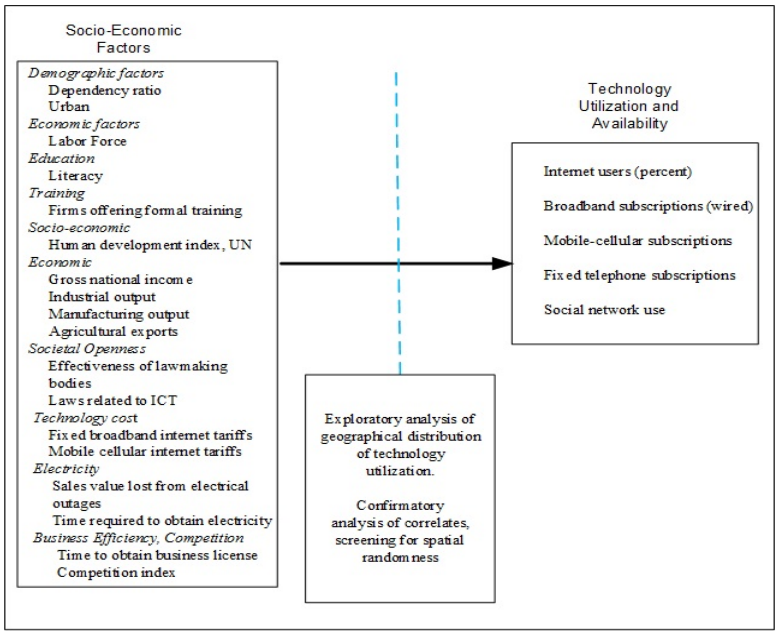

Figure 1. Conceptual Model, Technology Use in African Nations

METHODOLOGY AND FINDINGS

Data for various dependent and independent variables were obtained from the World Bank's World Development Indicators database (2012), World Telecommunications/ICT Indicators Database of the International Telecommunications Union (2012, 2013), World Economic Forum's Global IT Report (2012), and the International Human Development Indicators database produced by the UN Human Development (2013). The dependent variables were first tested for spatial autocorrelation. To explore the continent's geographical agglomerations, based on the ICT dependent variables, K-means cluster analysis is employed and maps are produced to identify spatial agglomerations of nations. Next, OLS regression is performed for five dependent variables (see Figure 1), based on eighteen independent variables. Variables were pre-tested for multi-collinearity and regression residuals were screened for spatial autocorrelation using Moran's I to check for the presence of spatial bias.

The descriptive statistics show that technology use in Africa is at a low level by worldwide standards. In 2012 the average proportion of individuals using the Internet and fixed broadband for the African nations was 13.8% and 1.0% respectively, much lower than the world averages of 41.3% and 9.8%. 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. This paper analyzes and explains this variation. The moderate differences for social network use can be ascribed to its utilization predominantly by more educated people in metropolitan areas. For the independent variables, Africa's lower worldwide development level is evident.

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 excluded in the cluster analysis due to its many missing values and its high correlation with Internet users, broadband subscriptions and mobile phone subscription. Clusters 1 (Egypt, Mauritius, Morocco, South Africa, Tunisia) and 5 (Libya, Seychelles) stand out as much higher than the other clusters, with internet usage corresponding to world average and broadband corresponding to half of world average. For them, mobile phone subscriptions are 40% above world average reflecting leapfrogging and lower cost relative to their more prosperous economies. These 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 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 demonstrates Africa's historical greater urbanization/industrialization on its coasts. Clusters 3 (Angola, Burundi, Eritrea, Liberia Rwanda, Uganda, etc.) and 4 (Botswana, Gabon) tend to be located in the northwest, central west, and southern parts of the country, with exceptions of Sudan and Kenya. About half are coastal and they are agglomerated geographically. These nations have low internet use and almost no broadband use by world standards; mobile phones are somewhat higher than world average, reinforcing that cellphones are Africa's most widespread and primary ICT. At the low end for the continent is Cluster 3, comprising mostly central and eastern countries in which ICT use levels are among the world's lowest.

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 (GNIPIC) and urban variables are very significantly correlated, two sets of regression runs were done: (i) with *GNIPC included, urban excluded* and (ii) with *GNIPC excluded, urban included*. For the full sample (N = 51 nations) with GNIPC included, factors in the societal openness and economic categories dominate. The most important correlate 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 and its enforcement and necessitate greater information exchange, consequently opening up 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 with 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 correlate 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 subscriptions and social networks. For the "lower tech" 44-nation sample, 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 the effect of ICT laws 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 mentioned earlier.

IMPLICATIONS AND CONCLUSIONS

The study findings demonstrate that Africa's relatively high-tech countries are located in 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. This is explained by the greater industrial and urban development of these parts of the continent due to their proximity to ocean transport and earlier history of economic development. The more central, agricultural sections of the continent did not have the transport advantages and were too remote to industrialize and develop large cities. In terms of world systems theory, we regard Africa's coastal nations as core and the central nations as periphery. It can be expected that in the 21st century more of central Africa will industrialize/urbanize, especially since population is growing rapidly, a trend implying greater use of ICTs. Economic, societal openness, demographic factors particularly urban, and technology cost are strongly associated with ICT utilization. Education and literacy, so influential in the literature, have no impacts for Africa. An explanation is 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 more understandable if its recent influence at the national level 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 interpreted as less important in the 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 measurement of spatial autocorrelation proves useful as a gauge of how much the 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 spatially biased findings.

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