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GLOBAL DIFFUSION OF THE INTERNET XII: THE INTERNET GROWTH IN AFRICA: SOME EMPIRICAL RESULTS

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ABSTRACT

This study identifies the significant factors affecting Internet growth levels at an early stage of growth in African nations. The average growth levels of Internet users for 1995 and 2003 are calculated and the associations between Internet growth level and several types of factors such as economic, educational, institutional, infrastructural, innovation-related, and environmental factors are examined. Human development, higher education, technology availability, and computer growth levels explain more than 84 percent of the variance in African Internet growth levels. When compared to non-African nations, Africa lacks the influence of institutional variables. Compared with a set of economically similar developing nations (based on similar GDP per capita and income inequality levels), Africa has different Internet growth levels, even though the number of Internet hosts per 1,000 and delays in starting Internet diffusion are similar. These differences are probably due to lack of education, human development, infrastructural and environmental variables.

Keywords: ICT in Africa, Developing nations, Internet growth, Growth level, Growth factors, ICT diffusion, Matched-pair comparisons.

I. INTRODUCTION

Africa has shown a lower economic growth level than most other developing nations over the past thirty years [Ofodile 2001; Bernstein and Goodman 2005]. It is generally acknowledged that information and communication technology (ICT) is important for developing regions, such as Africa, since economies that successfully adopt ICT have benefited from its impact in all aspects of business transactions [Gutierrez and Berg 2000; Fomin et al, 2005; Rada 1985; Bennet and Kalman 1981; Tottle and Down 1983]. Nonetheless, despite the benefits experienced by other nations, African nations are still lagging in ICT adoption. African nations need to accept ICT as a priority measure for development and invest accordingly [Shibanda and Musisi-Edebe 2000]. Danowitz et al. [1995] have pointed out that the use of ICT in North Africa is essential for efficient business practices and for improving living standards, literacy, and trade.

The Internet is an example of ICT with profound worldwide impact and popularity [Bernstein and Goodman 2005; Wolcott and Goodman 2003; McCoy and Mbarika 2005]. Consequently, we need

to understand how Internet growth is occurring in Africa, what prompts, or inhibits, usage, and how Africa compares to other sets of nations.

The diffusion of ICTs is not uniform among African nations. For example, São Tomé and and Príncipe (2.82 Internet users per thousand) and Seychelles (6.54 Internet users per thousand) have much higher levels of Internet diffusion than the Democratic Republic of Congo (0.001 Internet users per thousand) and Ethiopia (0.00018 Internet users per thousand). By some estimates, in parts of Africa there was about one Internet user for every 250-400 people in 2002, while globally about one person in 15 used the Internet [Anonymous 2002]. For the same year, half the inhabitants of North America and Europe were Internet users [World Bank 2005a]. Although African nations lag behind other nations in technology adoption [Hamilton 2003; Roycroft and Anantho 2003; Udo and Edoho 2000], few empirical studies have investigated the factors affecting Internet diffusion levels in this part of the world.

The important research questions that need to be addressed are:

- What factors are important for Internet growth levels? Are the impacts of these variables different in Africa than in the rest of the world (ROTW)?
- Are African nations falling behind in Internet growth compared to the ROTW – as indicated by Internet growth factors?
- Does Internet growth in African nations differ from Internet growth in economically similar developing nations? What factors influence the differences?

To address these questions based on the existing literature, we consider six groups of factors at a national level that may impact Internet growth: economic, educational, infrastructural, institutional, environmental, and innovation variables. Within Africa, these factors vary widely from one nation to another. For example, in the year 2000 the illiteracy rate (an educational variable) in Burkina Faso was 76 percent while in South Africa it was only 16 percent. For Sierra Leone, the GDP per capita (an economic variable) was $148 (in 1995 U.S. dollars) while in Gabon it was $4,378. Inflation (an economic variable) also varied widely in the year 2000, with Equatorial Guinea having a rate of 52.17 percent and Ethiopia registering only 1.4 percent. Considering the fact that no two developing nations are alike [Austin 1990], our intent is to identify the common growth factors that affect developing African nations.

While many of these factors have been investigated previously, they have received attention as either the sole variable of interest or in conjunction with a few other variables, and either in a selected group of nations (e.g., a few developing nations) or in a specific nation (e.g., the US). The present study investigates these factors to determine which, if any, significantly impact ICT adoption in Africa. The study contributes to the existing body of knowledge as follows:

1. It empirically investigates all six groups of factors, whereas, to the best of our knowledge, no single past study has ever done so.
2. No previous study has used all of these variables in the context of African nations.

Also innovation indicators have not been studied in cross-national studies.

In the following sections, we develop a theoretical model based on previous studies and discuss each of the groupings of variables and the individual variables that constitute the groupings. We then further develop the research questions before presenting the methodology, data sources, results and findings in that order.

II. THE THEORETICAL MODEL

ICT diffusion has been studied from various viewpoints [Fichman 1992; Kwon and Zmud 1987; Ho 2005]. Wolcott, Press, McHenry, Goodman, and Foster [2001] observed that factors such as

legal, economic, political, and social conditions that surround Internet users also affect the level of adoption in the country. Bagchi et al., [2004] found that economic, educational, and institutional factors matter in ICT diffusions. Milner observed that aside from technological and economic factors, environmental factors such as domestic and political institutions play a role in Internet diffusion levels [Milner 2003a and 2003b]. Beilock and Dimitrova [2003] found that economy, openness of a society, and technology infrastructure such as telephone and personal computer densities do impact Internet user per capita of a nation. In addition, there is a need for institutional variables to explain the diffusion of ICT in general in Africa [Wilson and Wong 2003].

In a recent release, the World Bank's Knowledge for Development (K4D) program introduced several sets of variables that can be considered pillars of a knowledge economy [World Bank 2005b]: economic and educational, institutional, information infrastructure, and innovation-related. Except for innovation variables, we described these indicators in relation to ICT and Internet diffusion before. We now conjecture that innovation variables may also play a role in ICT and Internet growth, as innovativeness in a nation makes it more aware of ICT and thus encourages diffusion [Stoneman 1991; Cohen and Leventhal 1989].

The focus of the present study is on national-level factors. The national-level factors[1] responsible for ICT diffusion in general have been investigated in the literature to some extent. It would be helpful to use an existing framework to assess the role of various factors in Internet adoption in a nation such as the Global Diffusion of the Internet (GDI) framework by Wolcott et al. [2001]. This framework consists of six dimensions used to describe the state of the Internet within a country: connectivity infrastructure, organizational infrastructure, sophistication of use, pervasiveness, geographic dispersion and sectoral absorption. Determinants of dimensions can be identified that cause the states of these dimensions. Many research results on Internet diffusion in a given nation are derived using this framework [Wolcott et al. 2001; Goodman et al. 1994; Press et al. 1997; Wolcott and Goodman 2003; Foster et al. 2004; Bernstein and Goodman 2005; Ho 2005]. However, some of the dimensions require experts to evaluate and rank each country for each individual characteristic, which can only be done through a detailed case study for each nation. In the absence of a framework, our research focus is therefore on proposing a model consisting of different categories of factors that could be useful for studying Internet diffusion among nations. Figure 1 shows the model proposed in this research paper.

The model has only one dependent variable: the Internet growth level (Internet users per 1,000). We do not consider the Internet growth rate in this study since the growth level is an indicator of technology penetration, whereas the growth rate is an indicator of the speed at which penetration is taking place.

The independent variables are explained in detail as follows:

ECONOMIC VARIABLES

The economic variables considered in the above model are (1) the economic growth level, (2) the economic growth rate, (3) inflation, and (4) human development.

Economic Growth Level. The economic growth level of a nation (usually measured by GDP per capita) is critical to most ICT diffusions. High income, high education, and human resources play an important role in high economic and ICT growth [Bagchi et al. 2004; Barro 1991; Barro 1997; Chin and Fairlie 2004; Dewan et al. 2005; Lucas and Sylla 2003; Quibria et al. 2002]. Wealthier nations tend to have a greater demand for and supply of new technologies [Milner 2003a].

[1] Although culture is a known national-level factor that can influence ICT diffusions in many nations (Straub et al., 2001; Straub et al., 2002; Hasan, H. and G. Ditsa , 1999; Bagchi et al., 2004), the present study is at a macro-level and does not include the influence of culture, due to lack of macro-level cultural data for African nations.

Wealthier countries also tend to adopt innovations earlier, as their consumers can afford the greater economic sacrifice associated with investment in new, and initially more expensive, innovation [Dekimpe et al. 1994; Hovav and Schuff 2005]. Previous research has shown that countries whose people are better off economically tend to have higher Internet penetration [Elie 1998; Hargittai 1999]. Gruber and Verbove [2001] also found that the GDP affects Internet diffusion. It is therefore expected that the level of economic growth (GDP per capita) will be related to Internet diffusion.

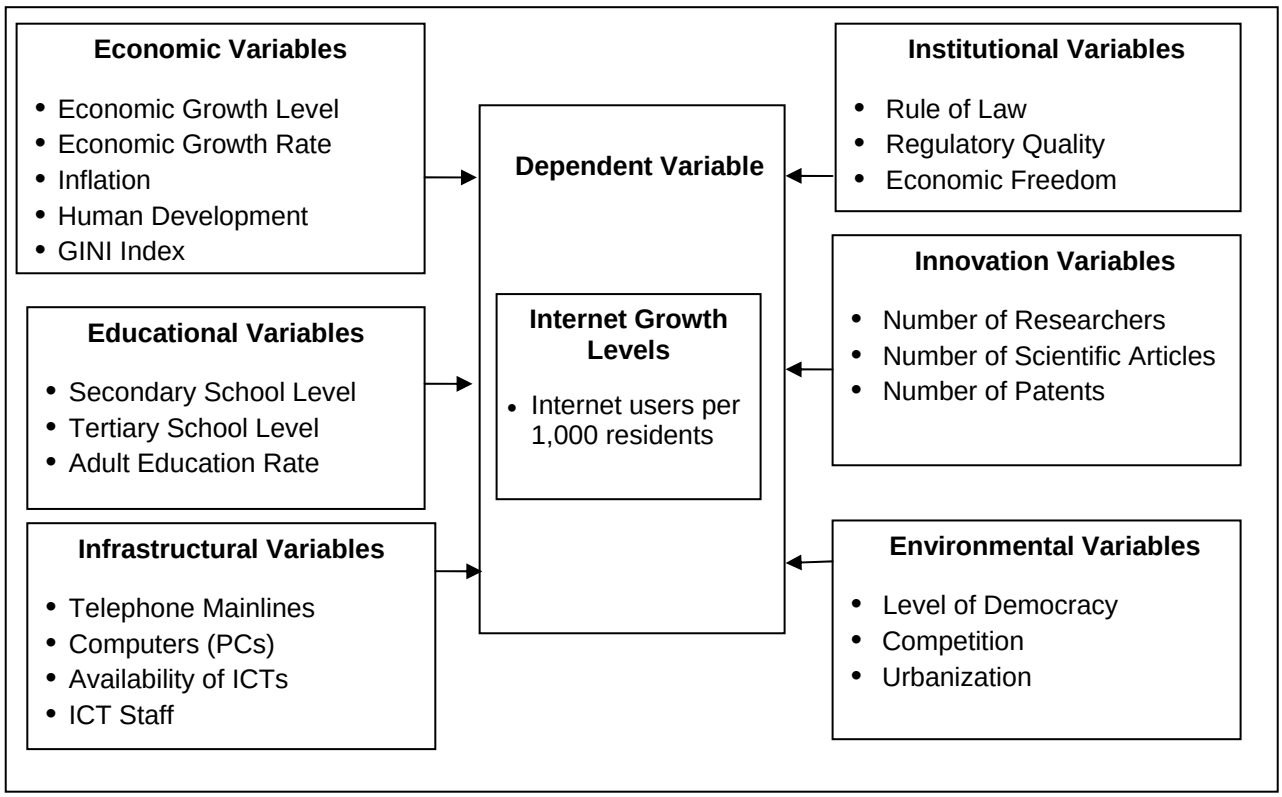

Figure 1. The Conceptual Model

Economic Growth Rate. The economic growth rate is an important indicator of the overall economic status of a nation together with the economic growth level [Barro 1997]. ICT innovations in the form of new technologies (such as the Internet) are introduced by way of economic investment in the ICT of a nation. During periods of the most rapid economic growth, a higher economic growth rate results, which may induce more Internet diffusion.

Inflation. Inflation plays a negative role in economic growth and consequently may play a negative role in ICT growth [Davis and Kanago 1998].

Human Development. Economic developmental growth theory states that industrial countries differ from developing countries by much more than their level of capital or even their human capital [Hoff and Stiglitz 2000]. The inclusion of the term human capital in economic developmental growth theory is the recognition that people are an important and essential element of national development and growth [Welch 1970]. Growth theorists have also suggested that the accumulation of human capital as an indicator of Human Development Index (HDI) is necessary to sustain long-term growth [Ciccone 1994]. Press et al. [1998] also identified several determinants of Internet adoption such as financial resources as well as human capital as indicated by the HDI. The HDI does not measure absolute levels of development, but rather is a composite measure that ranks countries in relation to each other or to a common goal [Justus

2005]. Consequently, the HDI has been shown to be a useful tool for comparing the human development between countries, but not for assessing intra-country human development inequalities [Kempf 2004]. The index has previously been applied to a number of areas of interest, including healthcare [Sumathipala 2004], the environment [Poghossyian 1998], and the economy [Dasgupta and Mäler 2000].

It should be noted that we would have liked to include disparities in wealth (GINI) as an economic variable, since it has been shown that wealth distribution affects prices and wages [Hoff and Stiglitz 2000]. Due to lack of data, we were unable to use this measure in our initial set of regressions. However, we do use an income distribution measure in a later analysis where we compare Internet growth in African nations with economically similar nations from the rest of the world.

EDUCATIONAL VARIABLES

We considered three educational variables: secondary education level, tertiary education level, and adult literacy rate.

Secondary and Tertiary Education Levels. Kiiski and Pohjola [2002] found that the tertiary education level in a nation influences ICT diffusion. Lee [2001] and Caselli and Coleman [2001] also found that education impacts ICT diffusion. Madon [2000] recognized training as a factor influencing ICT diffusion. However, Hargattai [1999] and Norris [2000] found no evidence that education affects ICT diffusion. Many developing nations are at an early stage of Internet diffusion and it has been found that early Internet users were well educated and belonged to the upper income groups [GVU Survey 1998; NTIA 1999]. In China, Bulgaria and Chile, it has been found that Internet users are mostly highly educated [Beilock et al. 2003]. Crenshaw and Robison [2006] also found that education level contributes to Internet diffusion. Dewan et al. [2005] found years of schooling to be an important indicator of Internet growth.

Adult Literacy Rate. Lack of education can also be captured by the adult literacy rate. A low adult literacy rate has limited the penetration of the Internet in Uganda and perhaps in other African nations [Mwesige 2003; Bernstein and Goodman 2005].

INFRASTRUCTURAL VARIABLES

In this research, our focus is on a nation's information infrastructure, or its existing base of ICT products, the ability to incorporate and use new technologies, and the number of ICT staff or personnel available. A nation's information infrastructure (hereafter referred to as infrastructure) is expected to play an important role in Internet diffusion levels and rates [Wolcott et al. 2001]. Although infrastructural requirements vary for different ICT products, in general, the degree of ICT diffusion should be positively related to a nation's infrastructure [King et al. 1994; Moore and Benbasat 1991]. Press et al. [1998] and Beilock and Dimitrova [2003] found that existing telecommunications infrastructure, personal computing, and software are factors that can affect Internet diffusion. Crenshaw and Robison [2006] found that the existing level of technological development contributes to Internet diffusion.

Telephone Mainlines. This technology was chosen because it represents a mature technology. Some African countries have developed better infrastructures than others [Makhaya and Roberts 2003]. For example, according to the World Bank [2005a], in the year 2000 Mauritius had 235 telephone mainline connections per 1,000 residents, whereas Niger had only 1.8 per 1,000 residents.

Computers (PCs). In contrast to telephones, computers are a relatively newer technology and in an earlier phase in the technology adoption lifecycle. As with telephones, however, the level of diffusion varies. Computers per 1,000 in this article means personal computer penetration and use per 1,000. Seychelles had 136 PCs per 1,000 residents whereas Ethiopia had only 0.95 users per 1,000 residents.

Availability of ICTs. As a measure of supply constraint, we use the average waiting time for telephone connections [Bartels and Islam 2002]. It is assumed that lengthy waiting times discourage ICT usage and hence adoption.

ICT Technical Staff Strength. Mbarika et al [2005] cite the acute shortage of ICT technicians as one of the factors that inhibits ICT diffusion in sub-Saharan Africa.

INSTITUTIONAL VARIABLES

The economic relationship between technology diffusion and institutional forces has been theoretically considered [Haggerty and Golden 2002; King et al. 1994; Orlikowski 1992], but few empirical studies have been conducted. A number of authors [King et al. 1994; Orlikowski 1992; Haggerty and Golden 2002] have suggested that institutional forces and the regulatory powers of institutions affect ICT diffusion.

Rule of Law and Regulation. Kauffman et al. [2002] have pointed out that national – level factors and regulation policies can be responsible for mobile commerce growth. Okoli [2003] discussed the role of national policies and institutional factors in promoting e-commerce in sub-Saharan Africa. Kaufmann et al. [2003] have pointed out that factors such as government intervention, rule of law, regulation, restrictive trade policy, and the existence of black markets can all act as barriers to economic growth. Shih et al. [2005] found the importance of rule of law in e-commerce growth. In addition, informal regulations in the form of "community pressure" can influence the diffusion of a technology [Blackman and Bannister 1998]. It is expected that many of these factors will also act as barriers to Internet diffusion.

Regulatory Quality. Djankov et al [2002] found that countries with more entry regulations tend to be more corrupt and have lower quality public and private goods. Wallsten [2005] found that countries with less effective governments, more corruption, and worse regulatory quality are somewhat more likely to impose price regulations than other countries hence reducing technology growth.

Economic Freedom. Economic freedom consists of many of the institutional factors cited previously. Corruption and bureaucratic efficiency have also been proposed as institutional factors that negatively influence economic growth. These are the components of the Economic Freedom Index. The Economic Freedom Index has been shown to impact information technology diffusion [Green et al. 2002].

INNOVATION VARIABLES

A nation's innovativeness may play a positive role in Internet or other ICT diffusion. Whereas innovativeness may best be measured by a country's research and development (R&D) efforts, reliable measures are not available. We consider three surrogate innovation variables: number of researchers, number of scientific articles, and number of patents. Past research has suggested that diffusion of new technologies stimulates research and development (innovation), and in return, R&D stimulates diffusion [Stoneman 1991; Cohen and Leventhal 1989]. Research has also found that early adopters of a new technology are firms that spend more on R&D [Romeo 1975; Hovav and Schuff 2005]. Increase in R&D activities will promote an increase in the number of researchers, number of scientific articles and number of patents. Adams [1990] found that number of academic scientific papers of various scientific fields contributed significantly to the growth of U.S. industries

ENVIRONMENTAL VARIABLES

Environmental factors refer to the atmosphere in which the marketplace operates in and includes such considerations as (a) heterogeneity levels such as the level of urbanization and the level of democracy or freedom of interaction and (b) competitiveness.

Level of Democracy. A measure of the level of heterogeneity is the level of democracy. Freedom House's political rights and civil liberty indices [Freedom House 2005], based on these component factors, have previously been used as a measure of a nation's environment [Milner 2003a; Scully 1988]. Crenshaw and Robison [2006] postulated that "political openness" matters in Internet diffusion.

Competition. Similarly, competition [Gruber and Verboven 2001; Wallsten 2001] is also expected to play an important role in Internet diffusion.

Level of Urbanization. Urbanization, defined as urban density, or the percentage of residents living in urban areas, may be viewed as a factor impacting ICT diffusion since urban centers are typically wealthier and tend to be more innovative [Gatignon et al. 1989]. It is generally acknowledged that urban environments play a vital role in education, culture, and productivity. Consumers living in the country's major metropolitan areas tend to be more cosmopolitan [Hannerz 1990], and because metropolises also tend to have a denser retail infrastructure, it is easier for consumers to acquire a new product. For example, Loboda [1974] showed that the diffusion of televisions in Poland was most prevalent in the richest and most urban parts of the country. Wealthier countries tend to have greater demands for, and supply of, new technologies [Milner 2003b].

III. RESEARCH QUESTIONS

We formally frame our research questions (RQs) as follows:

RQ1: What factors are important for Internet growth levels? Are the impacts of these variables different in Africa than in the rest of the world (ROTW)?

The ROTW nations consist of all developed and developing non-African nations. Some researchers have argued that ICT growth in developing nations may not necessarily correspond to growth in developed nations [Sahay and Avgerou 2002], since technology access is inconsistent across developing nations. As Musa et al. [2005] note:

"Since ICTs are not simple artifacts, it would seem reasonable that we cannot simply extrapolate the experiences from the developed nations to technology transfer, diffusion, or adoption to apply to developing regions such as sub-Saharan Africa." [p. 594]

RQ2: Are African nations falling behind in Internet growth compared to the ROTW – as indicated by Internet growth factors?

Since African nations are generally classified as developing nations, it follows that their Internet growth should be compared with the Internet growth of other developing nations from other regions in the world. Because economies vary considerably within the set of African nations, it is necessary to compare individual African nations with economically similar developing nations. Although economic comparisons of nations can be based on a host of economic indicators, economic similarity can be broadly captured by similar GDP per capita and income inequality levels (the Gini index). It can be mentioned that Hargittai [1999] investigated the role of income distribution on Internet diffusion, as represented by the Gini coefficient, but the results were insignificant. However, GDP differences capture average income differences, whereas differences in income inequality capture the divergence in income disparity. Neither the GDP nor the HDI takes into account differences in individual income distribution patterns. Thus the GDP (PPP) and the Gini index together can better capture the economic status of the population of a nation.

RQ3: Does Internet growth in African nations differ from Internet growth in economically similar developing nations? What factors influence the differences?

V. DATA

The study variables and their definitions together with their sources are shown in Table 1. Data from 128 nations were included in this study (details about the nations chosen are given in Appendix A). Some African nations could not be included due to data unavailability. However, the thirty African nations selected represent the most important segments of Africa. The ROTW nations, on the other hand, include wealthy, middle-income, and low-income nations. Internet growth is represented as the average number of Internet users in the years 1995 and 2000 (the only period that had relevant data for all nations) [World Bank 2005b]; the factors hypothesized to affect Internet growth are also the averages for the same time frame.[2] Averages were used to smooth any anomalies that may occur in a single year and these specific years were selected because the data were generally complete for the nations considered.

THE DEPENDENT VARIABLE

Internet growth could be measured as the number of Internet hosts, the number of Internet users, the number of adults, or even the number of people with Internet access. We selected the number of Internet users per 1,000 (INTUSER). This measure as well as the Internet infrastructure level measures, although frequently used in academic research, are not free of measurement problems (See Lucas and Sylla [2003] and Milner [2003b] for discussion). In our regression analysis, we use the average of the natural logarithm for the years 1995 and 2003 of the INTUSER variable.

INDEPENDENT VARIABLES

ECONOMIC VARIABLES

There are four economic variables used for answering RQ1 and RQ2: the GDP per capita (GDP), the GDP growth rate (GDPPER), the inflation rate (INFL), and the HDI. All of these variables (except the HDI) are available from the World Bank [2005a] database of indicators. Operationalization of the GDP was accomplished by using the natural logarithm of the GDP, as denoted by LNGDP.

To obtain precise human development profiles for countries, the United Nations Development Programme (UNDP) created the Human Development Index (HDI) in 1990 [Fukuda-Parr 2001; UNDP 1990]. The HDI is based on three primary indicators, with each indicator given equal weight:

1. ***Longevity***, as measured by life expectancy at birth;

2. ***Education Attainment***, as measured by the combination of adult literacy and combined primary, secondary and tertiary enrollment ratios; and

3. ***Standard of Living***, as measured by real GDP (Gross Domestic Product) per capita adjusted with Purchasing Power Parity (PPP$).

Table 1. Variables and their Sources and Meanings

Variables	Source	Meaning
DEPENDENT VARIABLE:		
•Growth Level (INTUSER)[1]	ITU[3]	• Internet users[8]

[2] Income inequality data were not available for Angola, the Sudan, and Haiti, and hence these nations were omitted from that component of the analysis.

INDEPENDENT VARIABLES:		
Economic/Demographic Variables: •GDP Per Capita (LNGDP) (US$)[2] •GDP Growth (%) (GDPPER)[2] •Inflation (INFL) (%)[2] •Human Development Index (HDI)[2]	World Bank[4] UNDP[5]	• Personal wealth • Growth rate of personal wealth • Annual rate of inflation (%) • National Human Development
Educational Variables: •Secondary school enrollment (SECEDU)[2] •Tertiary School Enrolment(TEREDU)[2] •Adult Literacy Rate (%)(LITERACY)[2]	World Bank[4]	• Percentage population enrolled in secondary or tertiary schools • Percent literacy (aged 15 or more)
Infrastructure Variables: •Telephones (TEL)[2] •Computers (COMP) •ICT availability variable[2]: Wait time in telephone mainline connections (WTTL) •ICT staff (STF)[2]	ITU[3]	• Number of Telephone Mainlines[8] • PC penetration and Use [8] • Waiting list for Mainlines[8] • Full Time ICT Staff [8]
Institutional Variables : •Rule of Law (RULEOFLAW)[2] •Regulatory Quality (REG)[2] •Economic Freedom INDEX (HERIT)[2]	World Bank[4] World Bank[4] The Heritage Foundation [6]	• Perceptions of the rules of the society • Regulatory Quality • Index of Economic Freedom made of various indicators such as corruption
Innovation Variables: •No. of Researchers(RD)[2] •No. of Scientific articles(JOURNAL)[2] •No. of Patents (PATENT)[2]	World Bank[4]	• Number of R&D researchers[9] • Number of journal articles[9] • Number of patent applications[9]
Environmental Variables: • Level of Democracy (FREEDOM)[2] • Urbanization Level (URBAN)[2] • Competition variable: Tariff Rate(TARIFF)[2]	Freedom House[7] World Bank[4] World Bank[4]	• Higher values imply less democratic nation • Percentage National Urban Population • Tariff rate, barriers and corruption

[1] Based on average values of 1995-2003

[2] Based on average values of 1995 and 2003

[3] http://www.itu.int/ITU-D/ict

[4] http://www.info.worldbank.org

[5] http://www.undp.org

[6] http://www.heritage.org

[7] http://www.freedomhouse.org

[8] per 1,000 residents

[9] per million

EDUCATIONAL VARIABLES

Education was represented by three variables: secondary (SECEDU), tertiary (TEREDU) school enrollments, and adult literacy rates (LITERACY). These data are also available from the World Bank database.

INSTITUTIONAL VARIABLES

Three variables were used to represent institutional factors. The World Bank was the source of the metrics of regulatory quality (REG), a measure of market friendliness and of perceptions of regulation in areas such as foreign trade and business development, and rule of law (RULEOFLAW), or perceptions of societal rules. The other institutional indicator is the Heritage Index of Economic Freedom (HERIT) which is available from the Heritage House [Heritage 2006]. This index includes an array of institutional factors such as corruption, barriers to trade, fiscal burden of the government, the rule of law, regulatory burdens on business, restrictions on banks, labor market regulations, and black market activities. A high Heritage Index value indicates that a nation's institutional policies are not conducive to economic activities.

INFRASTRUCTURE VARIABLES

A number of metrics were used to represent the information infrastructure. Telephone mainline connections (TEL) and computers (COMP), the latter measured in terms of personal computer penetration and use, were used as indicators of technical infrastructure (all in terms of users per 1,000 residents). In the absence of a direct measure of total full-time telecommunications staff per 1,000 residents, we used the surrogate measure of ICT staff (STF). The availability of ICT was approximated by the waiting list for main lines per 1,000 (WTTL) which signifies unmet applications for mainline connections due to a lack of technical facilities (e.g., equipment, lines). These data are available from the ITU database of indicators [ITU 2005].

INNOVATION VARIABLES

Innovation was represented by three variables: the number of researchers in R&D per million population (RD), the number of scientific and technical journal articles per million population (JOURNAL) and the number of patent applications (PATENT) granted by the U.S. Patent and Trademark Office (USPTO) per million population. All data were available from the World Bank.

ENVIRONMENTAL VARIABLES

The level of urbanization (URBAN) denotes the percentage of individuals living in urbanized areas in a nation, and is available from the World Bank [World Bank 2005b].

The level of democracy (FREEDOM) is a variable denoting various aspects of political liberties, and is available from Freedom House [Freedom House 2005]. The values range from 1 to 7, with 7 representing the least political freedom. Our competitiveness variable (TARIFF) is the tariff barrier which is a composite metric of tariff rate, non-tariff barriers, and corruption in customer services. Thess data are available from the World Bank.

OTHER VARIABLES.

In addition, for answering RQ3, we used three additional variables, GINI, TIME and INTHOST. Disparities in wealth (represented by GINI in the text) were represented using the Gini Index [Deininger and Squire 1997]. The Gini Index [Gini 1955] was developed to capture the extent to which income distribution among individuals or households within a country deviates from a perfectly equal distribution. The index measures the area between the Lorenz curve and a hypothetical line of absolute equality, expressed as a percentage of the maximum area under the line. A "0" rating implies perfect equality, while a "100" value signifies perfect inequality. These data are available from the World Bank, and we use this variable in answering RQ3.

Time to diffusion, or the period of time between a technology's introduction and its diffusion in a nation (TIME), is calculated as the number of years between the global availability of the Internet and a nation's adoption of it. INTHOST is the number of Internet hosts per million in 1995 in the natural logarithm and is adopted from the ITU database of indicators [ITU 2005].

V. METHODOLOGY

Two sets of OLS regressions were conducted, one using non-African nations (ROTW) and one using African nations. Because of missing data and small sample sizes, we were forced to run twelve different regressions, six for non-African nations and six for African nations. For each national grouping, the impact of each factor grouping (economic, educational, institutional, infrastructural, innovation, and environmental) on the number of Internet users per 1,000 was considered separately. An additional forward regression was then conducted for each national grouping using all of the individual variables (i.e., not segregated by factor grouping), bringing the total number of regressions to fourteen. In this regression scheme, variables are added sequentially, one at a time based on the strength of their squared semi-partial correlations, without regard to their factor grouping.

All variables were standardized. All regressions were checked and corrected for such problems as multi-collinearity and autocorrelation [Netter et al. 1996]. The regression error terms were also checked against a normal distribution. Thus, the rules of OLS were not violated.

To compare Internet growth in African nations with economically similar nations from the ROTW, we matched each African nation with a non-African nation based on similar average GDP and income inequality for the years 1995 and 2003. The set of matched nations is given in Appendix B. A Wilcoxon signed ranks test was performed to test for any differences between the matched pairs. This test is a nonparametric alternative to the paired t-test, has less-stringent assumptions, and is generally more powerful than the sign test [Bharadwaj 2000]. As with other paired tests, Wilcoxon signed-ranks test assumes that we have two groups and that we have drawn our sample in pairs. Each pair contains an item from the first group and an item from the second group. The procedure tests the hypothesis that the frequency distributions for the two groups are identical. P-values were computed for small sample sizes. In the present study, we wanted to find any significant changes in indicators. The z-score in the Wilcoxon signed-rank test calculates the significance, based on a normal distribution.

VI. RESULTS

The results of the first set of regressions are given in Tables 2a (ROTW) and 2b (African nations). In each of the tables, the rightmost column contains the results from the overall regression (i.e., not segregated by factor grouping).

For the ROTW, it was observed that some groups of factors (educational, institutional, and environmental), when considered in isolation, can explain 45 to 88 percent of the variance in the dependent variable (Internet growth level). When considered together in the overall regression, the human development (HDI) and the economic freedom (HERIT) variables can explain 88 percent of the variance for the ROTW.

For African nations, we found that some groups of factors, when considered in isolation, can explain 25 to 84 percent of the variance in Internet user levels (slightly less than the ROTW). The number of computers (COMP), wait time for telephone lines (WTTL), human development variable (HDI), and tertiary education (TEREDU) are significant factors in the forward regression, explaining 84 percent of the variance in the normalized Internet growth values. Urbanization (URBAN) is the only environmental factor that significantly impacted Internet growth levels in the regressions involving the environmental group of variables.

Table 2a. Regression Results for the Rest of the World (ROTW)

Variables	**Standardized Coefficient**						
Economic							
LNGDP	.07						X
GDPPER	.05						X
HDI	.89***						**.82*** **
INFL	.004						X
Educational							
LITERACY		.19*					X
SECEDU		.37***					X
TEREDU		.25**					X
Institutional							
REG			-.05				X
RULEOFLAW			.52***				X
HERIT			-.42***				**-.15** **
Infrastructural							
TEL					.87***		X
WTTL					-.14		X
COMP					-.06		X
STF					.01		X
Innovation							
RD				.24*			--
JOURNAL				.50***			X
PATENT				-.004			--
Environmental							
FREEDOM						-.89***	X
TARIFF						.32***	X
URBAN						.37***	X
Method	OLS	OLS	OLS	OLS	OLS	OLS	Forward
No. of Nations	79	96	96	81	80	95	69
Adj R^2	.85	.53	.72	.45	.72	.65	.88

Note: ***: p<.000, **: p<.05; *:p<.10

X: The variable did not enter regression;

--: not included for lack of data;

Table 2b. Regression Results for African Nations

Variables	**Standardized Coefficient**						
Economic							
LNGDP	-.18*						X
GDPPER	.02						X
HDI	.93***						.37**
INFL	-.09						X
Educational							
LITERACY		.22					X
SECEDU		.62**					X
TEREDU		.11					**.26***
Institutional							
REG			-.66**				X
RULEOFLAW			.05				X
HERIT			-.90***				X
Infrastructural							
TEL					.60***		X
WTTL					-.15		**-.21****
COMP					.22		**.37*****
STF					-.04		X
Innovation							
RD				--			--
JOURNAL				1.3***			X
PATENT				-.7			--
Environmental							
FREEDOM						-.17	X
TARIFF						-.14	X
URBAN						.55**	X
Method	OLS	OLS	OLS	OLS	OLS	OLS	Forward
No. of Nations	28	31	30	18	29	30	26
Adj R^2	.80	.71	.30	.51	.69	.25	.84

Note: ***: p<.000, **: p<.05; *:p<.10

X: The variable did not enter regression;

--: not included for lack of data

The results are summarized in Table 3, based on the final regressions. Of the six groups of factors, four groups had at least one variable that was found to be significant. Environmental (level of urbanization, democracy, or tariff rates) factors were not found to affect Internet growth levels. Only human development was a significant indicator for both groups of nations. Tertiary education, telephone wait time, and the number of computers per 1,000 residents were other significant factors for African nations only. Economic freedom (based on the Heritage Index) was a significant factor in Internet growth levels for the ROTW. The results provide some insight into our first research question (*What factors are important for Internet growth levels? Are the impacts of these variables different in Africa than in the rest of the world (ROTW)?)*

The results in Table 4 are used to answer RQ2 (*Are African nations falling behind in Internet growth compared to the ROTW – as indicated by Internet growth factors?*). For all but one of the indicators (literacy), the gap between Africa and the ROTW increased from 1995 to 2003. Further, the improvement in literacy may be viewed cautiously since, in real terms, literacy rates in African nations are still significantly lower than those in the ROTW. During the period of study, Africa, as a whole, lags behind the ROTW in Internet-related developments, although this may be because while African nations have improved, the ROTW has made greater improvements.

Table 3. Summary of Results: Africa and the Rest of the World (ROTW)

(Significant Results only)

	Internet Users	
Variables	**Africa**	**ROTW**
Economic Indicators:		
Human Development	*	*
Education:		
Tertiary Education	*	
Infrastructural Variables:		
Telephone Wait Time	*	
Computers	*	
Institutional Indicators:		
Heritage Index		*

Note. * denotes the variable is statistically significant

The results in Tables 5 through 7 are used to answer RQ3 (*Does Internet growth in African nations differ from Internet growth in economically similar developing nations? What factors influence the differences?*) As discussed in the methodology section, we matched African nations with non-African nations based on GDP and income inequality [Bharadwaj 2000].

Some of the values of income inequality varied considerably, so we applied a Wilcoxon signed-ranks Test (Table 5) which showed that the differences were not significant between the paired nations at the 5 percent level of significance. However, because matches could not be made for all African nations, the sample size was reduced to seventeen nations.

Table 4. Summary of Descriptive Statistics for Two Years: The ROTW and Africa

Indicator Variables	ROTW 2003	ROTW 1995	ROTW Difference 2003-1995	Africa 2003	Africa 1995	Africa Difference 2003-1995	Difference between ROTW and African Differences[1]
GDPPER	2.66	2.16	0.500	3.72	3.55	0.175	0.325
HDI	0.80	0.77	0.027	0.50	0.50	0.006	0.021
TARIFF	6.11	5.45	0.658	3.53	2.93	0.600	0.058
REG	0.35	0.06	0.293	-1.19	-0.62	-0.568	0.861
RULEOFLAW	0.43	0.29	0.140	-1.47	-0.96	-0.507	0.647
RD	1,610.11	1,353.53	256.575	151.29	112.96	38.338	218.237
JOURNAL	171.96	165.89	6.072	8.21	7.45	0.765	5.307
PATENT	35.74	19.67	16.063	0.24	0.25	-0.015	16.079
LITERACY	90.87	88.42	2.453	63.04	57.17	5.869	-3.416
SECEDU	85.84	77.79	8.041	38.13	32.21	5.922	2.120
TEREDU	34.85	28.05	6.803	6.53	5.07	1.458	5.344
TEL	712.49	258.54	453.947	128.99	24.16	104.833	349.114
COMP	184.70	71.96	112.738	23.76	5.51	18.254	94.484
N (Number of Nations)	96	96		31	31		

[1] Equal to the change in the ROTW nation ratings - the change in African nation ratings

Table 5[1]. Wilcoxon Signed-Ranks Test: Average Disparities in GINI and GDP Disparity

	GINI Disparity	GDP Disparity
Z	-1.363 (a)	-0.312 (a)
Sig. (2-tailed)	0.173	0.755
N	15	17

[1] GINI Disparity = Income Inequality in Africa – Income Inequality in the ROTW

GDP Disparity = Average GDP-PPP in Africa – Average GDP-PPP in the ROTW

(a) Based on positive ranks

We next compared Internet growth for these paired sets of samples. The results are shown in Table 6. AfInt and OthInt (with year suffixes) denote Internet users for African and ROTW nations We considered two years for comparison: 1995 and 2003. The Wilcoxon signed-ranks Test revealed that the Internet user growths (OthInt95, AfInt95; OthInt03, AfInt03) were significantly different ($p < 0.05$; see Table 6) in both the years 1995 and 2003.

Table 7 shows that the z-scores were significant for human development (HDI), each of the education variables (secondary school enrolment (SECEDU), tertiary school enrolment (TEREDU), and adult literacy rates (LITERACY)), telephone mainline connections (TEL), and

barriers to tariffs (TARIFF). Weak significance (p = 0.068) was also found for urbanization (URBAN). Within our framework, it is possible that these significant variables are responsible for the differences in Internet growth between these two sets of economically similar nations.

Table 6. Wilcoxon Signed-Ranks Test Results (Internet Diffusion Variables)

Ranks				
		N	Mean Rank	Sum of Ranks
OthInt03-AfInt03	Negative Ranks	4	4	33
	Positive Ranks	13	9.231	120
	Ties	0		
	Total	17		
OthInt95-AfInt95	Negative Ranks	3	2	6
	Positive Ranks	9	8	72
	Ties	0		
	Total	12		
Negative Ranks	OthInt03<AfInt03			
Positive Ranks	OthInt03>AfInt03			
Ties	OthInt03=AfInt03			
Negative Ranks	OthInt95<AfInt95			
Positive Ranks	OthInt95>AfInt95			
Ties	OthInt95=AfInt95			
Test Statistics*	OthInt03-AfInt03	OthInt95-AfInt95		
Z	-2.059	-2.59		
Asymp. Sig. (2 tailed)	**0.0395**	**0.01**		
*Based on Negative Ranks				
	AfIntxx--Internet Users for African Nations in Year xx			
Legend:	OthIntxx--Internet Users for Matched Other Nations in Year xx			

Table 7. Wilcoxon Signed-Ranks Test Results (Internet Diffusion Independent Variables)

Variables	**Z-value**	**No. of nations**	**Sig. (2-tailed)**
TIME[b]	-1.300	17	0.194
INTHOST	-0.517	17	0.605
Economic			
HDI	-2.699	17	**0.007**
GDPPER[b]	-0.970	17	0.332
INFL	-0.804	13	0.422
Educational			
SECEDU	-1.917	17	**0.055**
TEREDU	-2.675	17	**0.007**
LITERACY	-2.059	17	**0.039**

Variables	Z-value	No. of nations	Sig. (2-tailed)
Institutional			
REG	-0.828	17	0.407
RULEOFLAW	-0.876	17	0.381
HERIT	-0.497	17	0.619
Infrastructural			
TEL	-2.722	17	**0.006**
COMP	-1.241	16	0.215
WTTL	-0.827	16	0.408
STF	-1.065	17	0.287
Innovation			
RD	-1.153	6	0.249
JOURNAL	-0.672	16	0.501
PATENT	-0.765	11	0.444
Environmental			
FREEDOM[b]	-1.632	17	0.103
TARIFF	-2.758	17	**0.006**
URBAN	-1.823	17	**0.068**

Note**.** b**:** Based on positive ranks

VII. DISCUSSION

A summary of findings with respect to the research questions is given in Table 8.

Table 8. Summary of Research Question Findings

RQ	Intent	Findings
RQ1	Factor Identification Different factors for African Nations?	(see below) Yes
RQ2	African Nations falling behind?	Yes
RQ3	African growth different from growth of economically similar nations? Factors influencing difference?	Yes (see below)

Our preliminary results show the following:

1. Economic, educational, and infrastructural groups are the primary classes of factors that inhibit Internet growth in Africa (see Table 3). More specifically, variables affecting African Internet growth include human development, secondary and tertiary education, regulatory quality, economic freedom, urbanization, and telephone lines per 1,000 residents (see Table 2b). All of these factors can be associated with national policies.

2. Institutional factors and human development are the primary factors affecting Internet usage in the ROTW (see Table 2a).

3. The only factor affecting Internet growth levels in both Africa and the ROTW is human development (which includes longevity, education attainment, and standard of living). This is not surprising and lends strong support for the fact that people are an important and essential element of national development and growth.

4. Innovation variables were not significant in regressions. This was somewhat surprising, and requires additional investigation.

5. The gap between African nations and the ROTW is not decreasing, contrary to popular assumptions. The difference in Internet growth levels between the two national groupings in 1995 was significant at $p = 0.01$ and remained significantly different in 2003 ($z = -2.06$, $p = 0.04$; see Table 6). This may be due to the factors discussed in answering RQ1 above, or perhaps a poor ICT infrastructure development environment (indicated by tariff differences and differences in the availability of main-line telephones, as indicated by the results in Table 6). It seems reasonable to assume that for the gap to be reduced, African nations will need faster-than-present growth rates perhaps by shifting resources to address these shortcomings (also shown in Table 4).

6. African nations started using the Internet at about the same time (denoted by TIME in Table 7) as economically similar nations from the ROTW and had a comparable number of Internet hosts as nations of ROTW (denoted by INTHOST in Table 7).

Based on the study findings, the following specific comments on the role of various factors in Internet growth can be made.

Economic Development: Economic factors are significant indicators of Internet growth levels. The finding that human development (which has the GDP as a component) has significant influence on Internet growth is consistent with previous research [Bagchi et al. 2004; Chin and Fairlie 2004; Dekimpe et al. 1994; Lucas and Sylla 2003; Quibria et al. 2002].

Education and Training: The results in Table 7 show that when compared with economically similar nations from the ROTW, African nations are lacking at all levels of education (primary, secondary, and literacy). The impact of the HDI (above), which also has an educational component, adds further evidence for the impact of education on Internet growth. African nations need to improve their delivery of education and training in order to develop, maintain, and use information technologies.

Institutional Factors: In this study, institutional factors seem to play no significant role in Internet growth in Africa (as shown in Tables 3 and 7). This may be because institutions in Africa are generally categorized as “mostly un-free” or “repressed” [Freedom House, 2005]. The role of institutional influence (positive or negative) on technology diffusion has been long predicted [King et el. 1994]. This study shows that institutional factors matter for the ROTW’s Internet growth (Table 3).

Infrastructural Factors: The results show that telephone wait time and the number of computers impact African Internet growth (Table 2b). When compared with economically similar nations, telephone growth in Africa is significantly lower (Table 7).

VIII. CONCLUSIONS

This preliminary study has addressed a number of important issues related to Internet growth in Africa, and developing countries in general. We found that Internet growth level differences between African and other economically similar nations persist, most likely due to a lack of education, human development, and infrastructural factors. It remains to be seen how the Internet

can (if at all) reduce the gap between African nations and the ROTW in the future. For that to happen, the Internet needs to emerge as a readily available and commonly used technology in African life. Most African nations are presently far from achieving such a goal.

There are several limitations in the present study. African nations are in an early stage of Internet growth, and so the results must be interpreted with caution. Factors impacting growth may differ when these nations enter the next stage of maturity [Rogers 1995]. Another area that should be addressed by future research is to view the Internet as a cluster of innovations instead of a single technology [Wolcott et al. 2001]. Lack of data for all nations also limits our findings.

It would be useful to investigate the effect of culture and other social factors. We hope to extend the study to include these factors in a future study. Future research should also explore the strict causal relationships between the dependent and independent variables as was recently done in Crenshaw and Robison's [2006] Internet diffusion study.

Although the study is preliminary in nature, we believe the results of this study are of value to different groups of people who are interested in ICT growth in developing countries.

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EDITOR'S NOTE: The following reference list contains the address of World Wide Web pages. Readers, who have the ability to access the Web directly from their computer or are reading the paper on the Web, can gain direct access to these references. Readers are warned, however, that

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APPENDIX A. LIST OF NATIONS USED IN THE STUDY

Africa	Other Nations		
sub-Saharan Africa			
Angola	Albania	Haiti	Pakistan
Benin	Argentina	Honduras	Paraguay
Botswana	Armenia	Hong Kong	Peru
Burkina Faso	Australia	Hungary	Philippines
Cameroon	Austria	Iceland	Poland
Cote D'Ivoire	Bahrain	India	Qatar
Eritrea	Bangladesh	Indonesia	Romania
Ethiopia	Barbados	Iran (Islamic Rep. of)	Russia
Ghana	Belarus	Ireland	Saudi Arabia
Kenya	Belgium	Israel	Serbia
Madagascar	Bolivia	Italy	Singapore
Malawi	Bosnia & Herzegovina	Jamaica	Slovak Republic
Mauritania	Brazil	Japan	Slovenia
Mauritius	Bulgaria	Jordan	Spain
Mozambique	Canada	Kazakhstan	Sri Lanka
Namibia	Chile	Korea (Rep. of)	Sweden
Nigeria	China	Kuwait	Switzerland
Senegal	Colombia	Kyrgyzstan	Syria
Sierra Leone	Costa Rica	Lao P.D.R.	Taiwan, China
South Africa	Croatia	Latvia	Tajikistan
Sudan	Cyprus	Lebanon	Thailand
Tanzania	Czech Republic	Lithuania	Turkey
Uganda	Denmark	Luxembourg	Ukraine
Zambia	Dominican Rep.	Malaysia	UAE
Zimbabwe	Ecuador	Mexico	United Kingdom
	El Salvador	Moldova	United States
North Africa	Estonia	Mongolia	Uruguay
Algeria	Finland	Nepal	Uzbekistan
Djibouti	France	Netherlands	Venezuela
Egypt	Georgia	New Zealand	Viet Nam
Morocco	Germany	Nicaragua	Yemen

Tunisia	Greece	Norway
	Guatemala	Oman

APPENDIX B. LIST OF MATCHED PAIR NATIONS USED IN THE STUDY

Africa	Avg. GDP, 1995-2003	Income Inequality	ROTW	Avg. GDP, 1995-2003	Income Inequality	% Absolute Difference in GDP
Angola	1786	..	Vietnam	1786	37	0
Madagascar	732	38.1	Yemen	733	33.4	0.136612
Botswana	6240	63	Thailand	6020	41.4	3.52564
Uganda	1135	37.4	Nepal	1180	36.7	3.964758
Senegal	1331	41.3	Moldova	1271	40.6	4.50789
Cote	1443	36.7	Mongolia	1443	33.2	0
Sudan	1564	..	Haiti	1503	..	3.90026
Mauritania	1614	37.3	Pakistan	1708	41	5.82404
Cameroon	1681	47.7	Georgia	1737	37.1	3.33135
Zimbabwe	2490	50.1	Honduras	2331	56.3	6.38554
Egypt	3123	28.9	Ecuador	3114	43.7	0.28818
Morocco	3248	39.5	Albania	3196	28.2	1.60099
Algeria	4929	35.3	Venezuela	5238	49.5	6.26902
Namibia	5413	70.7	Iran	5395	43	0.33253
Tunisia	5493	41.7	Turkey	5539	41.5	0.837429
Mauritius	8555	37	Poland	8615	31.6	0.701344
S Africa	8774	59.3	Estonia	9034	37	2.963301

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