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# INTERNET DIFFUSION IN SUB-SAHARAN AFRICA: A CROSS-COUNTRY ANALYSIS

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**Abstract**

In this paper, we employ the notions of digital inequality and digital divide to describe two levels of access to Information and Communications Technologies (ICTs). On the one hand there is the inequality of access to the cluster of technology measured by Internet use intensity and on the other are the confluence of skills and other resources that differentiate countries in sub-Saharan Africa. Using cross-country data, we test hypotheses developed from a review of the literature from which we draw preliminary conclusions on the nature and pattern of digital access in the region. The variables are analyzed through a simultaneous equation system because the high correlations ruled out the use of a single econometric model. The paper confirms the vital importance of telecommunications infrastructure - represented by the high correlation of telephone density - with Internet use, no matter the per capita income level of a country.

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# 1. INTRODUCTION

The Internet has diffused rapidly but its spread has been highly asymmetrical both across and within regions and countries. It is hard to conceive that the Internet came into commercial domain only in the early 1990s, but its trajectory of diffusion has taken on an almost predictable pattern. Advanced societies, particularly the OECD have witnessed the fastest spread. Current estimates show that Internet use in Africa lags behind that of other regions. Table 1 on the regional distribution of Internet users in the first quarter of 2002 shows a global figure of 580.78 million users, of which only 6.31 million were in Africa -about 1 percent of world total.

The growth of investment in telephone services has been particularly crucial to the spread of the Internet -supporting an almost 80-fold increase, from seven million Internet accounts in 1990. According to Wellenius et al (2000), information infrastructure in developing and transition economies - represented by main line telephones plus mobile phones per 100 inhabitants - is less than 15 percent the size of those in OECD countries with only 19 percent of world's population.

**Table 1: Regional distribution of Internet users (millions)**

| | | |
|---|---|---|
| World total | 580.78 | 100% |
| Africa | 6.31 | 1.09% |
| Asia/Pacific | 167.86 | 28.9% |
| Europe | 185.83 | 31.9 |
| Middle East | 5.12 | 0.9% |
| Canada & USA | 182.67 | 31.5% |
| Latin America | 32.99 | 5.7% |

Bridges.org (2002), Spanning the Digital Divide, www.bridges.org

## 1.1 Digital Inequality

Contrary to the more optimistic utopian conception, the "digital divide" continues to widen. DiMaggio et al. (2001) define the digital divide as "inequalities in access to the Internet, extent of use, knowledge of search strategies, quality of technical connections and social support, ability to evaluate the quality of information, and diversity of uses." In dynamic terms the gap seems to be widening instead of closing or at least narrowing. Based on an Index of Technological Progress (ITP) constructed by Rodriguez and Wilson (2000), the average growth rate of ITP in developed areas is 23% (1994-1996) while that of poorer countries is 18% on average. This output gives cause for concern given that developing areas are starting from a lower level and should therefore grow at a faster rate. Of all the regions, only East Asia seems to be keeping up with the developed nations while others are falling behind or barely keeping up. Among the reasons for the substantial growth differentials are lower levels of investment in knowledge and physical infrastructure. The OECD invests about ten times as much of their per capita income on research and development (R&D), they also have seventeen times as many technicians and scientists per capita as the countries of SSA.

Income inequalities have also been exacerbated. Predictions of convergence in per capita income between the rich and poor countries have not proved accurate. While we have no evidence of clear links between ICTs and income gaps, studies in the United States show that ICT adoption has led to inequality among social classes, races and educational divides ( DiMaggio et al. 2001). Unlike consumer goods such as television and radio, inequalities in access to the Internet and support devices such as telephone, and modems, tend to persist. There are also qualitative differences in the requirements for continuing access to the Internet depending on the quality of use sought by the user. ICT applications for commonplace tasks like word processing, and electronic mail may require no more than basic literacy. Progressing to higher levels of usage such as software design, demands a qualitative move to higher academic training. As Robinson (et al 2000) reported, using multivariate control, the impact of educational qualification is two times that of income. In other words, gaps in education as much as income, lead to access inequality. While wealth has been established as being linked to ICT access, the direction of causality is more complex to establish.

A safe hypothesis is that causality flows both ways but other findings show that superior technical education is strongly associated with certain kinds of inequality, and among a certain community of users. First, individuals with superior education are more likely to benefit from ICT-related opportunities that tend to command higher wages. Second, but this is no more than a conjecture, the computer may well substitute work ordinarily carried by skilled craftsmen. The point of the ICT-inequality nexus is well put by Rodriguez and Wilson (2000), that "…when a new technology is introduced into a social setting where the scarce resources and opportunities are distributed asymmetrically, the greater likelihood is that those with more resources will employ them to gain additional ones, including ICTs." Without clear action particularly by states, it is not unlikely that patterns of skewed distribution of ICT adoption and use will be reinforced in much the same way as patterns of educational inequality have persisted. Given the dynamism of technological diffusion, it is the changes in the configuration of technologies and the social use to which they are put that over time that may well prove the most challenging for theory and policy. As DiMaggio et al. put it, “Patterns of inequality are likely to reflect such changing factors as public connection availability, private subscription price, services available, and the technology necessary to access them effectively, as well as the diffusion of knowledge and the evolution of informal technical-support networks.”

Access to the Internet is therefore mediated at complex multidimensional levels. Conceptualization of access as a binary divide of users and non-users is only one dimension, which cannot fully explain the nature of access. Inequality at the level of the individual and the artifact, the PC and modems, is equally not adequate. Beyond the device is the *network* of electrical power, the telephone and communication facilities without which the Internet does not exist. Hargittai (2001) suggests that digital inequality should be considered at five different levels: differences in technical apparatus people use to access the Internet; location of access (i.e. autonomy of use); the extent of one’s social support networks; the types of use to which one puts the medium; and one’s level of skill.  In effect ICTs possess the character of use and user differentiation that depend on the intensity of utilisation and qualitative user demand. Given that inequalities in income, and education are more pronounced within poorer countries, this paper examines cross country patterns of access and use of the Internet in Sub-Saharan Africa. The paper is organized as follows:

Existing digital inequalities and economic conditions of SSA countries are discussed in Section 2 while data sources as well as further cross-country differentiated analyses are presented in Section 3. Hypotheses are formulated in Section 4. The analytical model and results are discussed in Sections 5 and 6 respectively. Conclusions and policy implications are drawn in Sections 7.

## 2. DIGITAL INEQUALITIES AND ECONOMIC CONDITIONS OF SUB-SAHARAN AFRICA

The United Nations (UN) defines the Least Developed Countries (LDCs) to which most SSA belongs) as low-income countries, characterised by their low human capital development and a high vulnerability to natural and man-made shocks. A majority of countries in this region - 33 out of 49 - thus fall into this group. With the exception of South Africa, Mauritius, Botswana, Zimbabwe, and Nigeria - for different human and materials resource reasons - the other countries differ only marginally. In what follows, we present the characteristics of this group of countries.

The thirty-three African LDCs differ widely in size and resource endowments, however, they share important common characteristics, which distinguish them from other developing countries. Low levels of income, a low degree of industrialization and human capital development, high levels of export concentration, often in one or two primary commodity lines, and a high level of vulnerability to external shocks, are common features of these economies.

The average per capital GNP is only a quarter of the developing country average. In fact, the average per capita GNP for this group of countries is barely 20 per cent that of developing country levels. At the prevailing levels of per capita income, the majority of the population in sub-Saharan Africa lives close to subsistence level. On average more than 55 per cent of the population has a per capita income below one dollar a day, and about 85 per cent of the population has a per capita income of less than two dollars a day.

The extremely low levels of per capita income reflect the underdeveloped structure of these economies compared to other developing countries, and their meager stock of capital. On average, more than two thirds of the population and labour force reside in the countryside and work in the agricultural sector. The share of agriculture in GDP is more than double the average for other developing countries. The low level of industrialisation is also reflected in the extremely low levels of modern sources of hydrocarbon based energy use, compared to other developing countries. The per capita consumption of combined coal, oil, gas, and electricity is one-tenth the prevailing levels in the developing countries. By contrast, fuel-wood sources of energy still constitute the bulk of energy consumption in much of SSA.

The region lags far behind other developing countries in educational attainment and other aspects of human capital development required in an increasingly knowledge-based global economy. Available data indicates that adult literacy rate is on average 49 per cent in these countries compared to 81 per cent for other developing countries. Primary and secondary school enrolment rates are respectively on average about 30 and 50 percentage points below the other developing country averages, and tertiary enrolment rates are a tenth that of other countries. The indicators suggest that African countries are fast falling behind other developing countries with respect to human capital formation in spite of the significant progress made since independence. The vast majority of the population is either rural based, or has recently migrated to urban areas. The degree of economic retrogression in these countries over the past few decades and, the gap with other developing countries in terms of the stock of human capital, is likely to widen in the face of rapid advances in science and technology in the more developed societies.

African countries have a comparably weak physical and knowledge infrastructure base, exemplified by poor telecommunications and transport facilities. The number of telephone lines per thousand people, for example, is about five - one twentieth of the average for other developing countries. The cost of local telephone calls is one hundred per cent higher than the average for the latter. The considerable lag in the development of telecommunication infrastructure within African countries and between SSA and other developing countries is likely to lead to their increasing exclusion from the global economy.

In sum, the foregoing highlights three broad features of African economies, which have important implications for attenuating digital inequalities. First, the majority of Africa's population lives in countries with very low per capita incomes and underdeveloped production structures. Second, extremely low levels of knowledge and physical infrastructure constrain efficient use of productive resources in these countries. And third, largely as a consequence of the first two characteristics, SSA countries and particularly the African LDCs are highly vulnerable to external shocks arising from the vagaries of nature and external economic factors. These factors have important implications for theory as well as policy for mitigating income and digital inequalities.

## 3. DATA SOURCES AND MEASUREMENT ISSUES

Data for GDP per capita in US Dollars at constant price (in 1995) have been taken from WDI (2002), telephone, personal computer use (PC use), Internet use and Internet hosts data were taken from ITU (2002).

Using a median per capita income of US$ 360, we divided the African countries into two broad groups of relative *low* and *high income.* This exercise is intended only for analytical comparison in this paper and does not suggest a permanent category. Its arbitrariness is reflected in Table 1 showing that about six of the countries in our category of high income are actually LDCs. In this aberrant grouping however, we make our first observation, which is that some countries with low income have succeeded in attaining a decent host per capita ratio and a modest Internet User Index (IUI)[1]. Take for instance the Gambia with an IUI of 0.126, and Ethiopia with 0.001. Both countries are LDCs but the Gambia has more than 120 times the value of IUI as Ethiopia. Mauritius, which leads in the group, has 1000 times the value of Ethiopia. Zambia, an LDC, shares with Angola, Senegal, and Zimbabwe, a relatively modest IUI and income per capita.

[1] We define IUI as a normalized value using the formula shown under table 1.

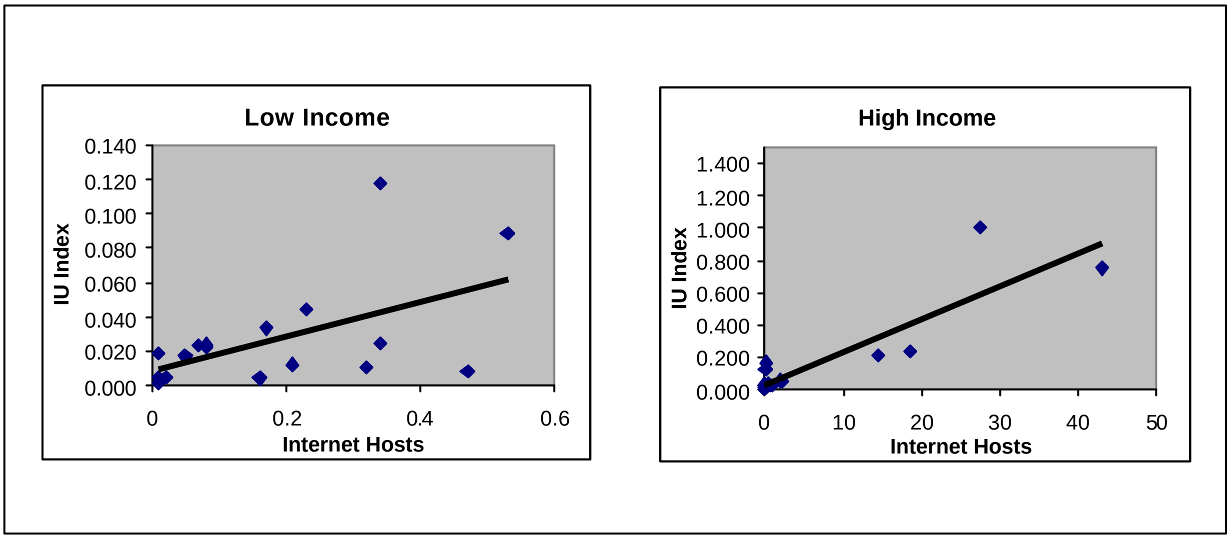
**Table 1: Economic wealth and other determinants of the Internet use in SSA (2000)**

| Country | GDP (USD) in 1995 | IU density (per 10,000) | IU INDEX | IH density (per 10,000) | PC density (per 1,000) | Tele density (per 1,000) |
|---|---|---|---|---|---|---|
| **Low Income** | | | | | | |
| Ethiopia | 115.88 | 1.58 | 0.001 | 0.01 | 0.945 | 3.23 |
| Burundi | 140.70 | 7.47 | 0.009 | | .. | |
| Sierra Leone | 147.39 | | | | | |
| Eritrea | 155.05 | 13.05 | 0.017 | 0.05 | 1.608 | 8.09 |
| Malawi | 168.63 | 14.51 | 0.019 | 0.01 | 1.161 | 3.86 |
| Tanzania | 190.49 | 32.75 | 0.044 | 0.23 | 2.847 | 4.87 |
| Niger | 202.80 | 3.73 | 0.004 | 0.16 | 0.466 | 1.86 |
| Guinea-Bissau | 209.76 | 24.97 | 0.033 | 0.17 | .. | |
| Chad | 217.84 | 3.92 | 0.005 | 0.01 | 1.341 | 1.46 |
| Rwanda | 241.77 | 6.47 | 0.008 | 0.47 | .. | |
| Madagascar | 245.80 | 18.82 | 0.025 | 0.34 | 2.195 | 3.43 |
| Burkina Faso | 252.05 | 8.38 | 0.011 | 0.32 | 1.257 | 4.35 |
| Nigeria | 253.60 | 17.57 | 0.023 | 0.07 | 6.587 | 3.84 |
| Mali | 287.74 | 16.74 | 0.022 | 0.08 | 1.157 | 3.36 |
| Sudan | 319.08 | 9.65 | 0.012 | 0.21 | 3.216 | 11.15 |
| Togo | 326.61 | 86.41 | 0.118 | 0.34 | 21.603 | 9.22 |
| Kenya | 328.20 | 65.21 | 0.089 | 0.53 | 4.891 | 10.88 |
| Central African Republic | 338.57 | 4.15 | 0.005 | 0.02 | 1.660 | 2.80 |
| Uganda | 347.95 | 18.01 | 0.024 | 0.08 | 2.701 | 2.87 |
| **High Income** | | | | | | |
| Gambia, The | 370.48 | 92.11 | 0.126 | 0.12 | 11.514 | 24.42 |
| Zambia | 392.38 | 19.19 | 0.026 | 0.86 | 6.717 | 9.20 |
| Ghana | 413.25 | 14.84 | 0.020 | 0.01 | 2.969 | 9.93 |
| Benin | 414.17 | 24.6 | 0.033 | 0.415 | 1.640 | 8.05 |
| Comoros | 435.79 | 21.61 | 0.029 | 0.58 | 4.323 | 10.27 |
| Mauritania | 495.68 | 18.87 | 0.025 | 0.45 | 9.434 | 7.17 |
| Angola | 506.07 | 22.84 | 0.031 | 0.01 | 1.142 | 8.39 |
| Guinea | 603.40 | 10.12 | 0.013 | 0.25 | 3.669 | 8.16 |
| Senegal | 609.24 | 42 | 0.057 | 1.93 | 16.800 | 20.71 |
| Zimbabwe | 620.70 | 37.08 | 0.050 | 2.16 | 11.867 | 27.08 |
| Cote d'Ivoire | 742.52 | 27.05 | 0.036 | 0.41 | 6.087 | 17.01 |
| Djibouti | 783.07 | 21.94 | 0.029 | 0.064 | 10.188 | 14.09 |
| Congo, Rep. | 841.42 | 1.75 | 0.002 | 0.02 | 3.492 | 7.68 |
| Equatorial Guinea | 1598.60 | 15.45 | 0.020 | 0.13 | 2.264 | |
| Namibia | 2407.60 | 170.78 | 0.234 | 18.51 | 34.157 | 68.35 |
| Botswana | 3951.10 | 154.13 | 0.211 | 14.53 | 36.991 | 89.93 |
| South Africa | 3985.10 | 549.38 | 0.754 | 42.95 | 61.805 | 133.63 |
| Gabon | 4378.00 | 122.35 | 0.167 | 0.28 | 9.788 | 32.28 |
| Mauritius | 4429.00 | 728.91 | 1.000 | 27.44 | 100.539 | 257.85 |

IUI = Internet User Index = $\{X_{j,i} - \text{Min}(X_{j,i})\}/\{\text{Max}(X_{j,i}) - \text{Min}(X_{j,i})\}$, Xi refers to the Internet user per capita and I, and j refer to the number of countries reporting data.
Data Source: World Development Indicators, The World Bank (2002), and ITU (2002).

With the exception of Kenya, all the countries that fell into the low IUI and low-income group belong to the least developed African countries confirming what we know about the correlation of wealth and Internet diffusion. Figures 1 to 3 show the graphical correlation of IUI for the two income groups, with Internet host, PC density and telephone density. Irrespective of the level of wealth, we found that these variables are correlated with Internet use.

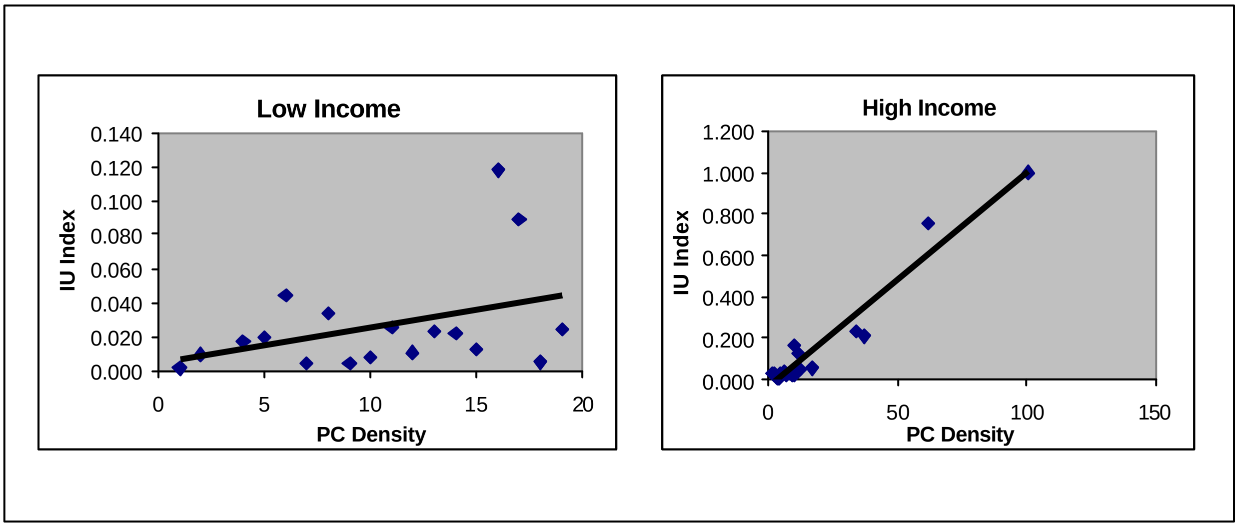
**Fig. 1: Internet users and hosts in SSA (2000)**




From Fig. 1, the IUI of some countries such as Togo and Kenya, with income per capita less that half of several countries (Cote d'Ivoire, Djibouti, Congo, Rep, and Equatorial Guinea), have a level of Internet use that is five to ten times higher than that of these countries. Fig. 1 also shows that the gradient, ∂(IUI)/∂(IH) of high-income countries is significantly higher than that of low-income countries. Larger changes in per unit of IUI with respect to unit change in IH suggests that the prerequisites for high Internet use - such as telecommunication infrastructure and last mile connectivity - are more likely to be found in high-come countries where presumably, the Internet Service Providers (ISPs) are better able to cover comparatively large numbers of end-users per Internet host.

Fig.2 depicts the diagrammatic relationship between IUI and PC density in low- and high-income countries. In this case also the per capita income of Togo, representing a low-income country, is roughly a quarter that of Equatorial Guinea, while the penetration of PCs is about 10 times higher.

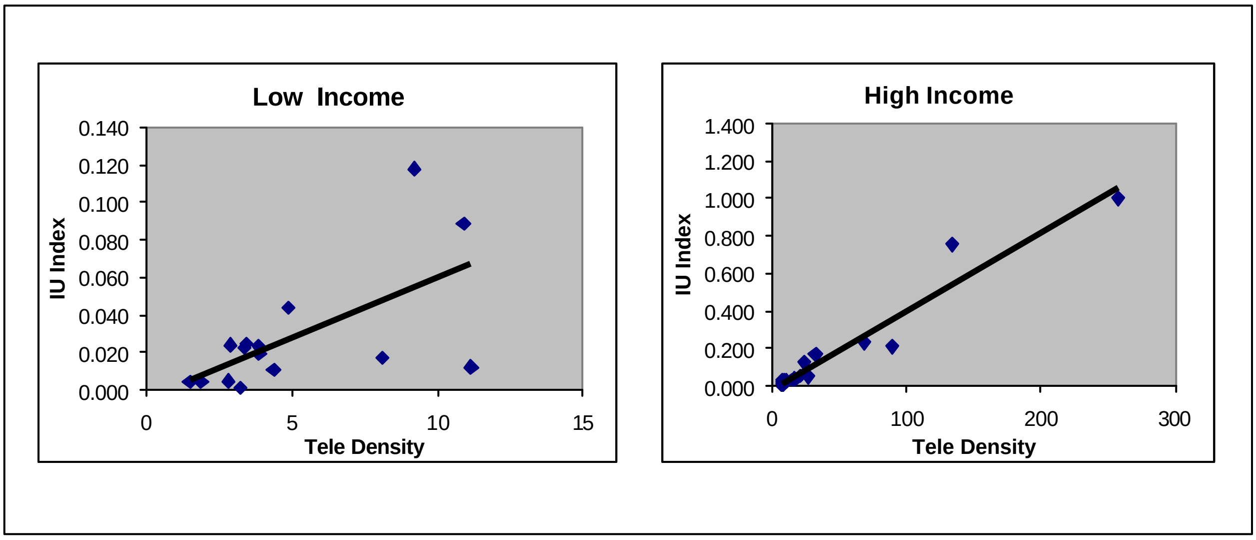
**Figure 2: Internet users and PC density in SSA (2000)**




It can be seen from Fig. 2 that the rate of change of IUI with respect to PC density is generally much higher in high-income countries. We can infer from these trends that PCs are more effectively used for the Internet in high-income countries.

The relationship between telephone density and IUI in two groups of countries is presented in Fig. 3. The range of telephone density in low-income countries varies from 1.46 to 10.88 per thousand persons while in high-income countries it is 7.17 to 257.85. It is clear that there is a substantial difference in the telephone density in two groups of countries and not surprisingly, IUI is significantly different in these countries.

**Figure 3: Internet users and telephone density in SSA (2000)**



Unlike in Fig. 1 and 2, however, the slopes of the trend lines in Fig. 3 are similar. This suggests that controlling for the growth in telephone density all the countries have experienced a similar growth rate in Internet users. We conclude that of the variables considered, telephone density is expected to be the most important factor influencing the diffusion of the Internet in SSA.

## 4. HYPOTHESES

From our review of the literature we found that the driving force behind the diffusion of the Internet is the quality of telecommunication infrastructure available in a country. In addition, other factors expected to influence the use of the Internet are economic wealth, access points, and human capital. In this section we formulate the hypotheses regarding these factors that are expected to be determinants of the adoption and diffusion of the Internet.

### 4.1 Gross domestic product (GDP)

Economic wealth, which is represented by GDP per capita in this study, has always been a major factor in the production and diffusion of a new technology. ICTs, particularly the Internet, are very different from earlier technological innovations. The most distinctive character of the new technologies is their knowledge, rather than capital, intensiveness. Like all innovations before it, empirical studies (Kiiski and Pohjola, 2002; Hargittai, 1999) suggest that economic wealth is a prerequisite for the diffusion of the Internet. Secondly, the development of the Internet and other ICTs is different from earlier innovations in terms of their pervasiveness. The applications of earlier technologies were for long limited to institutions, manufacturing, services, and other organizations whereas the Internet was simultaneously adopted by individuals as well as by corporate bodies. Hence, individual income, as well as institutional financial capital, are expected to influence the growth of the Internet. In view of the empirical evidence and the nature of the technology under consideration, we hypothesise that countries, whose per capita income is higher, should experience a higher Internet diffusion rate.

### 4.2 Human Capital (EDU)

As mentioned earlier ICTs are regarded as knowledge intensive technologies and several studies (Doms et al., 1997) have found that firms that employ more skilled workers are in a better position to reap the benefit of ICTs. However, several other studies (Oyelaran-Oyeyinka, 2002; Hargittai, 1999) did not find any evidence of a crucial role of differential human capital on diffusion of the Internet, although their samples are different. One very important distinction to be kept in mind is that while Doms et al. analyses firm level data of American firms, the conclusions of Hargittai are based on macro-level data of OECD countries. Although data for the study of Oyelaran-Oyeyinka came from Nigeria, the respondents were university teachers. The measurement of human capital is also different in all these studies. Oyelaran-Oyeyinka used levels of academic qualification as a proxy of human capital while Hargittai derived level of education from first-, second-, and third-level gross enrollment ratios. Keeping in mind the developing nature of the sample countries, we expect human capital to be significantly different in countries where the penetration of the Internet is higher as compared to countries in which Internet users form only a small fraction of the society. Again the types of skills required are vastly different in these countries. The basic literacy skills required for simple Internet use are in short supply in poor countries. Given the evident importance of education for literacy and numeracy associated with ICTs adoption, we hypothesise that education is associated with Internet diffusion.

### 4.3 Investment of telecommunication infrastructure (ITI)

Connectivity of computers is the backbone of electronic networks. Connectivity occupies a pivotal place in various types of networks, that is, Local Area Network (LAN), Wide Area Network (WAN), Intranet, and Internet. The type of technology used for networking of computers depends on the nature and configuration of the network. For instance, for LAN structured cable with mega bits per second (MBPS), speed may be sufficient while for WAN fiber optic cable solution may more appropriate. For Intranet and the Internet, digital and satellite modes of communication are preferred. Almost all the studies (Kelly and Petrazzini, 1997; Hargittai, 1999; Kiiski and Pohjola, 2002) have analysed the role of communication network in diffusion of the Internet. Although different indicators of communications technologies have been used by these studies, the finding of all the studies suggest that networking technologies play a significant role in the diffusion of the Internet. Unlike a number of earlier studies that have considered access cost as one factor that influenced the penetration of the Internet, we have used per capita investment on the communication infrastructure as a measure of the quality of connectivity. From the above, we hypothesise that diffusion of the Internet is higher in those countries that have invested relatively more on communication networks.

### 4.4 Telephone density (TELEDEN)

Although telephone density is a part of the telecommunication network, we considered it separately in the analysis. This is because the last mile connectivity to end-users is provided by Public Switched Telephone Networks (PSTN). The last mile connectivity is the mode of communication between a user of the Internet and the Internet Service Provider (ISP). Although several other technologies such as Integrated Service Digital Network (ISDN), Digital Subscriber Link (DSL) are available for this purpose, the most preferred technology is PSTN. The use of both investments on telecom infrastructure and telephone density is justified because investment in telecom is part of a country’s institutional infrastructure that is beyond the control of individual Internet users. Several empirical studies (Kiiski and Pohjola, 2002; Hargittai, 1999; Lal and Shampa, 2002) have analysed the role of last mile connectivity in the diffusion of the Internet. Kiiski and Pohjola used access cost as well as telephone density as a proxy of telecom variable in their study of OECD and non-OECD countries whereas Hargittai and Lal & Shampa used telephone density in their study of OECD and Asia-Pacific countries respectively. All the above studies conclude that last mile connectivity significantly influenced the penetration of Internet. Drawing upon the empirical evidence we expect that telephone density will have a significant association with the diffusion of the Internet in African countries.

### 4.5 Density of personal computers (PCDEN)

Although the Internet can be accessed though systems other than personal computers (PCs), institutional access of the Internet is usually through LANs. The access points of the Internet in LAN are usually a combination of PCs (intelligent terminals) and dump terminals. Therefore the use of the Internet might not only be a function of PCs within institutions. However, access of the Internet in households is possible through PCs. Moreover commercial access to the Internet (Cyber Cafes) is also enabled through PCs only. In fact households and cyber cafes dominate the access of the Internet. In view of the fact that availability of a PC is a necessary but not sufficient condition for the Internet access, PC density is expected to emerge as a significant determinant of Internet diffusion. Having no a priori of knowledge of the role of PC density in the diffusion of the Internet, it is hypothesised that the penetration of PCs and Internet use are highly correlated.

### 4.6 Density of Internet hosts (IH)

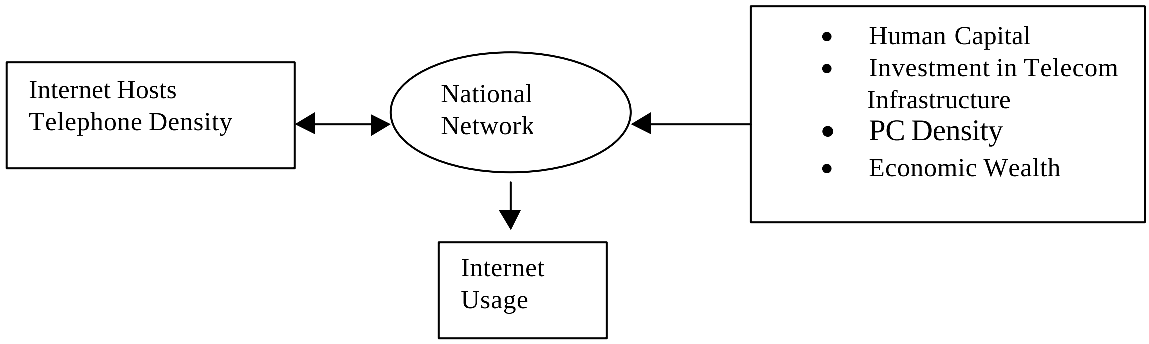
A host is a computer through which Internet can be accessed. Several Studies (Clarke, 2001; Kiiski Pohjola, 2002, Hargittai, 1999) have identified factors influencing Internet diffusion. Kiiski & Pohjola and Hargittai used macro-data of OECD and non-OECD countries while Clarke’s is a firm level study. Clarke uses data for 10,000 enterprises of 80 countries. The data include enterprises that belong to transition economies. While Kiiski & Pohjola and Hargittai use density of Internet hosts as a measure of Internet diffusion, Clarke uses number of Internet users as a proxy of Internet diffusion. In case of OECD and other developed countries, Internet hosts and users might explain the same phenomenon. While these variables are expected to be positively correlated with each other in developing countries, however, the context here is different, (Clarke 2001). In developing countries, access of Internet from homes is not a common phenomenon. Users tend to access the Internet from common service providers such as cyber cafes and other institutions. This means one host provides Internet access to a large number of people. In his study of Nigerian universities Oyelaran-Oyeyinka (2002), finds that a large number of faculty members within the university community access the Internet from cyber cafes. Ease of access to the Internet is facilitated by the wide availability and quality of

Internet hosts. Thus the number of Internet hosts is expected to emerge a significant determinant of the Internet use the proxy of Internet diffusion in this study.

## 5. ANALYTICAL MODEL

The diffusion of the Internet cannot be captured through a single econometric equation. This is because the explanatory variables discussed in the earlier sections might be highly correlated. Moreover, we intend to explain the diffusion of the Internet in terms of economic wealth and investment in telecommunication infrastructure where the latter is heavily dependent on the former, (Roller and Waverman, 2001). The authors used a simultaneous equation system approach to investigate the affects of telecommunication infrastructure on economic growth of 21 OECD countries. Although Kiiski and Pohjola (2002) have used the well known Gompertz[2] model of technological diffusion, they extend the analysis in a simultaneous equation framework to overcome the problem of multicollinearity among the explanatory variables. To examine the role of the variables discussed in Section 4, we propose to use the simple analytical framework proposed in figure 5.

**Figure 5: Theoretical Framework**




Drawing upon the empirical evidence regarding association of macro variables, we employ a system of equations to explain the variability in the diffusion of the Internet in African countries:

| | | |
|---|---|---|
| IU | = f (IH, PCDEN) | Diffusion of Internet |
| IH | = f (TELEDEN, ITI [-1], EDU) | Infrastructure Equation |
| TELEDEN | = f (IU, GDP) | Communication Network Equation |

[2] Grompertz model of diffusion suggests that diffusion rate of technology is directly proportional to the log difference between current use and long-run equilibrium.

Where,

IU→ Internet users per 10,000 persons

IH→ Internet hosts per 10,000 persons

PCDEN→ Personal computers per 1,000 persons

TELEDEN→Telephone lines per 1, 000 persons

ITI→ Per capita investment on telecommunication infrastructure in USD

EDU→ Percentage of enrollment to the total at tertiary education

GDP→ Per capita GDP in USD (constant price at 1995)

The first equation in the model shows the relationship between Internet users and Internet hosts and the penetration of computers in the society. It is assumed that Internet hosts and PC density are two variables that directly influence the adoption of the Internet. However, Internet hosts cannot be treated as independent of the existing telecommunication infrastructure in general, and PSTN in particular. This is because Internet service providers are unlikely to invest in cyber cafes unless a reliable communication network is available. In addition to last mile connectivity, investment on national and international telecommunication infrastructure, which includes long distance and satellite communication, is equally important. Further, reliable national and global communication is necessary for the smooth functioning of the Internet at the end-user level. Therefore, we have included this as one of the explanatory variables in the second equation. A one-year lag of investment on communication infrastructure is preferred to the current value. This is because telecommunication investments require a long gestation period to make the desired impact.

The third equation depicts the relationship between the existing telephone density and demand, and the ability of countries to meet increasing demands for telephone lines, which might partially be due to the perceived potential benefits of the Internet. Hence, in the third equation we propose that telephone density is likely to be influenced by the increasing number of Internet users and GDP per capita.

## 6. RESULTS

Data were first analysed in a univariate framework and subsequently parameters of the model presented in Section 4 were estimated using maximum likelihood method. The results are presented in the respective sub-sections.

### 6.1 Univariate analysis

For a better understanding of the pattern of diffusion of the Internet in SSA, the countries were categorized into two groups on the basis of economic wealth. The median value of GDP per capita was used as a cut off point between low- and high-income countries. The mean value of the variables and the statistical significance of the mean values between the two groups of countries are presented in Table 2.

**Table 2: Mean value of variables in low and high income countries (2000)**

| Variables | Income level | | F-statistics | Level of Significance |
|---|---|---|---|---|
| | Low (< 360 USD) | High (>360 USD) | | |
| EDU | 2.11 (2.15) | 4.72 (4.08) | 5.74 | 0.022 |
| GDP | 236.31 (73.29) | 1472.5 (1522.9) | 12.49 | 0.001 |
| IH | 0.18 (0.17) | 5.85 (11.81) | 3.89 | 0.056 |
| ITI | 0.29 (0.49) | 6.26 (10.40) | 5.56 | 0.024 |
| IU | 19.63 (22.28) | 110.26 (195.18) | 3.83 | 0.058 |
| PCDEN | 3.58 (5.25) | 17.65 (25.31) | 4.46 | 0.043 |
| TELEDEN | 5.02 (3.19) | 41.90 (63.89) | 4.96 | 0.033 |

*Note:* Figures in parentheses are standard deviations.

From Table 2 we see that the mean values of all the variables differ significantly between the two groups. However, the level of significance differs. For instance, the level of significance of EDU, ITI, PCDEN, and TELEDEN is 5% whereas IH and IU differ less significantly, at 10 %.

The variables were analysed by another classification of sample countries, on the basis of density of the Internet users. In this case also, the groups were categorised on the basis of the median value of Internet users - at 19 persons per 10,000 inhabitants. Descriptive statistics of variables along with significance of group mean differences is presented in Table 3.

**Table 3: Distribution of mean value of variables by the intensity of Internet use (2000)**

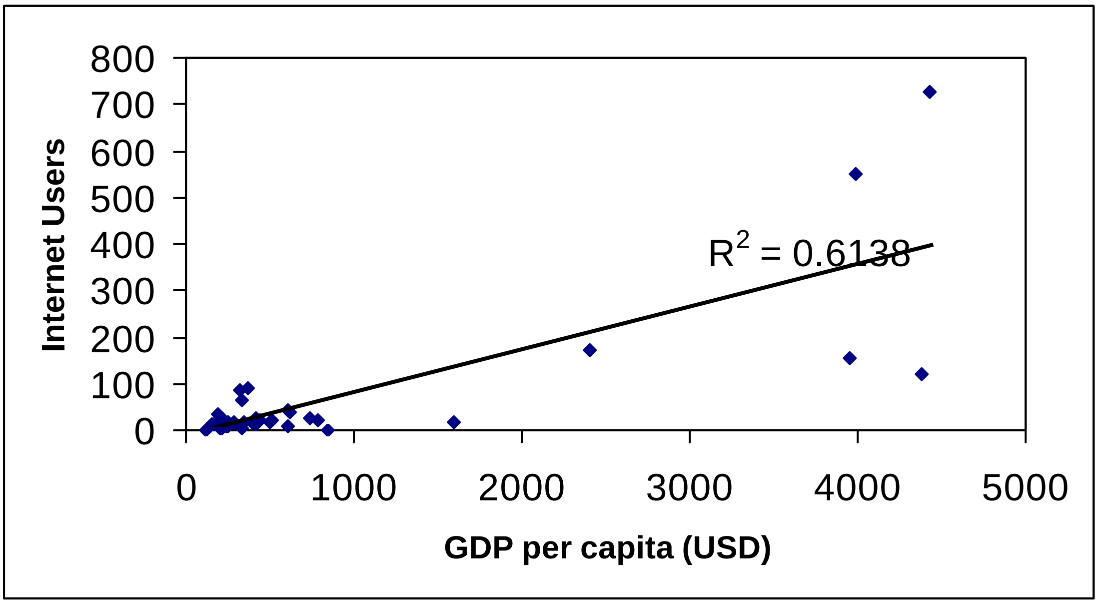
| Variables | Intensity of Internet use | | F-statistics | Level of Significance |
|---|---|---|---|---|
| | Low | High | | |
| EDU | 2.604 (2.33) | 4.23 (4.33) | 2.11 | 0.155 |
| GDP | 381.61 (334.57) | 1452.2 (1642.9) | 8.14 | 0.007 |
| IH | 0.18 (0.22) | 6.51 (12.35) | 5.28 | 0.028 |
| ITI | 0.02 (0.34) | 6.36 (10.40) | 5.98 | 0.020 |
| IU | 10.71 (6.48) | 130.83 (199.67) | 7.64 | 0.009 |
| PCDEN | 2.94 (2.39) | 21.01 (26.72) | 8.19 | 0.007 |
| TELEDEN | 5.44 (3.07) | 46.06 (66.79) | 6.29 | 0.018 |

*Note:* Figures in parentheses are standard deviations.

Table 3 shows that the ratio of enrolment at the tertiary level of education does differ significantly between the two groups. The table also shows the high significance level of many of the variables. For instance, PC density and income level of countries in both groups differ significantly (1%). The significance level of the remaining variables, that is, IH, ITI, and TELEDEN is 5 %. It is difficult to draw any inference from Table 3 for two reasons. First, the figures presented in the table are based on the data for one year, and second, the results are based on univariate tests that exclude the interaction of other variables. Before analysing the data within the simultaneous equation framework, we explore the relationship between Internet users and the most significant variables in the univariate analysis. The trends are presented in Figures 5 to 7.

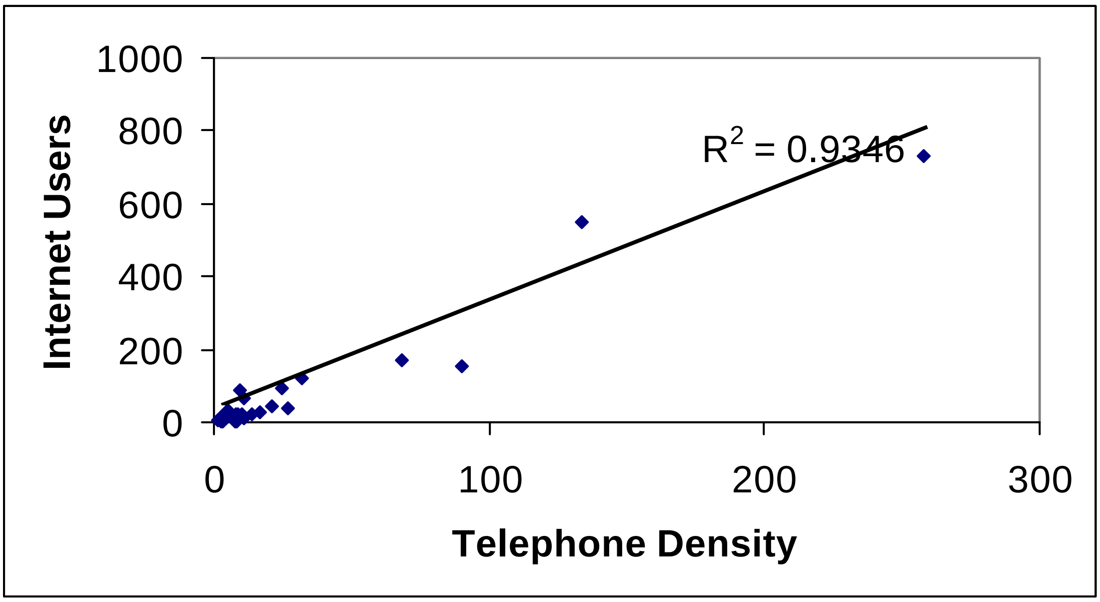
Fig. 5 presents the relationship between the density of the Internet users and the economic wealth of the countries studied. The figure shows that GDP is an important determinant of diffusion of the Internet. The R-square of a trend line between Internet users and GDP is 0.62, which indicates the explanatory power of GDP in influencing the use of the Internet. 62 percent of the variance of the dependent variable is explained by GDP per capita. This confirms similar findings cited earlier.

**Figure 5: Internet users and GDP per capita in USD (2000)**




Similarly Fig. 6 presents the relationship between use of the Internet and last mile connectivity. The value of the R-square of the trend line between these variables is 0.93, a very high figure. In other words, 93 percent of the variance of the dependent variable is explained by telephone density.

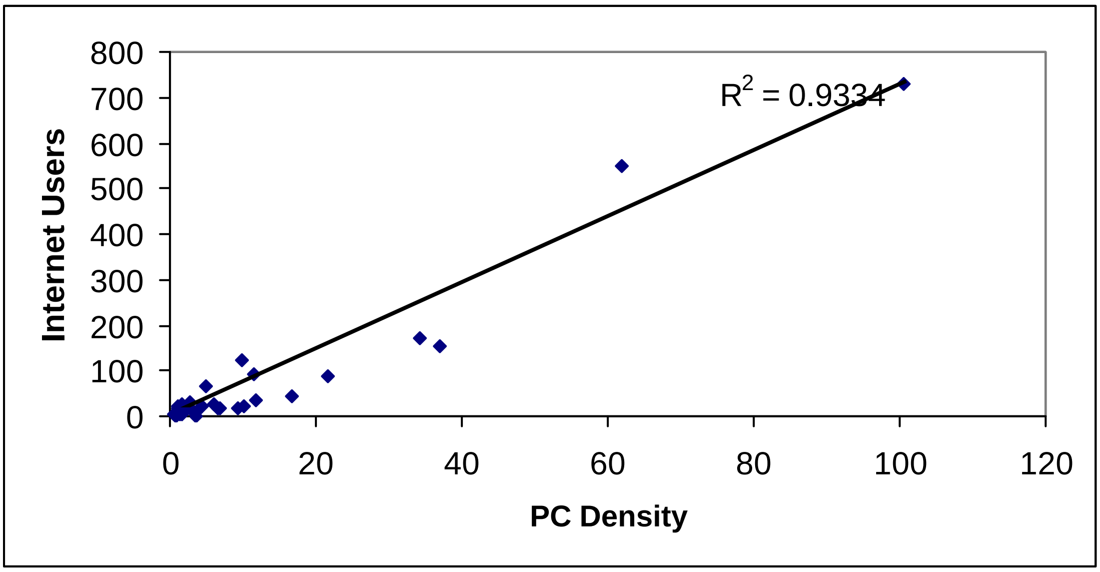
**Figure 6: Internet users and telephone density (2000)**




We conclude from Fig. 6 that telephone density is more important than GDP in explaining the variations in Internet diffusion in the sample countries when they are analysed separately in a single equation framework. However, their relative importance might change in a simultaneous equation model.

The mean values of PC density also emerged as significantly different in low- and high-Internet using countries. The relationship between these variables depicted in Fig. 7 therefore justifies the statistics presented in Table 3. A very high R-square (0.93) of the trend line between these variables suggests that the explanatory power of PC density is also very high.

**Figure 7: Internet users and PC density (2000)**




The graphs depicted in Figures 5, 6, and 7 are based on data for the year 2000. The trends depicted in these figures may change in coming years. In order to obtain a more robust relationship between the diffusion of the Internet and other macro variables, the data was analysed using the simultaneous equation approach.

### 6.2 Estimates of simultaneous equation system

Data was analysed using pooled series as well as separately for each year. The pooled results are presented and interpreted in Table 4, while the results of each year are presented in Appendix I.

**Table 4: Maximum likelihood estimates of pooled data**

| | | |
|---|---|---|
| Internet Diffusion Equation: Dependent Variable (Internet Users) | | |
| Independents | (1) | (2) |
| Internet hosts | 1.177 (3.531)*** | 1.419 (4.378)*** |
| Computer Density | 4.684 (32.573)*** | 4.531 (32.193) *** |
| $R^2$ | 0.67 | 0.69 |
| No. of cases | 199 | 199 |
| DW | 1.85 | 1.86 |
| Infrastructure Equation: Dependent Variable (Internet Hosts) | | |
| Independents | (1) | (2) |
| Existing telephone density | 0.075 (12.838)*** | 0.099 (13.249)*** |
| Investment on Telecom (Pre. Year) | 0.092 (6.263)*** | |
| Education Level | 0.047 (0.493) | 0.565 (6.932)*** |
| $R^2$ | 0.46 | 0.57 |
| No. of cases | 157 | 200 |
| DW | 2.96 | 2.43 |
| Telecommunication Equation: Dependent Variables (Telephone Density) | | |
| Independents | (1) | (2) |
| Internet Users | 0.412 (33.625)*** | 0.426 (34.982)*** |
| Economic Wealth | 0.006 (8.377)*** | 0.005 (7.684)*** |
| $R^2$ | 0.64 | 0.63 |
| No. of cases | 208 | 208 |
| DW | 1.67 | 1.66 |

*Note:* Level of significance: ***→ at 1 %; **→ at 5 %; *→ at 10 %

Table 4 presents two sets of results. In the first case, parameters of full model specification as discussed in Section 4 were estimated while in the second set, ITI was dropped. Although, the results of both specifications for pooled series are different, the results for years 1999 and 2000 do not differ. For other years the system did not converge and hence the results are not reported.

Table 4 shows that education level did not emerge significant in Model 1 whereas it became significant as soon as investment on telecom infrastructure was dropped from the model. R-square, number of observation, and DW are reported for each equation. This is because the model uses unbalanced data and hence it is important to report the number of cases that have been used for estimating the initial value of parameters of a particular equation.

The results also show that the density of Internet hosts and PCs significantly influenced the diffusion of the Internet. The results confirm our hypothesis. Higher Internet host density in a country suggests the existence of a large number of Internet access points. The presence of a large number of access points promotes ease of the Internet access. Similar findings were reported by Oyelaran-Oyeyinka (2002) in his study of use of the Internet in Nigerian universities. A clear distinction has to be made between an Internet host and PC. A PC becomes an Internet host once appropriate hardware and software are installed on a PC that makes it an Internet access point. There are two possibilities: first, an Internet host could provide Internet connectivity from the same system and second, with the appropriate software, it may allow

Internet access from all the computers that are connected with the master computer. In the latter case there could be one Internet host but a large number of PCs. This type of connectivity is very common - not only in institutions where computers are connected through LAN, but also in cyber cafes that are commercial providers of Internet access. The emergence of PC and Internet density as significant determinants of the Internet diffusion suggests that ease of Internet access facilitates its diffusion.

The second equation of the model - labeled as the infrastructure equation - identifies the factors that influence the density of Internet hosts. It can be seen from Table 4 that the present level of telephone density and one year lag of investment in telecommunication infrastructure are significant determinants of Internet hosts in a country. The results not only support our hypothesis but are also in line with the findings of earlier studies (Kiiski and Pohjola, 2002; Hargittai, 1999). Although both variables are related to the quality and quantity of telecommunication networks, they represent different dimensions of networking. A decision to have a telephone is an individual's choice that is influenced by several factors, of which access to the Internet could be one. By contrast, investments in telecommunication infrastructure are decided by local and national governments. Lal (2001) found that the institutional environment plays a crucial role in the diffusion and production of ICTs in developing countries. It can be argued that investment in telecommunication networks is a necessary condition for rapid diffusion of the Internet. This is because the speed of hypertext signal will be very slow in the absence of digital and high bandwidth provided by national and international carriers.

The emergence of telephone density as an important factor influencing the growth of the Internet is not surprising. The fixed telephone provides last mile connectivity between end-user and ISPs. Although several other technologies are available for this purpose, the lack of data on DSL and leased circuits prevents our use of those variables. Having some form of connectivity from end-user to ISPs is a necessary condition for accessing the Internet. Being the most popular medium of connectivity, the telephone was considered as a separate variable. Table 4 shows that education level is insignificant in the first model but it becomes important once the ITI is removed from the model. This could be due to multicollinearity between ITI and EDU. The findings related to education level and the diffusion of the Internet have produced mixed results in several earlier studies. The results of Equation 2 of the model suggest that supply side factors have important significance for the use of the Internet.

The third equation of the model establishes the relationship between demand side factors and use of the Internet. The results presented in Table 4 suggest that both the use of the Internet and national wealth influenced telephone density. A high R-square (0.64) shows that these variables are not only significant in explaining the variations in telephone density but that their joint explanatory power is very high. These results again confirm our hypothesis. The role of economic wealth has been found crucial not only in ICTs but also in the promotion of a new technology. With regards to the influence of economic wealth on telecommunication technologies a study by Roller and Waverman (2001) concludes that they had very strong bi-directional links. The results of this study support our hypothesis on the impact of GDP. Several other studies (Kiiski and Pohjola, 2002; Hargittai, 1999) have investigated the role of GDP in influencing the use of the Internet in a single equation framework. Findings from both studies suggest that GDP emerged as an important determinant of the use of Internet in OECD and non-OECD countries. We may conclude that the findings of the study are in line with other studies.

## 7. SUMMARY AND CONCLUSIONS

The study aimed at identifying and analysing the factors that influenced the diffusion of the Internet access in forty-one Sub-Sahara African countries. Data for 1995-2000 was used. The role of macro economic indicators such as GDP per capita and per capita investment of telecommunication infrastructure was investigated. Technological variables such as density of telephones, personal computers, and Internet hosts were also included. Since ICTs are regarded as skill-biased technologies, we examined the role of human capital as well. The data was analysed in a simultaneous equation framework. The parameters of the model were estimated using pooled data as well as each year separately. The model consists of three equations, labelled as Internet diffusion, Infrastructure, and Communication Network Equations.

Internet diffusion equation identifies the factors that are expected to directly influence diffusion of the Internet. The second equation examines role of existing telephone density and per capita investment on telecommunication infrastructure, while the third equation investigates the role of economic wealth and the density of Internet users in influencing telephone density.

The findings of the study suggest that the density of Internet hosts and personal computers significantly influence the diffusion of the Internet. The findings confirm our expectations. The emergence of these variables as important determinants is not surprising because the existence of a computer is a necessary condition for Internet access. A large number of Internet hosts facilitates the efficient and effective use of the Internet. The results support findings by Oyelaran-Oyeyinka (2002) that the ease of accessibility of the Internet was a significant factor in its diffusion in Nigerian universities.

The results also show that a one-year lag in telecommunication infrastructure investments, as well as the existing telephone density, are important determinants of the numbers of Internet hosts, which in turn influences the use of the Internet. These finding are not surprising and support the findings of earlier studies (Hargittai, 1999; Kelly and Petrazzini, 1997). The one-year lag - rather than the current value of investments in telecommunication networks - might have emerged as an important factor due to gestation period of these technologies. Using an alternative measurement of last mile connectivity, Kiiski and Pohjola (2002) had similar results with regard to importance of telephone density in influencing use of the Internet.

The study captures the significant role of economic wealth in stimulating the diffusion of the Internet. Similar results have been found by almost all the studies that have examined the predictive role of GDP per capita. Economic wealth is particularly relevant in the case of ICTs because governments need significant investment capital to develop a reliable and efficient national and global telecommunication network In his seminal book, Landes (1999) cites Gerschenkron (1962) on three possible sources of investment capital, namely: (1) A country with plenty of private wealth and well funded merchant banks that can finance small loans. (2) A poorer country with fewer and smaller private fortunes to finance industry through the creation of investment banks. (3) A poorer country still, where private wealth is not sufficient, leaving the state as the only source of finance (cited in Landes, 1999, p.275). Much of the African LDCs will be hard put to tap into any of these sources for capital. Yet, "You need money to make money," as Landes aptly title the chapter.

The study also finds a strong causal relationship between the diffusion of the Internet and telephone density. In sum, high levels of GDP, a strong presence of Internet hosts and an effective telephone network, are indispensable to the diffusion of the Internet, and by extension to all innovations. However, network capacity without an educated citizenry may not lead to the required transformation into the network society. Our study has shown that education is a major factor in development. Internet diffusion is certainly more pervasive in the relatively high-income category of African countries even if comparatively these countries are poor relative to other developing countries.

What then should poor countries do in order to improve access to the Internet and in the end, bridge their digital inequality? There are two divides in broad terms, the global divide between Africa and the industrialised countries and the regional divide within the region. Evidently African countries need greater investment flows, since huge investments are a prerequisite to building effective communications networks. African countries have recorded improvements in literacy levels at the primary, secondary and tertiary levels since after independence, however, they are still far behind the rapidly industrialising developing countries. Even then, basic literacy is not adequate. Explicit investments will have to be made if African countries are to develop a digitally literate citizenry. Other factors found to be significant predictors are institutions, telecommunications regulation, and forms of government.

However, the main policy implication of this study is that the need for a reorientation in telecommunication and economic policies to promote public as well as private investments in ICTs that in turn might further boost economic growth (Roller and Waverman, 2001). Future studies might consider the role of technological and other institutions that support the effective use of the Internet. Further research is needed to examine the role of such institutions in the diffusion of ICTs in general and the Internet in particular.

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## APPENDIX

**Appendix I: Cross Section Results (2000)**

| | | |
|---|---|---|
| Internet Diffusion Equation: Dependent Variable (Internet Users) | | |
| Independents | (1) | (2) |
| Internet hosts | 3.536 (3.667)*** | 13.036 (26.534)*** |
| Computer Density | 5.862 (11.808)*** | 1.085 (2.868)*** |
| $R^2$ | 0.95 | 0.85 |
| No. of cases | 34 | 34 |
| DW | 2.46 | 2.81 |
| Infrastructure Equation: Dependent Variable (Internet Hosts) | | |
| Independents | (1) | (2) |
| Existing telephone density | 0.121 (16.774)*** | 0.213 (16.835)*** |
| Investment on Telecom (Pre. Year) | 0.155 (4.814)*** | |
| Education Level | 0.011 (0.093) | -0.022 (-0.374) |
| $R^2$ | 0.92 | 0.63 |
| No. of cases | 27 | 33 |
| DW | 3.10 | 2.56 |
| Telecommunication Equation: Dependent Variables (Telephone Density) | | |
| Independents | (1) | (2) |
| Internet Users | 0.304 (14.762)*** | 0.305 (27.093)*** |
| Economic Wealth | 0.003 (1.386) | 0.0008 (0.988) |
| $R^2$ | 0.94 | 0.94 |
| No. of cases | 33 | 33 |
| DW | 1.78 | 1.85 |

*Note:* Level of significance: ***→ at 1 %; **→ at 5 %; *→ at 10 %

**Appendix I (Contd.): Cross Section Results (1999)**

| Internet Diffusion Equation: Dependent Variable (Internet Users) | | |
|---|---|---|
| Independents | (1) | (2) |
| Internet hosts | 0.612 (1.189) | 9.823 (19.934)*** |
| Computer Density | 5.349 (18.536)*** | 2.354 (5.653)*** |
| $R^2$ | 0.90 | 0.79 |
| No. of cases | 33 | 33 |
| DW | 1.81 | 3.33 |
| Infrastructure Equation: Dependent Variable (Internet Hosts) | | |
| Independents | (1) | (2) |
| Existing telephone density | 0.050 (4.124)*** | 0.155 (7.919)*** |
| Investment on Telecom (Pre. Year) | 0.104 (2.078)** | |
| Education Level | -0.090 (-0.451) | -0.047 (-0.516) |
| $R^2$ | 0.50 | 0.30 |
| No. of cases | 27 | 34 |
| DW | 3.35 | 2.13 |
| Telecommunication Equation: Dependent Variables (Telephone Density) | | |
| Independents | (1) | (2) |
| Internet Users | 0.379 (18.301)*** | 0.368 (22.712)*** |
| Economic Wealth | 0.005 (3.443)*** | 0.003 (3.316)*** |
| $R^2$ | 0.90 | 0.90 |
| No. of cases | 35 | 35 |
| DW | 1.44 | 1.47 |

*Note:* Level of significance: ***→ at 1 %; **→ at 5 %; *→ at 10 %

**Appendix I (Contd.): Cross Section Results (1997 & 1998)**

| Internet Diffusion Equation: Dependent Variable (Internet Users) | | |
|---|---|---|
| Independents | 1998 | 1997 |
| Internet hosts | 1.921 (2.831)*** | 1.726 (3.916)*** |
| Computer Density | 2.878 (12.878)*** | 2.145 (17.908)*** |
| $R^2$ | 0.59 | 0.46 |
| No. of cases | 33 | 33 |
| DW | 1.53 | 1.59 |
| Infrastructure Equation: Dependent Variable (Internet Hosts) | | |
| Independents | (1) | (2) |
| Existing telephone density | 0.034 (3.210)*** | 0.024 (2.272)** |
| Investment on Telecom (Pre. Year) | 0.191 (4.505)*** | 0.134 (4.938)*** |
| Education Level | 0.208 (1.214) | 0.218 (1.287) |
| $R^2$ | 0.59 | 0.56 |
| No. of cases | 27 | 26 |
| DW | 3.17 | 3.14 |
| Telecommunication Equation: Dependent Variables (Telephone Density) | | |
| Independents | (1) | (2) |
| Internet Users | 0.576 (8.990)*** | 0.797 (12.444)*** |
| Economic Wealth | 0.006 (2.986)*** | 0.005 (3.258)*** |
| $R^2$ | 0.62 | 0.41 |
| No. of cases | 38 | 34 |
| DW | 1.58 | 1.72 |

*Note:* Level of significance: ***→ at 1 %; **→ at 5 %; *→ at 10 %

**Appendix I (Contd.): Cross Section Results (1995 & 1996)**

| | | |
|---|---|---|
| Internet Diffusion Equation: Dependent Variable (Internet Users) | | |
| Independents | 1996 | 1995 |
| Internet hosts | 1.697 (3.927)*** | 1.624 (3.900)*** |
| Computer Density | 2.084 (14.133)*** | 1.994 (10.025)*** |
| $R^2$ | 0.48 | 0.56 |
| No. of cases | 33 | 33 |
| DW | 1.58 | 1.56 |
| Infrastructure Equation: Dependent Variable (Internet Hosts) | | |
| Independents | (1) | (2) |
| Existing telephone density | 0.048 (4.110)*** | 0.021 (1.715)* |
| Investment on Telecom (Pre. Year) | 0.073 (3.640)*** | 0.040 (3.280)*** |
| Education Level | -0.178 (-1.065) | 0.224 (1.654)* |
| $R^2$ | 0.34 | 0.42 |
| No. of cases | 26 | 24 |
| DW | 3.65 | 3.35 |
| Telecommunication Equation: Dependent Variables (Telephone Density) | | |
| Independents | (1) | (2) |
| Internet Users | 0.840 (11.031)*** | 1.081 (10.409)*** |
| Economic Wealth | 0.006 (4.100)*** | 0.005 (2.939)*** |
| $R^2$ | 0.40 | 0.35 |
| No. of cases | 34 | 34 |
| DW | 1.78 | 1.73 |

*Note:* Level of significance: ***→ at 1 %; **→ at 5 %; *→ at 10 %

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