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Internet diffusion in sub-Saharan Africa: A cross-country analysis

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Abstract

In this paper, the notions of digital inequality and digital divide have been employed to describe two levels of Information and Communications Technologies (ICTs) access. On the one hand is the inequality of access to the cluster of technology measured by Internet use and on the other are the confluence of skills and other resources that differentiate countries in sub-Saharan Africa. Using cross-country data, hypotheses are tested within a simultaneous equation system. The paper confirms the vital importance of telecommunications infrastructure represented by the high correlation of telephone density with Internet irrespective of per capita income level of the country.

JEL classification: C33; L86; L96; O38

Keywords: Internet diffusion; Developing countries; Economic wealth; Tertiary education

1. Introduction

The Internet has diffused rapidly but its spread has been highly asymmetrical across regions and countries and within regions and countries. It is hard to conceive that the Internet came into the 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

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Table 1
Regional distribution of Internet users (million)

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 and USA	182.67	31.5%
Latin America	32.99	5.7%

Bridges.org (2002), Spanning the digital divide, www.bridges.org.

spread. Current estimates show that Internet use in Africa lags behind that of other regions. Regional distribution of the Internet users in Table 1 shows that in the first quarter of 2002 world wide users of the Internet reached 580.78 million with only 6.31 million in Africa, only about 1% of world total.

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

2. Digital inequality

Contrary to more optimistic utopian conceptions, the "digital divide" tends to be widening. DiMaggio, Hargittai, Neuman, and Robinson (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 rather than being close or at least narrow, seems to be widening. 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 averaged 18%. This output gives cause for concern given that developing areas are starting from a lower level and should have been expected to grow at a faster rate. Of all the world's regions, only East Asia seems to be keeping up with the developed nations while others tend to be falling behind or barely keeping up. What gives rise to substantial growth differentials can be located in the levels of investment in knowledge and physical infrastructure. The OECD invests about ten times as much of its per capita income on research and development (R&D); it also has 17 times as many technicians and scientists per capita as the countries of sub-Saharan Africa (SSA).

Income inequalities have also been exacerbated. Per capita income between the rich and poor countries is widely divergent and predictions of convergence have not proved accurate. While there is hardly any evidence on the association of Information and Communications Technologies (ICTs) and income gaps, studies in the United States show that ICT adoption leads to inequality among social classes, races and educational provision, 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 provision such as software design at another extreme demands a qualitative move to higher academic training. As Robinson, Kestbaum, Neustadtl, and Alvarez (2000) have reported, using multivariate control, the impact of educational qualifications is twice 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 more secure 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 the likely beneficiaries of the ICT-related opportunities that tend to command higher levels of wages. Secondly, although this is no more than a conjecture, the computer may well substitute work ordinarily carried out by skilled craftsmen. The point of the ICT-inequality nexus is well put by Rodriguez and Wilson (2000), who argue that "when a new technology is introduced into a social setting where 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 most appropriately undertaken by the state, 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. In as much as the diffusion of technologies is dynamic, it is the changes in the configuration of technologies and the social use to which they are put that over time 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 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 utilization and the qualitative user demand. Given that inequality of income, and education is more pronounced in poorer countries and even more poignantly between poor and rich countries, this paper examines cross-country patterns of access and use of the Internet in SSA. The paper is organized as follows:

Existing digital inequalities and economic conditions of SSA countries are discussed in Section 2 whereas 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, while conclusions and policy implications are drawn in Sections 7.

3. Economic conditions of sub-Saharan Africa

As a group, the Least Developed Countries (LDCs) to which most of SSA belongs, are identified by the United Nations (UN) as low-income countries, with low levels of human capital that are highly vulnerable to natural and man-made shocks. Out of the 49 countries in SSA, there are 33 LDCs, putting the majority of SSA in this category. With the exception of South Africa, Mauritius, Botswana, Zimbabwe, and Nigeria which display different human and materials resource reasons, the other countries differ only marginally from the African LDCs. Selected characteristics of this group of countries are presented below.

The 33 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, in the large LDC countries in SSA where the majority of the populations live, per capita GNP is barely above 20% of the other developing country average levels. At the prevailing levels of per capita income, the majority of the LDC population in SSA lives close to subsistence level. On average more than 55% of the population have a per capita income below one dollar a day, and about 85% 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 structures of these economies compared to other developing countries, and their meager stock of capital. On average, more than two-thirds of the population and labor 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 industrialization 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. In contrast, fuel-wood sources of energy still constitute the bulk of energy consumption in much of SSA.

The countries lag 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 indicate that the adult literacy rate is on average 49% in these countries compared to 81% 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 of 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 recent migrants to urban areas. The degree of economic retrogression in these countries during the past few decades, and the lag between these countries and other developing countries in terms of the stock of human capital, is likely to widen in the face of the 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. For example, the number of telephone lines per thousand people is about five, one-twentieth of the average for other developing countries. The cost of local telephone calls is 100% 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 aspects 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. Secondly, extremely low levels of knowledge and physical infrastructure constrain the efficient use of productive resources in these countries. And thirdly, 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 or those arising from external economy-related factors. These factors have important implications for theory as well as policy for mitigating income and digital inequalities.

4. Data sources and measurement issues

Data for GDP per capita in US Dollars at a constant price (at 1995) have been taken from WDI (2002), telephone, personal computer use (PC use), Internet use and Internet hosts (IHs) data were taken from ITU (2002). An IH is a computer through which the Internet can be accessed. Using the median per capita income of US$ 360, sample countries were divided 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. Data used in the study are presented in Table 2. It can be seen from Table 2 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, also an LDC, shares with Angola, Senegal, and Zimbabwe, a relatively modest IUI and income per capita.

With the exception of Kenya, all the countries that fell into the low IUI and low-income group are the least developed African countries confirming what is known about the correlation of wealth and Internet diffusion.

[1]A normalized value of the Internet users per capita, i.e., Internet User Index has been used in the analysis. The definition of IUI is shown under Table 1. Normalization was necessary in view of the simultaneous equation framework particularly when variability in endogenous variables is very high which is the case in Internet users per capita.

Table 2
Economic wealth and other determinants of the Internet use in SSA

Country	GDP (USD) at 1995	IU density (per 10,000)	IU INDEX	IH density (per 10,000)	PC density (per 1000)	Tele density (per 1000)
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
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

Internet user index $(\mathrm{IUI}_i) = \{X_i - \mathrm{Min}(X_j)\}/\{\mathrm{Max}(X_j) - \mathrm{Min}(X_j)\}$, X_i refers to the Internet user per capita of *i*th country and *j* refer to the number of countries reporting data.
Data Source: World development indicators, The World Bank (2002), and ITU (2002); data pertain to year 2000.

5. Hypotheses

From review of the literature it is 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 the hypotheses are formulated regarding those factors that are expected to be determinants of the adoption and diffusion of the Internet.

5.1. 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 in general and the Internet in particular are very different from earlier technological innovations. The most distinctive character of the new technologies is that they are knowledge rather than capital intensive. Like all innovations before it, empirical studies (Hargittai, 1999; Kiiski & Pohjola, 2002) 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, it is hypothesized that countries whose per capita income is higher are expected to experience higher diffusion rate of the Internet.

5.2. Human capital (EDU)

As mentioned earlier ICTs are regarded as knowledge intensive technologies and several studies (Doms, Dunne, & Troske, 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 and Adeya, 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. analyze firm level data of American firms, the Hargittai's conclusions are based on macro-level data from OECD countries. Although data for the Oyelaran-Oyeyinka and Adeya, study came from Nigeria, the respondents were university teachers. The measurement of human capital is also different in all these studies. Oyelaran-Oyeyinka and Adeya, used levels of academic qualification as a proxy for 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, it is expected that human capital will be significantly different in countries where the penetration of the Internet is higher than those where the Internet users are a small fraction of the society. Again the nature and types of skills required are vastly different in these countries. While what may well be required for Internet use is basic literacy and instruction in the computer manipulation, these skills are in short supply in poor countries. Given the evident importance of education for literacy and numeracy associated with ICTs adoption, it is hypothesized that education is associated with Internet diffusion.

5.3. Investment in 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 computer networking 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 be more appropriate. For Intranet and Internet media, a digital and satellite mode of communication is preferred. Almost all studies (Kelly & Petrazzini, 1997; Hargittai, 1999; Kiiski & Pohjola, 2002) have analyzed the role of communication networks in Internet diffusion. Although different indicators of communications technologies have been used in these studies, the finding of all the studies suggest that networking technologies play a significant role in the diffusion of the Internet. Unlike many earlier studies that have considered access cost as a factor that influenced the penetration of the Internet, per capita investment on the communication infrastructure has been used as a measure of the quality of connectivity. From the above, it is hypothesized that the diffusion of the Internet in those countries that have invested more on communication networks is higher than those that invest relatively less.

5.4. Telephone density (TELEDEN)

Although telephone density is a part of the telecommunication network, it was considered 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 an Internet user 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 the institutional infrastructure that is beyond the control of individual Internet users whereas access to a telephone is an individual's decision and is within their reach. Empirically, several studies (Hargittai, 1999; Kiiski & Pohjola, 2002; Lal & Paul, 2004) have analyzed 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 & Paul used telephone density in their study of OECD and Asia-Pacific countries, respectively. All the above studies conclude that last mile connectivity significantly influenced Internet penetration. Drawing upon the empirical evidence it is expected that telephone density will have a significant association with the diffusion of the Internet in African countries.

5.5. Density of personal computers (PCDEN)

Although the Internet can be accessed through systems other than personal computers (PCs), institutional access of the Internet is usually through LANs. The access points of the Internet in the LAN are usually a combination of PCs (intelligent terminals) and dumb terminals. Therefore the use of the Internet might not be a function of only PCs in institutions. However, access to the

Internet in households is possible through PCs. Moreover the commercial access of the Internet (Cyber Cafes) is also enabled through PCs only. In fact households and cyber cafes dominate Internet access. In view of the fact that the availability of a PC is a necessary but not sufficient condition for Internet access, PC density is expected to emerge as a significant determinant of Internet diffusion. Several studies (Caselli & Coleman, 2001; Lal & Paul, 2004) have analyzed the factors that have resulted in different level of PC diffusion. Without a priori knowledge of the role of PC density in the diffusion of the Internet, it is hypothesized that PC penetration and use of the Internet are highly correlated.

5.6. *Density of internet hosts*

There is an accumulating literature that investigates factors that determine the Internet diffusion. Several studies (Hargittai, 1999; Clarke, 2001; Kiiski Pohjola, 2002) have identified factors that have influenced Internet use. Kiiski and 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 in 80 countries. The data include enterprises that belong to transition economies. While Kiiski and Pohjola and Hargittai use density of IHs as a measure of Internet diffusion, Clarke uses the number of Internet users as a proxy for Internet diffusion. In the case of the OECD and other developed countries, IHs and users might explain the same phenomenon. In developing countries, however, these variables are expected to be positively correlated with each other but the context is different (Clarke, 2001). In developing countries, Internet access from homes is not a common phenomenon. Users have 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 persons. Oyelaran-Oyeyinka and Adeya (2002) in their study of Nigerian universities find 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 IHs. In view of the developing nature of the sample countries, the number of IHs is expected to emerge as a significant determinant of Internet diffusion.

5.7. *Analytical model*

The Internet diffusion cannot be captured through a single econometric equation. This is because the explanatory variables discussed in the earlier sections might be highly correlated. Moreover, it is intended 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 & 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

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

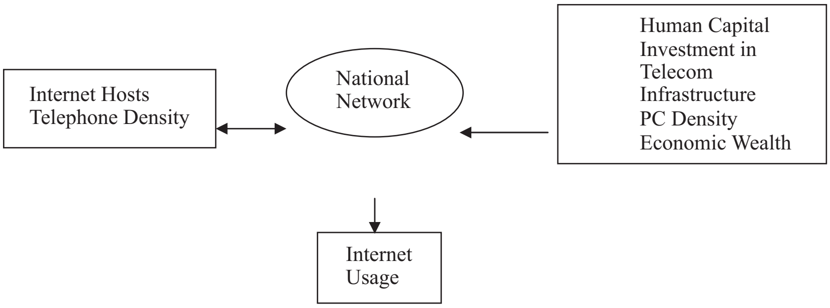

Fig. 1. Theoretical framework.

of the variables discussed in Section 4, it is proposed to use the simple analytical framework proposed in Fig. 1.

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

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

where, IU is the Internet users per 10,000 persons, IH the Internet hosts per 10,000 persons, PCDEN the personal computers per 1000 persons, TELEDEN the Telephone lines per 1000 persons, ITI the per capita investment on telecommunication infrastructure in USD, EDU the percentage of enrollment to the total at tertiary education, and GDP is the per capita GDP in USD (constant price at 1995).

It can be seen from the model that the first equation shows relationship between the Internet users with IHs and penetration of computers in the society. It is assumed that IHs and PC density are two variables that directly influence the adoption of the Internet. However, IHs cannot be treated as independent of existing telecommunication in general and PSTN in particular. This is because Internet service providers are not expected 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. A reliable national and global communication is necessary for smooth functioning of the Internet at the end-user. Therefore, it is included as one of the explanatory variables in the second equation. 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 existing telephone density and demand and the ability of countries to meet the increasing demand of telephones, which might be partially due to potential benefits of the Internet. Hence, in the third equation, it is proposed that telephone density is likely to be influenced by the increasing number of Internet users and GDP per capita.

6. Results

Data were first analyzed in a univariate framework and subsequently parameters of the model presented in Section 4 were estimated using the maximum likelihood method. Several methods, such as Seemingly Unrelated Regression (SUR), Maximum Likelihood (ML), and Generalized Method of Moments (GMM) can be used to estimate parameters of simultaneous equation systems. Each method is suited to a different situation and follows certain assumptions. For instance, GMM estimation is based upon the assumption that the disturbances in the equations are uncorrelated with a set of instrumental variables and ML estimates the likelihood function under the assumption that the contemporaneous errors have a joint normal distribution. GMM can be made robust to heteroskedasticity and/or autocorrelation of unknown form. ML is preferred compared to GMM because it is difficult to assume that disturbances are uncorrelated with instrumental variables in this case. Moreover, estimates are unlikely to suffer the problem of heteroskedasticity. The results are presented in the respective sub-sections.

7. 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 values of the variables and the statistical significance in their mean values between the two groups of countries are presented in Table 3.

From Table 3 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, that is, 10%.

The variables were analyzed by another classification of sample countries, that is, on the basis of density of the Internet users. In this case also, the groups were categorized on the basis of the median value of Internet users that is, 19 persons per 10,000 inhabitants. Descriptive statistics of variables along with significance of group mean differences is presented in Table 4.

Table 3
Mean value of variables in low and high income countries

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 parenthesis are standard deviations; data pertain to year 2000.

Table 4
Distribution of mean value of variables by the intensity of Internet use

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 parenthesis are standard deviations; data pertain to year 2000.

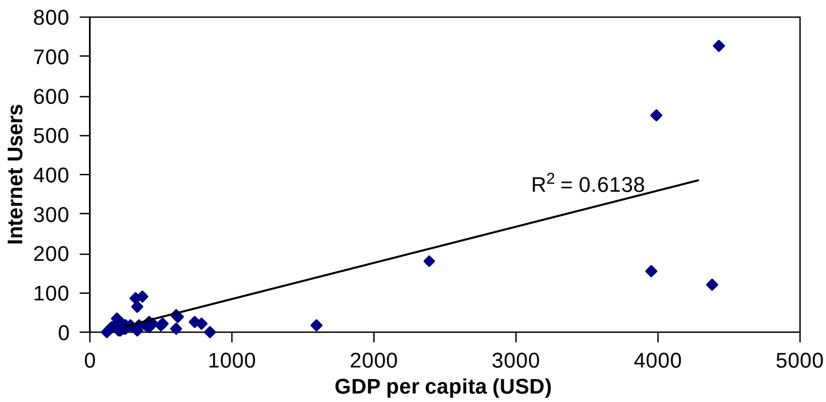

Fig. 2. Internet users and GDP per capita in USD (2000).

Table 4 shows that the ratio of enrollment at the tertiary level of education does not 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 the 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 4 for two reasons. First, the statistics presented in the table is based on the data for one year and secondly the results are based on univariate tests that exclude the interaction of other variables. Before analyzing the data within the simultaneous equation framework, the relationships between Internet users and the most significant variables have been explored in the univariate analysis. The trends are presented in Figs. 2–4.

Fig. 2 presents the relationship between the density of the Internet users and the economic wealth of the countries. The figure shows that GDP is an important determinant of Internet diffusion. The R^2 of a trend line between Internet users and GDP is 0.62 that indicates

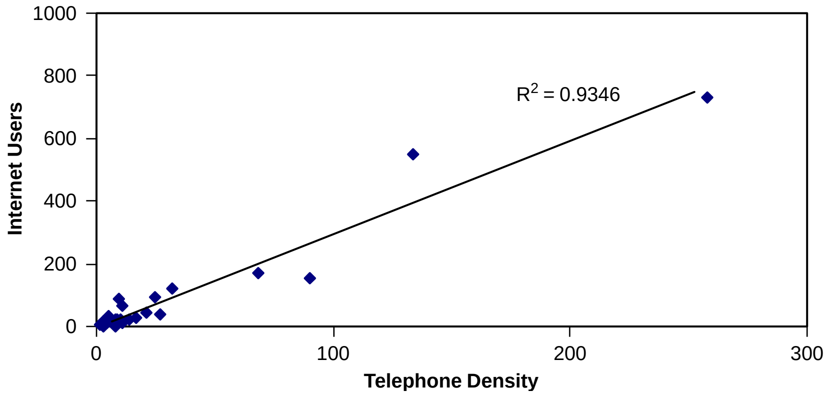

Fig. 3. Internet users and telephone density (2000).

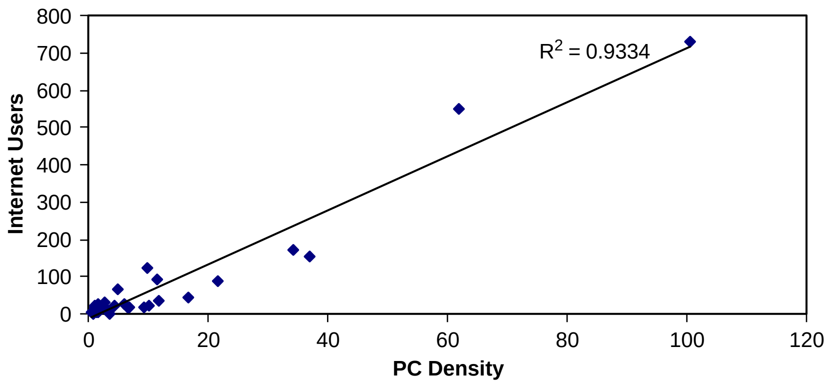

Fig. 4. Internet users and PC density (2000).

explanatory power of GDP in influencing use of the Internet. A 62% of the variance of the dependent variable is explained by GDP per capita. This confirms similar findings cited earlier.

Similarly Fig. 3 presents the relationship between use of the Internet and last mile connectivity. The value of R^2 of the trend line between these variables is 0.93 which is very high. In other words, 93% of the variance of the dependent variable is explained by telephone density.

It can be concluded from Fig. 3 that telephone density is more important than GDP in explaining the variation of Internet diffusion in the sample countries when they are analyzed 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 significantly differently in low- and high-Internet using countries. The relationship between these variables depicted in Fig. 4 therefore justifies the statistics presented in Table 3. A very high R^2 (0.93) of the trend line between these variables suggests that the explanatory value of PC density is also very high.

The graphs depicted in Figs. 2–4 are based on data for the year 2000. The trend depicted in these figures may not remain the same once the data are analyzed for other years. In order to obtain a more robust relationship between the diffusion of the Internet and other macro-variables, the data were analyzed using a simultaneous equation approach.

7.1. Estimates of simultaneous equation system

Data were analyzed using pooled series as well as each year separately. The pooled results are presented and interpreted in Table 4 while the results of year-wise analysis are presented in Appendix A.

Table 5 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 the 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 levels did not emerge as significant in Model 1 whereas they became significant as soon as investment on telecom infrastructure was dropped from the model. R^2, number of observations, 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.

Table 5
Maximum likelihood estimates of pooled data

	Model 1	Model 2
EQ1: Dep. variable (Internet users)		
Independents		
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
EQ2: Dep. variable (Internet hosts)		
Independents		
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
EQ3: Dep. variables (telephone density)		
Independents		
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: ***1%; **5%; *10%.

The results also show that the density of IHs and PCs significantly influenced Internet diffusion. The results confirm the hypotheses of the study. The presence of a large number of access points[3] promotes ease of Internet access. Similar findings were reported by Oyelaran-Oyeyinka and Adeya (2002) in a study of use of the Internet in Nigerian universities. A clear distinction has to be made between an IH and PC. An IH could be a stand-alone PC or PCs and dumb terminals connected through a network that allows Internet accessibility. A network type of configuration is very common not only in institutions where computers are connected through LAN and cyber cafes that are commercial providers of Internet access. The emergence of PC-density and IHs-density as significant determinants of Internet diffusion suggests that ease of Internet access facilitates its diffusion.

The second equation of the model labeled as an infrastructure equation identifies the factors that influence the density of IHs. It is seen from Table 4 that the present level of telephone density and a one year lag of investment in telecommunication infrastructure are significant determinants of IHs in a country. The results not only support the hypothesis but also are in line with the findings of earlier studies (Hargittai, 1999; Kiiski & Pohjola, 2002). Although both variables are related to quality and quantity of telecommunication networks, they represent different network dimensions. A decision to have a telephone is an individual's choice, which is influenced by several factors and use of the Internet could be one, whereas investment in telecommunication infrastructure is decided by local and national governments. The emergence of investments in telecommunications supports the findings of a study by Lal (2001) 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 a 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 that influenced 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 use of those variables. Having some form of connectivity from end-user to ISPs is a necessary condition for accessing the Internet. Telephones being the most popular medium of connectivity, were 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 produced mixed results in several earlier studies. The results of Eq. (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 5 suggest that both the use of the Internet and national wealth influenced telephone density. A high R^2 (0.64) shows that these variables are not only significant in explaining variations in telephone density but also their joint explanatory power is very high. These results again confirm a central hypothesis of the study. The role of economic wealth has been found to be crucial not only in ICTs but also in the promotion of a new

[3] A PC becomes an Internet access point once appropriate hardware and software are installed on it that enables accessibility of the Internet.

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. This study tried to indirectly assess the impact of GDP on the diffusion of the Internet. The results support the hypothesis. Several other studies (Hargittai, 1999; Kiiski & Pohjola, 2002) 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 the Internet in OECD and non-OECD countries. The findings of the study are in line with other studies.

8. Summary and conclusions

The study aims at identifying and analyzing the factors that influenced the diffusion of Internet access in 40 sub-Saharan countries. The study uses data for the 1995–2000 period. Macro-economic indicators such as GDP per capita and per capita investment in telecommunication infrastructure were used to investigate the role of each indicator in influencing the use of the Internet.

Technological variables such as density of telephones, PCs, and IHs were also included. Since ICTs are regarded as skill-biased technologies, the role of human capital was also examined. Data were analyzed 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. They are labeled as 'Internet diffusion', 'infrastructure', and 'communication network'.

The Internet diffusion equation identifies the factors that are expected to influence diffusion of the Internet directly. The second equation examines the status 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 the telephone density.

The findings of the study suggest that the density of IHs and PCs significantly influence Internet diffusion. The findings are in accordance with the 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 IHs facilitates using the Internet more efficiently and effectively. The results support the findings of Oyelaran-Oyeyinka and Adeya (2002) which concludes that ease of access to the Internet is a significant factor in its diffusion in Nigerian universities.

The results also show that one year investment lag in telecommunication infrastructure and existing telephone density are important determinants of the IHs that in turn influence use of the Internet. These findings are not surprising and support the findings of earlier studies (Kelly & Petrazzini, 1997; Hargittai, 1999). One year lag rather than the current value of investment on telecommunication networks might have emerged as important due to the gestation period of these technologies. Despite the use of an alternative measurement of last mile connectivity by Kiiski and Pohjola (2002), the results are akin to that of this study with regard to the importance of telephone density in influencing the use of the Internet.

The study captures the significant role played by economic wealth in stimulating Internet diffusion. Similar results have been produced by almost all the studies that have examined the predictive role of GDP per capita. The role of economic wealth becomes more relevant in the case of ICTs because governments need significant investment capital for a reliable and efficient communication network in order to experience a faster diffusion of these technologies. National and global communication networks are not possible without sufficient economic wealth. The countries explored in this study are in a position of relative economic backwardness, for which Gerschenkron (1962) recommends three levels of investment capital. The three levels are: (1) a country with an abundance 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, and (3) a poorer country still, where private wealth was not sufficient, and only the state could provide sufficient finance (cited in Landes, 1999, p. 275). Many of the African LDCs will be hard put to tap into any of these sources for capital.

The study has also found a strong causal relationship between Internet diffusion and telephone density. In sum, high levels of GDP, the strong presence of IHs, and an effective network of telephone are indispensable for Internet diffusion and by extension to all innovations. However, network capacity without an educated citizenry may not lead to the required transformation into the network society. This 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 the digital inequality gap? There are twin divides in broad terms, the global divide between Africa and the industrialized countries and the divide within a 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 at the primary, secondary and tertiary levels since independence; however, they are still far behind the rapidly industrializing developing countries. Even then, basic literacy is not enough, digital literacy is required and explicit investment will have to be made by African countries for individuals to become computer literate. There are other factors that have been found to be significant predictors such as institutions, telecommunications regulation, and forms of government.

The major policy implications that have emerged from this study are two fold: first, countries need to reorientate their telecommunication and economic policies to promote public as well as private investments in ICTs that in turn might further boost economic growth and, second, governments in developing countries need to encourage the use of PCs. Such use of computers should be encouraged in academic institutions, individuals, government organizations, and small business enterprises through offering incentives to both manufacturers and vendors to lower cost. Governments can put in place policies such as soft loans (subsidized rate of interest) on purchase of computers for individuals and academic institutions to achieve higher penetration of PCs.

Greater use of computers in academic institutions could serve a dual purpose. First, the graduates of these institutions will be computer savvy and thus familiar with the benefits of computers. Consequently they may help encourage their diffusion in society. Second, they will help improve universal access to educational resources which could enhance the overall level of education. For better access to the Internet, governments need to increase the density of Internet-access-points and IHs as well as providing a telecommunication network of high bandwidth. Due to lack of data, this study has not been able to analyze the significance of technological capability nor the role of technological institutions in the diffusion of the Internet. Therefore further research is needed to examine the role of institutional infrastructure in the diffusion of ICTs in general, and the Internet in particular.

Acknowledgments

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Appendix A. Cross section results

Year 2000	Model 1	Model 2
EQ1: Dep. variable (Internet users)		
Independents		
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
EQ2: Dep. variable (Internet hosts)		
Independents		
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
EQ3: Dep. variables (telephone density)		
Independents		
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
Year 1999		
EQ1: Dep. variable (Internet users)		
Independents		
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
EQ2: Dep. variable (Internet hosts)		
Independents		
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
EQ3: Dep. variables (telephone density)		
Independents		
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
Years 1997 and 1998	1998	1997
EQ1: Dep. variable (Internet users)		
Independents		
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
EQ2: Dep. variable (Internet hosts)		
Independents		
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
EQ3: Dep. variables (telephone density)		
Independents		
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
Years 1995 and 1996	1996	1995

EQ1: Dep. variable (Internet users)		
Independents		
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
EQ2: Dep. variable (Internet hosts)		
Independents		
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
EQ3: Dep. variables (telephone density)		
Independents		
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: ***1%; **5%; *10%.

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