

**The Macroeconomic Impacts of Information Technology Transfers:
Empirical Evidence and Policy Implications**

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Abstract

The United Nations has made access to Information and Communication Technology (ICT) a primary objective for the developing world. Several policies have been implemented to transfer technology from the developed to the developing world, specifically to increase Internet access. Unfortunately, there is little direct evidence that Internet usage has a positive impact on national income. This paper investigates the impact of Internet usage on national income using a cross section of 110 countries from 1999 through 2001. The results indicate that national income has a positive impact on the number of Internet users and the number of Internet users has a positive influence on national income. Using a sub-sample of 28 African countries, the empirical results suggest that policies intended to provide exogenous increases in ICT, specifically increased numbers of personal computers, are expected to have limited impacts on national income in the short-run. However, the long-run benefits of these transfers could be positive.

JEL Classifications: O1, O3, L5, L9

Keywords: infrastructure, economic growth, development, technology diffusion.

1. Introduction

The widespread use and implementation of Information and Communication Technologies (ICTs) has increased the world's potential for the dissemination of knowledge and information. As a result, a sense of optimism has emerged concerning the potential uses for, and benefits from, the continued growth of ICTs. This attitude was evident in the late 1990s during the rise of e-commerce and business-to-business (B2B) applications of Internet access. This enthusiasm eventually spilled over into economic development policy, as many analysts and policymakers now believe that ICTs can offer significant gains to developing countries. While some stress the significance of ICTs for individual human development, others focus on the increasing importance of e-commerce for both small and large businesses worldwide. Some suggest that not only will ICT be a significant catalyst for growth and development, but may also become a requirement. This view is conveyed in a United Nations Commission on Trade and Development (UNCTAD) report, which states "enterprises in developing countries that are or plan to be involved in international trade need to start incorporating ICT and the Internet into their business models in order to stay competitive" (UNCTAD, 2001). The height of the optimism is captured in the well-known "leap frog" analogy, which asserts that ICTs will enable underdeveloped countries to "leapfrog" over previous, less advanced technologies, thereby gaining substantial advantages in the international economy.

Hoping to make use of this new medium as a potential for increased growth and development, International Organizations, Non-Governmental Organizations (NGOs) and private agencies have supported a growing number of development assistance programs that stress the use of ICTs. The United Nations Development Programme (UNDP), for example, has launched a series of projects that aim to increase Internet connectivity and access in some of the poorest countries in the world. According to UNDP reports, the rationale is that "those nations that succeed in harnessing the potential of ICT can look forward to greatly expanded economic growth, dramatically improved human welfare [and]... an opportunity to meet vital development goals." The benefits of using technology and communication in development programs is further emphasized by Brown

(2001) who claims that “ICT can help us reach targets established by world leaders at September’s Millennium Summit, including the goal of halving poverty by 2015.”

The motivation for this growing trend to focus on ICT development is based on the notion that access to the Internet and worldwide communication in general serves as a stimulus to economic growth. At the individual level, the intuition is rooted in the theory of human capital; knowledge, abilities, and information acquired through the use of ICTs expands an individual’s skill set, thereby increasing the value of labor productivity and/or welfare of the individual. This view often focuses on expanding individuals’ opportunities by providing access to time-sensitive information such as market prices or travel conditions, the availability of government and private-sponsored assistance programs, and general education on healthcare, sanitation, etc.

On the production side of the economy, business-to-business (B2B) interactivity allows producers to access larger markets and offers the opportunity to purchase intermediate goods and inputs at more competitive prices. In the agricultural sector alone, it is claimed that production levels can be increased as a result of increased access to information such as new techniques for growing local crops, assistance in the conversion to the production of cash crops, and the benefits of crop rotation (although there is no hard evidence that this has ever occurred). The most commonly cited, although questionable, benefit is the availability of daily market prices for crops whereby farmers can obtain the appropriate market price for their product.

Despite the growing support for ICT-based initiatives, some question whether the funding of such policies is actually justified. According to Brown (2001), “in both developed and developing countries there is still considerable skepticism as to whether providing access to information and communication technology can play a significant role in reducing poverty.” Skeptics argue that this trend in development assistance may be based on unsubstantiated claims and overly optimistic attitudes reminiscent of the Information Technology hype that contributed to the U.S. stock market bubble several years ago (DFID, 2003). Thus, while ICTs may prove to be beneficial, empirical evidence regarding

the connection between Internet access and economic growth and development is largely non-existent.

Accordingly, this paper investigates whether the number of Internet users and other ICT infrastructures impact national income in an economically meaningful way. Specifically, using a sample of 110 countries (excluding the United States), simultaneous equations estimation indicates that the elasticity of Internet users (at the national level) is less than one with respect to national income. Likewise, the elasticity of national income is less than one with respect to Internet users (at the national level). Therefore, the estimation results support the hypothesis that Internet and ICT infrastructure do increase national income, although the impacts are relatively small.

The estimation is also undertaken focusing on 28 African nations. While the impact of Internet users has a statistically significant impact on income for this sample of countries, it seems that the number of personal computers alone has no impact on national income, perhaps indicating that the level of development in these countries is not great enough to use ICTs in an economically significant way, such that the results are evident at the macroeconomic level. Using the estimation results of the African sample, it is possible to estimate whether the technology-transfer programs being implemented by several private and public organizations are expected to be cost effective (on a global scale) in the short run. Given sample means and parameter estimates, technology transfer programs would have a positive net benefit in the short run only if the provision of technology remains less than approximately \$17,500 per computer. While it might seem easy for technology programs to satisfy this cost requirement, World Bank cost estimates indicate that the yearly cost of implementing technology transfers may be in excess of \$15,000 per year per computer, in addition to the nominal and opportunity cost of the computer. Thus, there is only a thin margin in which the short-run net benefits to the global economy might be positive, and the short-run net benefits may well be negative. However, the dynamic, long run effects of ICTs have yet to be determined and therefore the long-run benefits of technology transfers may be positive.

The remainder of this paper is structured as follows. The next section describes in more detail the different approaches to the role of the Internet in economic development and the existing literature on the topic. Section 3 outlines the empirical methodology used. Section 4 describes the data, estimation results and policy implications. The final section offers concluding remarks.

2. The Economic Benefits of the Internet

Even while the Internet, and computer technology in general, continues to mature and evolve over time, many have voiced concerns about the international disparities in ICTs. The programs and policies aimed at addressing these concerns have likewise become more numerous in recent years. In turn, as the number of policies and programs has grown, so has the debate over whether funding ICTs is a successful development strategy. Faced with the task of implementing successful development and economic growth programs, the question that has recently arisen is what, if any, role do ICTs play in this process? That is, are Information and Communications Technologies an effective means of stimulating economic growth and are they a vital part of a nation's development process? Even with respect to offering donations of foreign aid, international organizations, non-governmental agencies (NGOs), and private corporations are now faced with the decision of whether or not such funding should be devoted to the provision of basic necessities, i.e. food, shelter, and medical care, or used to provide computers, communication equipment, and the improvement of a telecommunications infrastructure.

Some, however, question the legitimacy of promoting Internet access in villages that currently lack electricity, or access to clean water for that matter. Even Bill Gates has expressed his skepticism regarding the effectiveness of such policies by remarking, "computers will not eliminate starvation and poverty from the world."

Because Information and Communication Technology requires a specific set of initial conditions to be effectively implemented, the mere provision of ICTs may not increase growth and fuel economic development as people still need to build skills and abilities

that can be converted into additional income. Further, the blanket promotion of ICTs as a means of successful development and growth for all countries may in fact be deleterious. In a paper unrelated to the specific details surrounding the ICT debate, Adelman (2001) warns that policymakers should be cautious not to accept one of the most common fallacies in development policymaking – the assumption that there is one, single solution to the problem of underdevelopment. She stresses that country-specific characteristics determine the appropriateness of implementing development policies and the resultant success or failure. Even at the most basic level, one can question the legitimacy of these initiatives once it is realized that over 80% of the information on the World Wide Web is provided in English (UNDP) and as Arunachalam (2002) asserts is “99% irrelevant to a peasant in Bolivia or a factory worker in Russia” (p. 7).

Further, even if there are substantial gains to implementing increased access to Internet and communications technology, the result might only exacerbate the existing level of income inequality within a country. Only those individuals who already possess the required skills may be able to increase their earnings potential with ICTs while those who lack the human capital may receive little or no added value from such technologies, and consequently may find themselves falling further behind. Thus increased access to ICTs may cause a “digital divide” within a country by increasing the relative disadvantages of the rural poor, uneducated, and unskilled.

Despite the fact that this issue is being feverishly discussed in the popular press, and within international organizations and academia, evidence of the specific impact of the Internet and computing technology has primarily been presented in the form of anecdotal evidence. Proponents of the ICT development revolution tout the success of individual programs and experimental policies. Typically, justification for continued funding of such projects is offered in the form of case studies and individual testimonials as to the resulting progress made in individual communities.

For example, the Information Village Project of the M. S. Swaminathan Research Foundation establishes centralized knowledge centers containing computers, radios,

telephones, and Internet access. The centers provide information relevant to the local community, including prices of agricultural products, information on entitlement programs, health care practices, and transportation issues, such as road and weather conditions. The foundation has also established a Value Addition Center where individuals access, among other sources of information, a website hosted by the U.S. Navy that posts daily weather and tide schedules. Local fishermen are encouraged to access the website to obtain information that can increase their earnings and reduce the risk and hazards associated with fluctuations in weather conditions. According to one of the project's developers, "[i]n the villages where the project operates we have shown that access to timely and relevant information does make a difference to the life of the rural poor" (Arunachalam, 2002).

But are specific gains, such as those "obtained" by the Information Village Project, enough to warrant the continued promotion of ICTs as a primary growth initiative? Within the academic literature, a few studies have made initial strides in this area by examining the extent to which ICTs have resulted in increased productivity and/ or increased earnings in various localities. Still other studies have focused on the role of economic wealth on the development of ICT infrastructure or Internet usage.

For example, Wigg (2003) examines the extent to which the use of ICTs in the Namibian Tourist industry has facilitated growth in that industry. Based primarily on an economies-of-scale argument, he concludes that, despite its access to the Internet, the local tourism industry is unlikely to effectively compete with the larger, established companies (travel brokers) in obtaining market share.

With respect to the 'digital divide' controversy, Antonelli (2003) finds that ICTs have resulted in an international digital divide due to composition effects - different initial conditions and levels of readiness to accept and implement new technology into total factor productivity growth. In a study of the U.S. economy between the years 1947 and 1997, Wolff (2002) finds that Information Technology is not a significant contributor to either the growing income or wealth gap in that country. Rather, he finds that de-

unionization and decreases in the real value of minimum wage of low-skill workers are the primary causes of the expansion in the U.S. income gap.

Norris (2000) uses a sample of 179 countries in a cross-sectional analysis of how economic and social factors influence Internet diffusion. Norris finds that per-capita GDP is the strongest predictor of the number of people on-line in early 2000 and that dummy variables for Western Europe, Scandinavia and North America indicate that these countries have significantly larger on-line populations. Norris interprets these regional dummy variables as evidence of different social and cultural institutions that lead these countries to more quickly adopt new technologies.

Two additional cross-country studies, Hargittai (1999) and Kiiski and Pohjola (2002), investigate the factors that contribute to the diffusion of the Internet. These studies measure Internet access as the number of Internet hosts per capita rather than the number of individuals on-line. As Internet hosts are computers that individual users connect to in order to access the Internet, using hosts is more accurately considered a measure of Internet infrastructure. Both studies find that GDP per capita is important in determining the expansion of Internet access in a country. However, the two studies differ in their opinions on other important factors. Hargittai suggests that social and cultural factors are important as well as the level of competition in the telecommunications industry. Kiiski and Pohjola claim that the cost of Internet access is the other primary determinant of Internet access and find no evidence to support the telecommunications-competitiveness hypothesis. Neither study (nor Norris, 2000) directly addresses the question of Internet use (or infrastructure) on national income.

To our knowledge there have been no empirical studies that address the general question concerning the effects of ICTs on the growth and development of a nation. While anecdotal evidence is often used to support claims, the literature currently offers no conclusive answer to the question: To what extent, if any, does the dissemination and implementation of ICTs have on the levels of GDP or growth rates of nations?

3. The Empirical Methodology

The impact of Internet usage on national income could be estimated in a single-equation model. However, if Internet usage were influenced by income, which is the general conclusion of the extant literature in this area, the single-equation approach would introduce an endogeneity bias that would invalidate the parameter estimates and statistical inference of OLS. The endogeneity bias has implications for public policy decisions. If attempts to provide and encourage Internet usage in developing countries are dependent upon the anticipated impacts of the medium on national income, then accurate estimates are pivotal. Therefore, in this study a simultaneous equations approach is used to ameliorate the endogeneity bias between income and Internet usage.

Using data from the International Telecommunications Union (ITU), the symbiotic relationship between Internet usage and national income is estimated. Two equations are estimated: one describes the number of Internet users at the national level; the second describes national income. The dependent variables are the log of total Internet users and the log of national income, in billions of U.S. dollars. The explanatory variables include controls for infrastructure consistent with accessing the Internet and other variables thought to influence national income and Internet usage.

The first equation describes Internet users and is specified as

$$\ln USERS_{it} = \mathbf{b}_0 + \mathbf{b}_1 \ln GDP_{it} + \mathbf{b}_2 \ln COMPS_{it} + \mathbf{b}_3 \ln HOSTS_{it} + \mathbf{b}_4 \ln DENSITY_{it} + \mathbf{b}_5 LITRATE_{it} + \mathbf{b}_6 ENGLISH_{it} + \mathbf{b}_7 YR99_{it} + \mathbf{b}_8 YR00_{it} + u_{it}, \quad (1)$$

where the β s are parameters to be estimated and u is a zero-mean stochastic error structure, i indexes country and t indexes time. The explanatory variables include a constant term, national income in country i in year t (GDP), the number of personal computers in country i in year t ($COMPS$), the number of Internet hosts in country i in year t ($HOSTS$), the population per square kilometer in country i in year t ($DENSITY$), the literacy rate country i in year t ($LITRATE$), whether English is the primary language of

country i (*ENGLISH*) and two year dummy variables for 1999 and 2000, the reference year is 2001 (*YR99* and *YR00*).

It is anticipated that Internet usage is a normal good ($\beta_1 > 0$), that personal computers and Internet hosts facilitate more Internet usage ($\beta_2 > 0$, $\beta_3 > 0$), population density facilitates Internet usage through network effects on both the supply and demand side ($\beta_4 > 0$), more people access the Internet when they are literate ($\beta_5 > 0$) and when English is their primary language ($\beta_6 > 0$), and more people have been accessing the Internet over time ($\beta_7 < 0$ and $\beta_8 < 0$).

As mentioned, the potential for endogeneity bias exists, especially if Internet usage is expected to have an impact on factor productivity or the ability to generate economic activity, both of which could be reflected in national income. Therefore it is necessary to specify an identifying equation for national income (*GDP*),

$$\ln GDP_{it} = \delta_0 + \delta_1 \ln USERS_{it} + \delta_2 \ln POP_{it} + \delta_3 \ln COMPS_{it} + \delta_4 \ln DENSITY_{it} + \delta_5 YR99_{it} + \delta_6 YR00_{it} + v_{it}, \quad (2)$$

where the δ s are parameters to be estimated and v is a zero-mean stochastic error structure, i indexes country and t indexes time. The explanatory variables include a constant term, the number of Internet users in country i in year t (*USERS*), the population of country i in year t (*POP*), the number of personal computers in country i in year t (*COMPS*), the population per square kilometer in country i in year t (*DENS*), and two year dummy variables for 1999 and 2000, the reference year being 2001 (*YR99* and *YR00*).

Equation (2) is not intended to replicate the extensive literature of estimating national income equations, rather it is intended to give insight into the impact of Internet users on national income, *en masse*, while controlling for other elements thought to influence national product. It is anticipated that Internet users have a non-negative impact on national income ($\delta_1 \geq 0$). Additionally, population is expected to have a positive influence

on national income ($\delta_2 > 0$), as does the number of personal computers ($\delta_3 > 0$) and population density ($\delta_4 > 0$). Finally, the worldwide economic slowdown is expected to cause the parameter estimates on *YR99* and *YR00* to be positive ($\delta_5 > 0$ and $\delta_6 > 0$).

Equations (1) and (2) comprise an identified simultaneous equations system which can be estimated with either limited or full information techniques. The limited information approach, also known as two-stage least squares (2SLS), regresses *lnGDP* on all exogenous variables in both equation (1) and (2), obtains fitted values for *lnGDP* and uses this fitted series as a single instrument for *lnGDP* in equation (1); the same approach is used for *lnUSERS* to create a single instrument to be used in equation (2).

The 2SLS approach is convenient and easy to implement but runs the risk of providing inefficient parameter estimates because any cross-equation correlation has not been incorporated into the variance-covariance matrix of the parameter estimates. A possible solution is three-stage least squares (3SLS), a full information estimator. In this case, the additional step of estimating the cross-equation covariance matrix is undertaken which adjusts the estimates of the parameter vectors β and δ , but more importantly provides more efficient estimates and better statistical inference. In the 3SLS approach, additional instruments can be introduced that are thought to influence one or both of the endogenous variables. In this case, additional instruments include variables that reflect the technological infrastructure of a country, which is thought to be correlated with Internet usage and national income: telephones per 100 people (*TELCAP*), total kilometers of telephone lines (*LINES*), the growth of telephone lines since 1995 (*dLINES*) and the number of telephone subscribers in thousands (*PHONESUBS*).

4. The Data and Empirical Results

Data gathered from various issues of the *World Telecommunication Development Report* published by the International Telecommunication Union (ITU) describe a total of 196 countries for various years from 1998 through 2001. Following Kiiski and Pohjola (2002), only countries that have a population of more than one million and more than 50 Internet

hosts are included. Complete data were available for a subset of 110 countries for the years 1999 through 2001. The United States is a clear outlier amongst the countries in the sample and is therefore removed from the full sample. The remaining observations were used to estimate equations (1) and (2) using a full information estimator, three stage least squares (3SLS). For comparison purposes, the full sample is constrained to 28 African countries for which complete data are available and the system of equations is re-estimated. The countries included in the full sample are listed in Appendix A.

When the full sample is employed, dummy variables are included that take a value of one if a country was located in Africa (*AFRICA*), Europe (*EUROPE*), Asia (*ASIA*), South America (*SAMER*), or Oceania (*OCEAN*), where countries were sorted by continent as defined by *www.worldatlas.com*.¹ These dummy variables are similar to the regional variables used by Norris (2000) and Kiiski and Pohjola (2002) and control for regional heterogeneities in Internet usage and national income not directly controlled for by the other explanatory variables. When the African sample is used these dummy variables are dropped due to colinearity.

Descriptive statistics of the data, for both the full and African samples, are reported in Table 1. For the full sample, the average number of Internet users was 2.49 million, with a low of 2,500 (Albania) and a maximum of 55.93 million (Japan).² The average number of personal computers was 2.6 million, with Niger having the fewest at 5,000 and Japan the most at 44.4 million in 2000.³ Internet hosts averaged approximately 245,000 per country but had a very high variance (the standard deviation in the full sample was approximately 670,000); Yemen had the fewest Internet hosts with 53 and Japan the most with 7.1 million in 2000.⁴ As Internet hosts are the ultimate gateways to the Internet, it is anticipated that Internet users would be influenced by the number of hosts in a given country, for both immediate access concerns but also because fewer Internet hosts might increase the cost of Internet access.

¹ The reference category is North America.

² The United States had 130 million Internet users in 2000.

³ The United States had 161 million personal computers in 2000.

⁴ The United States had 80.5 million Internet hosts in 2000.

The bottom panel of Table 1 presents descriptive statistics for the 28 African countries for which complete data are available. For all the variables listed, the African nations have substantially smaller averages than in the full sample. The consistent differences between the African averages and those of the full sample might support the claims that Africa in particular is on one side of a so-called “digital divide,” which the developed countries may play a role in alleviating. As supporting evidence, the maximum values of many of the variables in the African sub-sample are less than or close to the full-sample averages.

The additional variables listed in the upper and lower portion of Table 1 are the additional instruments used in the 3SLS estimation. Telephones per 100 people in the African nations average approximately one fourth of the full sample mean. Additionally, while the growth of telephone lines is approximately the same in the African and full samples, the average kilometers of telephone lines in African countries is less than one tenth of the average in the full sample of countries. Finally, the average number of phone subscribers in the African countries is also less than one tenth of the average number in the full sample of countries.

One simple explanation for why African countries tend to have fewer people on-line is that the African countries averaged 22 million in population whereas the full-sample countries averaged 50 million. Moreover, African national income averaged \$17.48 billion (U.S. dollars), approximately 9% of the full sample average of \$198.72 billion. However, the fact that the African nations have such significantly lower levels of income and substantially less infrastructure to access the Internet might suggest that the impact of Internet usage on national income, and vice-versa, may be different in African countries relative to the rest of the world. This hypothesis is tested in the full sample by interacting GDP (USERS) with the AFRICAN dummy variable when estimating the impact of GDP on Internet users (Internet users on GDP).

Empirical Results

Table 2a and Table 2b present estimation results of the Internet usage and GDP equations, respectively. Each table reports 3SLS for the full and the African samples for two specifications. Model I includes the *LITRATE* variable, which is the literacy rate as estimated by the United Nations. Unfortunately, for most developed countries the literacy rate is so close to 100% that the UN does not report the data. Therefore, Model II drops the *LITRATE* variable and increases the sample size from 245 observations to 309 observations. The increase in sample size arises by including many developed countries such as the United Kingdom, Canada, and Japan.

The results are generally consistent with the reduced-form estimates obtained by other authors, but provide a more efficient set of estimates and a deeper insight into the estimated impact of public policies intended to encourage and facilitate Internet usage in developing countries, especially in Africa. To facilitate discussion, only the results of Model II are directly addressed in the remainder, however there are not many qualitatively different results between the two sets of estimates.

Focusing on Table 2a initially, Internet access is a normal good in both the full and African samples as reflected in the positive and statistically significant parameter estimate on national income. This impact of GDP on Internet users is ostensibly free of a potentially significant endogeneity bias that would exist if the instrumental variable approach were not used. A one percent increase in GDP correlates with an increase in Internet users of 0.50% in the full sample and 0.52% in the African sub-sample; perhaps the difference lies in the different levels of Internet diffusion between the average African country and the rest of the world. In the full sample, there is some evidence that the income elasticity of Internet users is greater in Africa than in the rest of the world, as indicated by the positive and statistically significant parameter estimate on the interaction between *GDP* and *AFRICA*. In the full sample a one percent increase in GDP would be approximately \$1.9 billion and the corresponding increase in Internet users would be approximately 12,500 (or 6.5 users per \$1 million in additional GDP). In the African sub-

sample, a one percent increase in GDP, evaluated at the sample mean, would be \$174 million with a corresponding increase of approximately 1,350 in additional Internet users (7.7 users per \$1 million in additional GDP).

Not surprisingly, the number of personal computers has a positive and statistically significant impact on Internet users. A one percent increase in personal computers will lead to approximately a 0.26 percent increase in Internet users in the full sample and 0.27 percent increase in Internet users in the African sample. These parameter estimates indicate that simply having a computer is no guarantee that the computer will be connected to the Internet, either because of infrastructure limitations or because of costs of Internet access. In other words, simply handing out personal computers is not guaranteed to be a panacea for developing countries.

Additionally, the number of Internet hosts in a country is correlated with more Internet users in a country. This is not surprising as it is an Internet host that ultimately provides access to the individual residential or commercial Internet user. Moreover, Internet hosts often handle email accounts and World Wide Web pages for their clients. Therefore, more Internet hosts provide both network externalities and necessary infrastructure to access the Internet. While accessing the Internet using an international host is possible, it is more expensive than using a local host, perhaps prohibitively expensive.

Internet usage is not substantially impacted by either adult population literacy rates or using English as a primary language. Given the nature of the Internet as a medium, one might expect literacy a requirement to productively use the Internet either as an information resource or market expander. Moreover, approximately 85% of all information on the Internet is in English, thus an inability to speak, read or write English might reduce the appeal of the Internet vis-à-vis other information resources. The lack of significance could be explained by colinearity if adult literacy and speaking English as a primary language were highly correlated. However, the correlation between *LITRATE* and *ENGLISH* is only 0.66, but is statistically different from zero. On the other hand, categorizing a country as *ENGLISH* by the CIA World Fact book may not be an adequate

measure of English proficiency. One and a half billion Chinese are not considered to speak English as a primary language although many in China do speak functional English. The number of users was consistently less in 1999 and 2000 than in 2001, as reflected in the negative and statistically significant parameter estimate on *YR99* and *YR00*. This confirms the international trends of Internet usage reported by other sources. In the full sample, Africa had the fewest and South America had the most Internet users relative to the reference category: North America in 2000. This result confirms anecdotal evidence.

Turning focus to Table 2b, the number of Internet users is found to have a positive and statistically significant influence on national income. However, there is no difference in the impact of Internet users on GDP in African countries and the rest of the world. In the full sample, the elasticity of national income with respect to Internet users is approximately 0.66 whereas in the African sample it is approximately 0.92 (which is not statistically different from unitary elasticity). This indicates that in the developing countries of Africa, national income is more responsive to Internet usage than in the rest of the world. This does not necessarily imply that Africans are better at using the Internet. Rather, African countries may have fewer individuals on the Internet and therefore stand to gain more in the short run by increasing productive Internet usage. This would correspond to GDP being concave in Internet usage.

Population has a positive and statistically significant impact on national income, consistent with the findings of other authors. Population density has a statistically insignificant impact on national income in the full sample but a statistically significant and negative impact on national income in African countries, perhaps reflecting dual economies (relatively wealthy urban areas and relatively poor rural areas), in many African countries. The national income of the countries in the full and African samples was significantly higher in 1999 and 2000 than in 2001, consistent with the worldwide economic slowdown that started during this time period.

The number of personal computers is positive and statistically significant in explaining the variation in national income in the full sample of countries. However, personal computers

have no statistically significant relationship to national income in the African sample. Perhaps computers are not used as productively in African countries as computers in the rest of the world. An alternative possibility is that there are not enough computers in the average African nation to generate significant network externalities, learning-by-doing, and other positive externalities that would influence national income. Regardless of the source, if the magnitude of the parameter estimate on *COMPS* in the African sample reported in Table 2b proves robust, it indicates that simply handing out computers may not influence national income in the average African country. This, in turn, would indicate that the number of Internet users would not be affected by income changes (see Table 2a), although the number of Internet users would be expected to increase with more personal computers available, *ceteris paribus*.

Policy Implications

In the past few years several policy initiatives have been proposed or undertaken in the area of ITC transfers. These programs literally transfer ITC technology and infrastructure from developed countries to developing countries, particularly in Africa. The intuition is that reduced-cost access to computers, for instance, will motivate citizens of developing countries to begin using the Internet and therefore become more productive. This, in turn, is expected to increase domestic economic activity.

The proposed policies sound compelling and it may ultimately be difficult for the developed countries to choose not to contribute such technology to developing countries. However, it has yet to be determined whether simply closing the “digital divide” and having more Internet users will increase national income. The results presented in Table 2a and Table 2b allow for an initial foray into whether the technology transfer programs are expected to have a positive short-run net benefit (for the world as a whole). It should be noted that the calculations undertaken here are short-run in nature because of the data employed in the estimation. It is possible that the long-run benefits of technology transfers will be different than those calculated in the short-run.

For the average African nation in the sample, a one percent increase in personal computers would be expected to increase the number of Internet users by 0.276 percent (see Table 2a). This in turn would be estimated to increase national income by 0.252 ($=0.276 \times 0.915$) percent. The 95% confidence interval of the ultimate impact of a one percent increase in personal computers is a [0.017, 0.703] percentage increase in gross domestic product. While the 95% confidence interval does indicate that a one percent increase in personal computers would have a positive impact on gross domestic product, it is instructive to convert the impacts into estimated dollar amounts to facilitate a more traditional cost-benefit comparison.

For the average African nation in the sample, a one percent increase in personal computers would be approximately 2,500 computers. Combining the results from Model II of the African sample in Tables 2a and 2b and the African sub-sample mean GDP of \$17.48 billion, the result of a one percent increase in the number of computers in an African country would be an increase in national income of approximately \$44.17 million; the 95% confidence interval being [\$3.06 million, \$122.88 million]. Thus the projected gross benefits of such an international technology transfer to the average African nation in the sample is positive. However, the gross benefit does not take account of the costs of the technology transfers, which would determine the short-run benefits to the world economy. For such an international technology transfer to prove beneficial for the world in the short run, the total cost each computer, including the computer itself, access to software and the Internet, training, assisting in using the computer in productive ways, and the opportunity cost of the computer's alternative uses must be less than \$17,670 per year.

While the benefits seem high, perhaps ensuring that cost-conscious public policy would have net positive benefits, recently the World Bank reported initial (nominal) cost estimates for several transfer programs already underway. The organization estimates that under the SchoolNet Uganda Project, for instance, the installation of technology requires initial equipment costs (excluding computers) of \$6,700 per site, installation and site service of approximately \$4,000 per site, and operational costs of approximately \$400 per month (World Bank, 2002). In total, the World Bank puts the cost of technology transfers

at approximately \$15,500 per year (not including the nominal and opportunity costs of the computer itself).

Therefore, the estimation results presented here indicate that there may be a thin margin in which the short-run net benefits of technology transfers are positive, and indeed the short-run net benefits may well be negative. However, the dynamic long-run benefits of technology transfers may ultimately lead to positive net world benefits, a hypothesis that should be tested in the future.

5. Conclusions

This paper undertakes an initial investigation of the impact of Internet usage on national income. The investigation is potentially important because there is considerable interest in promoting policies to improve Internet access in the developing world with the goal of enhancing development and economic growth. However, there has been little direct investigation of the impact of Internet access or usage on national income despite the fact that existing programs are already spending almost US\$1 billion per year. At stake are additional billions of dollars of international aid-in-kind through technology grants, and the future economic development and well being of roughly half the world's population.

In the developed countries, the adoption of Internet technology has been rapid and continues to grow. In the developing countries, a lack of disposable income, secure property rights and access to Internet compatible infrastructure has retarded the rate of adoption. Multinational groups such as the United Nations and non-governmental organizations have taken differing views as to the ultimate impact of the different rate of technology adoption, which has been termed the "digital divide." The true economic consequences of this divide are still under debate.

Some claim that the digital divide will further exaggerate the wealth differences between the developed and developing world and that these differences will be permanent. The developed countries have a first-mover advantage in being on-line early in the Internet's

development, are able to capture economies of scale, secure market share in on-line retailing and otherwise learn how to use the new medium to be more productive. The optimistic view is that the continued evolution of the Internet will allow the developing countries to adopt a more sophisticated, and perhaps less expensive, form of technology to access the Internet when the development of other infrastructure, such as roads, water, health care, and education has been completed.

Both views assume that the Internet is a valuable addition to the combination of capital and labor used to generate national income. This study investigates this question by building on the cross-sectional econometric analyses that have been published in recent years. These studies consistently find that national income (either aggregate or per-capita) has a positive influence on the availability of Internet infrastructure or the number of people on-line. However, simply using Internet usage as an explanatory variable in an income equation would introduce a potentially debilitating endogeneity problem.

A simultaneous equations estimator is applied to data describing a sample of 110 countries from 1999 through 2001. A sub-sample of 28 African nations is also investigated. The results suggest that income, the number of computers, and the number of Internet hosts are statistically important influences on the number of Internet users in a country. However, the elasticity of Internet users with respect to national income (and the number of computers and hosts) is less than unity. Additionally, the results indicate that national income is positively related to the number of users on-line, but again in an inelastic way.

The estimation results and sample means are then used to determine if a technology grant or transfer that increased the average African country's stock of computers by one percent would be cost effective (at the global level). It is estimated that the ultimate impact on national income by the infusion of additional computers, *ceteris paribus*, would be approximately \$44.7 million per year. Therefore, the policy would have a positive net benefit as long as the computers (and additional resources required) were provided for less than \$17,500 per machine. Using figures recently reported by the World Bank, it seems that the short-run benefits of technology transfer programs may be slightly positive but

could easily be negative. The dynamic, long run impacts of these transfers might be positive, although additional research is required to support this hypothesis.

While there does seem to be a connection between Internet usage and national income, the aggregate data used here does not allow for a more detailed investigation of the source of the increase in national income. Specifically, is the positive impact of the Internet on domestic income a result of improved factor productivity or retail market expansion? As this is the first study to actually estimate the impact of such a technology transfer programs on African economies, it is difficult to offer solid policy suggestions. However, investigation into the impact of ICTs over longer periods of time will hopefully contribute to the results presented herein.

References

Adelman, I. (2001), "Fallacies in Development Theory and Their Implications for Policy," in *Frontiers of Development Economics: The Future in Perspective*, eds. G.M. Meier and J.E. Stiglitz, Oxford University Press: Oxford and New York, pp. 103-34.

Antonelli, C. (2003), "The Digital Divide: Understanding the Economics of New Information and Communication Technology in the Global Economy," *Information Economics and Policy*, **15**, pp. 173-99.

Arunachalam, S. (2002), "Reaching the Unreached: How Can We Use ICTs to Empower the Rural Poor in the Developing World Through the Enhanced Access to Relevant Information?" available at www.ifla.org/IV/ifla68/papers/074-095e.pdf, last accessed October 2003.

Brown, M.M. (2001), "Can ICTs Address the Needs of the Poor?" *Choices*, **10**, p. 4.

Brun, C. and Mangstl, A. (2001), "Worldwide Access to ICT: the Digital Divide," in *Villages in the future: Crops, Jobs and Livelihood*, eds. D Virchow and J von Braun, Springer-Verlag: Berlin, pp. 259-262.

Kiiski, S. and Pohjola, M. (2002), "Cross-country Diffusion of the Internet," *Information Economics and Policy*, **14**, pp. 297-310.

Hargittai, E. (1999), "Weaving the Western Web: Explaining Differences in Internet Connectivity Among OECD Countries," *Telecommunications Policy*, **23**, pp. 701-718.

Norris, P. (2002), "The Global Divide: Information Poverty and Internet Access Worldwide," *mimeo*, John F. Kennedy School of Government, Harvard University.

UK (DFID) Department for International Development (2003), "The Reality of E-Commerce with Developing Countries," available at www.gapresearch.org/production, last accessed July 2003.

UNCTAD (2001), E-Commerce Development Report, 2001, Geneva: UNCTAD.

UNDP (2000), "Driving Information and Communications Technology for Development," *A UNDP Agenda for Action 2000-2001*.

Wigg, A. (2003), "Developing Countries and the Tourist Industry in the Internet Age: The Case of Namibia," *Forum for Development Studies*, **30**, pp. 59-87.

Wolff, E. (2002), "The Impact of IT Investment on Income and Wealth Inequality in the Postwar US Economy," *Information Economics and Policy*, **14**, pp. 233-251.

World Bank (2002), "Presentation on SchoolNet Uganda: The Experience and Issues Surrounding a Project with 15 VSAT Schools," available at www.worldbank.org/wbi/ictforeducation/policymakers/html/pol_gd_11nov02.html, last accessed December 2003.

Table 1: Descriptive Statistics of the Data

Full Sample (N=309 without the United States)

Variable	Description	Mean	Std. Deviation	Minimum	Maximum
USERS	Internet Users (millions)	2.49	6.26	0.002	55.93
GDP	National GDP (U.S. billions)	198.72	530.44	0.390	4765.29
POP	Population (millions)	50.41	161.24	1.17	1312.71
COMPS	Number of Computers (thousands)	2689.91	5970.44	5.00	44400.00
HOSTS	Number of Hosts (thousands)	245.91	670.29	0.053	7118.33
DENSITU	Population per square kilometer	221.70	837.39	2.00	6332.00
LITRATE	Literacy Rate (percentage) ^a	79.66	20.54	15.96	99.80
ENGLISH	English is primary language (1=YES)	0.22	0.42	0.00	1.00
YR99	Year 1999 (1=YES)	0.33	0.47	0.00	1.00
YR00	Year 2000 (1=Yes)	0.34	0.47	0.00	1.00
TELCAP	Phones per 100 capita	42.81	44.79	0.21	154.57
LINES	Total kilometers of telephone lines	7310.71	17940.15	16.50	325188.00
DLINES	Percentage Increase in telephone lines since 1995	53.10	57.64	-15.79	324.78
PHONESUBS	Number of phone subscribers (thousands)	13082.35	31452.85	16.500	325188.00

African Sub-sample (N=75)

Variable	Description	Mean	Std. Deviation	Minimum	Maximum
USERS	Internet Users (millions)	0.173	0.489	0.003	3.06
GDP	National GDP (U.S. billions)	17.48	30.18	0.39	131.05
POP	Population (millions)	22.06	24.85	1.17	116.93
COMPS	Number of Computers (thousands)	250.54	547.39	5.00	3000.00
HOSTS	Number of Hosts (thousands)	8.88	39.32	0.06	238.46
DENSITY	Population per square kilometer	65.28	121.52	2.00	640.00
LITRATE	Literacy Rate (percentage) ^b	60.54	20.14	15.96	89.34
ENGLISH	English is primary language (1=YES)	0.43	0.49	0.00	1.00
YR99	Year 1999 (1=YES)	0.31	0.46	0.00	1.00
YR00	Year 2000 (1=Yes)	0.32	0.46	0.00	1.00
TELCAP	Phones per 100 capita	7.06	10.39	0.21	50.91
LINES	Total kilometers of telephone lines	668.04	1458.00	16.50	6650.00
DLINES	Percentage Increase in telephone lines since 1995	58.33	47.89	-15.78	213.51
PHONESUBS	Number of phone subscribers (thousands)	1285.15	2966.26	16.500	15802.50

Notes: Data obtained from the World Bank and various issues of the World Telecommunication Development Report published by the International Telecommunication Union. ^a Based on 245 observations. ^b Based on 72 observations.

Table 2a: 3SLS Estimation Results
Dependent Variable: Internet Users

	Full Sample		Africa Only	
	Model I	Model II	Model I	Model II
Intercept	-11.325* (3.69)	-9.934* (2.66)	-10.514* (1.99)	-10.533* (2.05)
GDP	0.564* (0.18)	0.500* (0.14)	0.509* (0.10)	0.524* (0.10)
GDP _x AFRICA	0.185 (0.17)	0.277** (0.16)	---	---
COMPS	0.240** (0.14)	0.266* (0.12)	0.203** (0.12)	0.276* (0.12)
HOSTS	0.177* (0.04)	0.209* (0.03)	0.175* (0.05)	0.141* (0.05)
DENSITY	0.102* (0.04)	0.061** (0.03)	0.265* (0.06)	0.228* (0.06)
LITRATE	0.001 (0.00)	---	0.006 (0.00)	----
ENGLISH	-0.118 (0.07)	-0.082 (0.07)	-0.166 (0.15)	0.000 (0.08)
YR99	-0.881* (0.11)	-0.783* (0.09)	-1.182* (0.17)	-1.172* (0.19)
YR00	-0.346* (0.10)	-0.299* (0.09)	-0.489* (0.16)	-0.508* (0.19)
AFRICA	-4.089 (3.95)	-6.327** (3.63)	---	---
EUROPE	0.271 (0.17)	0.103 (0.16)	---	---
ASIA	0.182 (0.16)	0.169 (0.16)	---	---
SAMER	0.436* (0.19)	0.302 (0.18)	---	---
OCEANIA	-0.435 (0.56)	-0.117 (0.31)	---	---
R ²	0.88	0.91	0.81	0.81
Observations	245	309	72	75

Notes: Continuous data converted to natural logarithms.

* (**) indicates statistical significance at the 5% (10%) level, respectively.

Table 2b: Estimation Results
Dependent Variable: National Income

	Full Sample		Africa Only	
	Model I	Model II	Model I	Model II
Intercept	19.287* (0.30)	19.006* (0.26)	18.936* (0.29)	19.144* (0.29)
USERS	0.605* (0.13)	0.656* (0.10)	0.724* (0.21)	0.915* (0.22)
USERS _x AFRICA	0.119 (0.13)	0.102 (0.13)	---	---
POP	0.171* (0.03)	0.157* (0.03)	0.336* (0.06)	0.277* (0.06)
DENS	-0.076* (0.04)	-0.063** (0.03)	-0.216* (0.07)	-0.246* (0.07)
COMPS	0.197 (0.13)	0.187** (0.11)	0.104 (0.19)	-0.057 (0.20)
YR99	0.734* (0.14)	0.698* (0.11)	0.951* (0.31)	1.132* (0.32)
YR00	0.292* (0.11)	0.268* (0.09)	0.331** (0.19)	0.410** (0.21)
AFRICA	-0.753 (0.56)	-0.511 (0.56)	---	---
ASIA	-0.131 (0.16)	-0.097 (0.15)	---	---
EUROPE	-0.449* (0.17)	-0.276** (0.14)	---	---
SAMER	-0.385* (0.20)	-0.349** (0.18)	---	---
OCEANIA	-0.625 (0.48)	-0.473** (0.26)	---	---
R ²	0.86	0.88	0.78	0.71
Observations	245	309	72	75

Notes: Continuous data converted to natural logarithms.

* (**) indicates statistical significance at the 5% (10%) level, respectively.

**Appendix A: Countries Included in the Sample
(African Countries in Bold)**

Albania	Guinea	Panama
Algeria	Honduras	Papua New Guinea
Argentina	Hong Kong	Paraguay
Armenia	Hungary	Peru
Australia	India	Philippines
Austria	Indonesia	Poland
Bangladesh	Iran	Portugal
Belgium	Ireland	Romania
Benin	Israel	Russia
Bolivia	Italy	Saudi Arabia
Botswana	Jamaica	Senegal
Brazil	Japan	Singapore
Bulgaria	Jordan	Slovak Republic
Burkina Faso	Kenya	Slovenia
Cambodia	Kuwait	South Africa
Cameroon	Laos	South Korea
Canada	Latvia	Spain
Chile	Lebanon	Sri Lanka
China	Lithuania	Sudan
Colombia	Madagascar	Sweden
Costa Rica	Malaysia	Switzerland
Cote d'Ivoire	Mali	Tanzania
Croatia	Mauritania	Thailand
Cuba	Mauritius	Togo
Czech Republic	Mexico	Trinidad-Tobago
Denmark	Moldova	Tunisia
Ecuador	Mongolia	Turkey
Egypt	Morocco	Uganda
El Salvador	Mozambique	Ukraine
Estonia	Namibia	United Kingdom
Ethiopia	Nepal	Uruguay
Gabon	Netherlands	Venezuela
Gambia	Niger	Viet Nam
Germany	Nigeria	Yemen
Ghana	Norway	Zambia
Greece	Oman	Zimbabwe
Guatemala	Pakistan	