Global Digital Divide: Influence of Socioeconomic, Governmental, and Accessibility Factors on Information Technology

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ABSTRACT

The research goal is to analyze the influence of socioeconomic, governmental, and accessibility factors on ICT usage, expenditure, and infrastructure in 71 developing and developed countries. Overall results indicate primary importance of scientific and technical capacity as measured by publications, and secondary significance of foreign direct investment, government prioritization of ICT, public spending on education, and math/science education. For developed nations, technology factors are again most strongly associated with scientific publications, followed by foreign direct investment, % of females in the labor force, and education variables. For developing countries, technology attributes are strongly associated with foreign direct investment, government prioritization of IT, and education variables. The cases of ICT development and growth in Egypt and Estonia are examined and found to be consistent with the regression results for developing nations. The article suggests policy steps that can be taken by national governments to narrow the digital divide. © 2008 Wiley Periodicals, Inc.

Keywords: Information technology; socioeconomic; governmental; R&D; digital divide; global; policy

1. INTRODUCTION

Because uneven distribution of benefits of information and communication technologies (ICT) is often reported between developed and developing nations and world regions, socioeconomic factors that impact utilization, expenditure, and infrastructure of information technology need to be better understood. Despite the increasing attention and academic literature on the digital divide, there is no consensus on the issue of proper policy making and implementation.

Rapidly growing disparities in the utilization, expenditure, and availability of technology are apparent worldwide. This is commonly referred to as the "Digital Divide," i.e.,

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that society has major divisions in intensity of ICT utilization and application including economic, educational, and social aspects. In a report on the global digital divide, the World Economic Forum indicated that 88% of all Internet users were from industrialized countries that comprised only 15% of the world's population (World Economic Forum, 2002). Brazil had the fastest worldwide rate of growth in computer and Internet usage, yet only 13% of its population in 2001 owned a computer and 5% had access to the Internet. Despite much talk about the power of ICT to transform the economic development process, relatively little research has been performed in a global context on causation of technology differences among nations, how ICT is being used at the developing country level, comparison of the barriers that exist to the diffusion and adoption of ICT among world regions and cultures, and what empirical lessons can be learned to support national and international leaders and policy makers in reducing the digital divide.

Technological change and accelerating growth have been central to the economic growth and productivity of many nations. Worldwide, information technology (IT), the Internet, and other communications technologies are reshaping organizations and business enterprises, including in decision making, workforce, business processes, employment structures, teamwork, and products. There is general consensus that this revolution is still in its infancy and will continue to transform the way we live and work. This gives reason to the following frequently asked questions: How will these accelerating changes affect our lives and will these advances of information and communication technology increase the already existing gap and inequality in ICT utilization, or will governments be able to direct these forces to benefit everyone?

The power of information and communications technologies (ICTs) to profoundly influence and change the conduct of business and people's lives is the subject of discussion in many international forums. This concern is evident from "the first phase of the World Summit on the Information Society (WSIS)—the first global effort to share and shape the use of information and communications technologies" (Anonymous, 2004. p. 29). Heads of state, prime ministers, and officials from 175 countries came together to discuss cooperation among governments, private business, and civil society to help bridge the digital divide. As stated by the Secretary-General of the Summit: ". . . if we do not take any action now, existing gaps may be widened." This sentiment is underlined by the title of the WSIS, "Building the information society: a global challenge in the new millennium."

In this article, we analyze and compare the influence of socioeconomic, governmental, and accessibility factors on the usage and expenditure on ICT in 71 countries by using data collected by two large-scale datasets, the *Global Information Technology Report 2002–2003* (Dutta et al., 2003) and the *World Development Indicators 2003* (World Bank, 2003). Due to missing data for some study variables, the original data-set of 81countries was reduced to 71, divided about equally into 32 advanced and 39 developing ones. Accessibility refers to gaining access to ICT and the Internet and access to the skills to utilize them.

The research objective is to better understand the relationship between socioeconomic, governmental, and accessibility factors and ICT usage, expenditure, and infrastructure, which together reflect the ICT maturity of a nation and its potential to benefit from ICT. This raises relevant questions that may help policy makers to identify and address social, educational, and economic problems related to the digital divide and it may increase dialogue among stakeholders.

The next section reviews literature on the digital divide. It is followed by sections on the research model, research questions, methodology, findings, and discussion that include two country case studies. The article ends with the policy implications, study limitations, and concluding thoughts.

2. BACKGROUND

The expansion of information and communication technologies (ICT) has stimulated productivity, driven the economic growth of countries, shortened product life cycles, diminished the importance of distance, and globalized markets and economies. New communication technologies link markets, institutions, and people all over the globe and radically alter people's lives and work. Expanded use of technology and the development of e-business are transforming established organizational patterns and profoundly changing current business structures. Social and economic advancement in the developing world have become increasingly tied to ICT creation, dissemination, and utilization (Baliamoune-Lutz, 2003; Hill & Dhanda, 2003).

The use of the Internet and e-commerce has grown exponentially in recent years. Despite this remarkable growth, the gap in access to the Internet between rich and poor regions of the world is increasing. For example, Internet host penetration rates in 1997 in North America were 267 times greater than in Africa. Three years later, i.e., by October 2000, the gap had grown to a multiple of 540 (Arunachalam, 2003). The World Economic Forum (2002) indicated that 88% of all Internet users are from industrialized countries that comprise only 15% of the world's population. Developing nations have low levels of technology use (Dutta et al., 2003; Norris et al., 2001; World Economic Forum, 2002). Not only is there a global technology gap between rich and poor nations but also gaps between the advantaged and disadvantaged regions within nations (Norris et al., 2001).

In this article, the digital divide is measured by technology usage, expenditure, and infrastructure. Some argue that the digital divide concept should be a broader one than end users' problems but it should also extend to community development (Lentz, 2000). Baker (2001) and Warschauer (2003) point out that the policy problem of the digital divide is best addressed through multiple dimensions. The lack of consensus stems from the complexity of society itself and technology's interactions with it.

James (2005) contends that the traditional measurement of the global digital divide in terms of direct access to technologies makes sense in the rich countries, where individual ownership is widespread among the population, but less so in low-income countries. In low-income nations, illiterate and poor population often located in geographically remote areas lacks direct access to the Internet but can nevertheless gain its benefits indirectly through intermediaries. For instance, this population listens to community radio stations, which obtain enriched news through the Internet. James estimates that indirect benefits may bolster Internet-based benefits by roughly 30%. Baliamoune-Lutz (2003) examines for 47 developing nations the relationship of socioeconomic factors such as per capita income, education, literacy and openness factors of economic freedom; political rights, and civil liberties on diffusion of use of mobile phones, Internet hosts, and PCs. She finds mixed associations of these attributes. Income is consistently positive. There are some significant positive associations for openness to international trade, while political rights and civil liberties are have mostly positive associations, except for cell phones. Contrary to expectations from prior literature, ICT diffusion is not associated with FDI or with adult literacy. She concludes that ICT can provide an additional source of income and economic growth in developing countries. However, poor social development and trade policies in some countries slow the diffusion of ICT, trapping them on the poor side of the digital divide (Baliamoune-Lutz, 2003).

Guillen (2005) examines the relationship of democracy and the Internet and argues that democratic regimes enable a faster growth of the Internet than authoritarian or totalitarian regimes. One of his hypotheses states, "The more democratic the polity, the greater the Internet use (p. 689)." Government can try to control the Internet by monopolizing control (Guillen, 2005). If there is less government control of it, the Internet flourishes, and it is associated with greater democracy and civil liberties (Norris et al., 2001). Furthermore, Norris et al. (2001) claims that "all the selected indicators of economic development, human capital, and democratization proved to be strongly and significantly related to use of the Internet. . . the proportion of the population online in each country [is] significantly related to levels of per capita GDP, R&D spending, literacy and secondary education, and level of democratization, according to the available measures" (p. 61).

There are studies that have examined socioeconomic influences on ICT usage, intensity, and impact (Azari & Pick, 2004, 2005; Dasgupta, Lall, & Wheeler, 2005; Igbaria & Iivari, 1999; Korupp & Szydlik, 2005; Liu & San, 2006; Onyeiwu, 2002; Quibria et al., 2003). These have a variety of geographic locales, units of analysis, methodological designs, and research questions. For example, in a survey study of end users of microcomputers in Finland (Igbaria & Iivari), the extent of influence of demographic variables (age, gender, education, and organizational tenure), computer experience, and job training on microcomputer utilization at the level of the individual was examined. Socioeconomic factors were related to utilization, especially gender and age. By contrast, at the county level in the United States, the most important factors were scientific/technical workforce, services workforce, income, federal grant funds, college education, and ethnicity (Azari & Pick, 2004, 2005).

At the global level, research has shown several indicators including income, education, labor force, occupation, infrastructure, openness, and competition variables to be significant (Dasgupta, Lall, & Wheeler, 2005; Liu & San, 2006; Quibria et al., 2003; Sciadas, 2003; Wallsten, 2005). Based on a global sample of nations, Quibria et al. utilized regression analysis to show that income, education, and infrastructure were the most important variables for per capita usage of six kinds of ICTs. These studies underscore the need for higher education, scientific and technical education, and specialized IS training. A global study of mostly advanced nations has found that the factors associated with the rapid diffusion of the Internet at the turn of the 21st century were lower cost of Internet access, greater societal openness, political stability/lack of violence, literacy, urbanization, and utilization of TV sets, factors taken together termed "social learning" (Liu & San).

Sciadas (2003) presented a comprehensive framework that utilizes a complex digital divide index known as "infostate," which comprises the constructs of infodensity and info-use (Sciadas). The infodensity sub-index is based on the country stocks of information technology equipment, networks, machinery, and IT skills, while info-use measures consumption and utilization of information technologies. The difference from the present research is that, similar to many studies such as Baliamoune-Lutz (2003) and Dasgupta, Lall, and Wheeler (2006), our dependent variables focus on single per-capita measures of important indicators of the digital divide. ORBICOM's index is based on a much more complicated model (Sciadas), which distills dozens of indicators but is not as clear and focused as studies with separate indicators.

A cross-country study of Internet use and mobile phone diffusion (Dasgupta, Lall, & Wheeler, 2005) points to importance of competition policy for developing nations. It indicates that long-term infrastructure such as for phones may be more important for the digital divide than access. Wallsten (2005) studied the impacts of regulatory policies on growth of Internet services in developing countries. He found regulation to be inhibitory to ICT—some regulatory policies tend to reduce the number of Internet users while others lead to higher Internet-access prices.

An earlier theoretical study of the profitability of investment in education indicated that primary education had higher returns on investment than secondary and higher education, and primary was even more dominant for developing versus developed nations (Psacharopoulos, 1994). However, the study did not include ICT factors in its model.

Regional and single-nation studies of developing nations include one for Africa (Onyeiwu, 2002), which indicates large variety in ICT access levels among nations, even ones of similar socioeconomic attributes. There is lack of ICT policies to develop and diffuse ICT. Instead, some African nations have deregulated and privatized the telecommunications sectors, hoping to stimulate ICT, but with mixed results (Onyeiwu). Policies are suggested including concentrating ICT resources on certain subregions. Warschauer (2003) in a multiyear case study of Egypt's ICT, pointed to the huge challenges in education, technology training, and investment for its very large population. Dutta (2007) pointed to the great ICT advances of Estonia and described how the government supported in many ways this development, as well as setting policy to open up competition, foreign and domestic, in the ICT sector in the country. The cases of Egypt (Warschauer) and Estonia (Dutta) are described in more detail in the discussion section and compared to this paper's regression findings.

Sharma and Gupta (2003) consider for India the socioeconomic influences of e-commerce adoption and propose a framework for examining this phenomenon. They point out that Indian e-commerce adoption has been comparatively slow and that adoption "has caused changes in the socio-economic characteristics of several communities in such areas as the demographics, housing, services, markets, employment, income, and aesthetic quality." They contend that participation in e-commerce and online access are determined by the socioeconomic factors of income, education, geography, gender, and age (Sharma and Gupta). But despite the pervasive interest in the digital divide, there are few studies of multicountry samples (Quibria et al., 2003) that analyze the impact of socioeconomic factors on utilization, expenditure, and infrastructure of ICT. This gap in understanding gave rise to the present research.

A study of global creativity points to components for nations to retain and grow their creative talent and build technology (Florida, 2005). Global competition is rising for creative workforce, spurred in part by expanding worldwide immigration of talented persons seeking education and career opportunities. Although in the 20th century, the United States exemplified a role as the global educator of scientists, technical people, creative professionals, that role may be eroded by the Scandinavian countries, Japan, Switzerland, the Netherlands, Germany, Canada, and Australia—nations consciously building structures to attract international high-talent students, top scientists, and technology specialists.

3. RESEARCH MODEL

Our research framework, shown in Figure 1, explores the association of selected socioeconomic, governmental, and accessiblity factors on the three dependent factors of technology usage, expenditure, and infrastructure. We are interested in both the overall model and how it may compare for developed and developing nations. Our unit of analysis is the nation-state and data are collected from *Global Competitiveness Report* (Dutta et al., 2003)

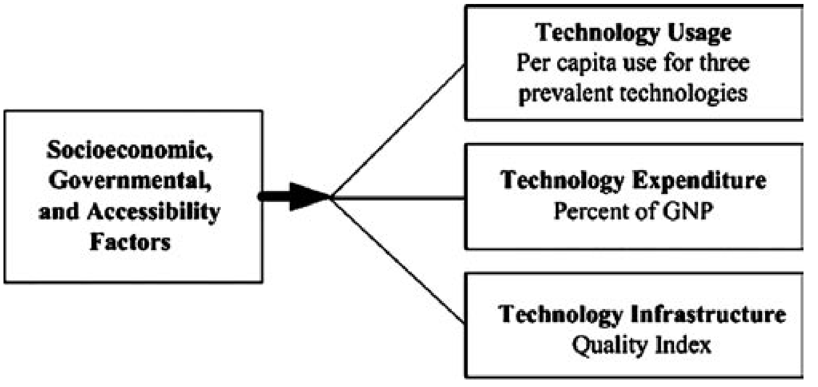

Figure 1 Framework for the association of socioeconomic, governmental, and accessibility factors with technology.

and the *World Development Indicators 2003* (World Bank, 2003). Data for the former were compiled by the World Bank from over 4,000 surveys in 82 countries that included over 100 questions.

The framework is somewhat related to the model developed by the World Economic Forum in collaboration with Harvard's Center for International Development (Dutta et al., 2003), which examined the network readiness index of nations according to three dimensions: ICT environment, readiness of a country, and actual usage of ICT, comprised of base variables.

The nation-state as a unit of analysis has the weakness of aggregating many different levels of technology within a single nation-state. However, this weakness is recognized by interpreting the effects as national ones, i.e., national factors result in national usages, expenditure, and infrastructure. Another limitation of the model is that it is unidirectional rather than bi-directional, as is the case for the preponderance of existing literature. This weakness is discussed in the Limitations of This Study section.

3.1 Research Questions

Based on the model, the specific research questions are as follows:

1. What are the most important socioeconomic, governmental, and accessibility factors that influence average per capita national technology usage for personal computers, Internet hosts, and mobile phones?
2. What are the most important socioeconomic, governmental, and accessibility factors that influence average per capita national technology expenditure for information and communications technology?
3. What are the most important socioeconomic, governmental, and accessibility factors that influence ICT infrastructure quality?
4. What are the differences in socioeconomic, governmental, and accessibility influences on average per capita national technology usage for personal computers, Internet hosts, and mobile phones between developing and developed nations?
5. What are the differences in socioeconomic, governmental, and accessibility influences on average per capita national technology expenditure for information and communications technology?

6. What are the differences in socioeconomic, governmental, and accessibility influences on ICT infrastructure quality between developing and developed nations?

4. METHODOLOGY

The analysis of the conceptual model is based on a regression model that includes five dependent variables for technology uses, prevalence, expenditure, and infrastructure and dependent variables for socioeconomic, education, accessibility to education, openness of government to public Internet access, training, R&D, and government variables. Dependent variables were narrowed based on the literature previously cited to a group of 13 and then further narrowed through collinearity considerations. The prior research discussed in the Background section was used to justify the selection of the variables. The data are drawn from a sample of 71 nations from which the dependent and independent variables are available with very little missing data.

4.1 Variables Used in This Study

The variables were chosen to support the framework in Figure 1 based on prior studies (Baliamoune-Lutz, 2003; Dasgupta, Lall, & Wheeler, 2005; Guillen & Suarez, 2005; Igbaria & Iivari, 1999; Mariscal, 2005; Norris et al., 2001; Quibria et al., 2003; Sharma & Gupta, 2003).

The dependent variables are significantly cross-correlated for the full sample. However, the correlations weaken somewhat for the subsample of less developed nations. Because they differed considerably in their correlates in other studies (Baliamoune-Lutz, 2003; Quibria et al., 2003), they are retained as five distinct variables. This allows regression differences to be explored, including comparison of developed and less developed nations. The dependent and independent variables are given below, with the prior research used to justify inclusion of the variable cited.

4.1.1 Dependent Variables

Personal computers per 1,000 persons (Igbaria & Iivari, 1999; Mariscal, 2005; Quibria et al., 2003)
Internet hosts per 1,000 persons (Quibria et al., 2003)
Mobile phones per 1,000 persons (Quibria et al., 2003)
Information and communications technology expenditure per capita (Quibria et al., 2003)
Index of overall ICT infrastructure quality (Mariscal, 2005; Quibria et al., 2003; Sharma & Gupta, 2003)

4.2 Independent Variables

Public spending on education (percent of GNP; Psacharopoulos, 1994; Sharma & Gupta, 2003; Warschauer, 2003)
Quality of math and science education (on 1 to 7 scale; Azari & Pick, 2004, 2005; Quibria et al., 2003; Warschauer, 2003)
Government Restrictions on Internet content (on 1 to 7 scale; Baliamoune-Lutz, 2003; Guillen & Suarez, 2005; Norris et al., 2001)

Gross Enrollment Ratio, Primary Education. (Guillen & Suarez, 2005; Kenny, 2000; Viswanath & Finnegan, 1996). This is the ratio of total primary school enrollment, regardless of age, to the population of that age group corresponding officially to the primary level of education (World Bank, 2003)
Government prioritization of ICT (Warschauer, 2003)
Percent of females in the labor force (Azari & Pick, 2005; Igbaria & IIvari, 1999; Korupp and Szydlik, 2005; Sharma & Gupta, 2003)
Primary pupil teacher ratio (pupils per teacher) (Korupp & Szydlik, 2005; Psacharopoulos, 1994; Sharma & Gupta, 2003)
Foreign Direct Investment in millions of dollars per 1,000 population (Dutta et al., 2003; Warschauer, 2003)
Science and Technical Journal Articles—natural log per million population (Florida, 2002, 2005)
Availability of scientists and engineers (on 1 to 7 scale)* (Azari & Pick, 2004, 2005; Florida, 2002, 2005)
Quality of local IT training programs (on 1 to 7 scale)* (Sharm & Gupta, 2003; Warschauer, 2003)
Gini Index* (Warschauer, 2003)
Cost of a business telephone subscription* (Liu & San, 2006)

The 13 independent variables were selected from hundreds of socioeconomic, educational variables, training, demographic, and government attributes available from major global data-collecting organizations (Dutta et al., 2003; World Bank, 2003) based on prior studies (Azari & Pick, 2004, 2005; Beliamoune-Lutz, 2003; Dasgupta et al., 2005; Florida 2002, 2005; Guillen & Suarez, 2005; Igbaria & Iivari, 1999; Korupp & Szydlik, 2005; Liu & San, Mariscal, 2005; Norris et al., 2001; Psacharopoulos, 1994; Quibria et al., 2003; Sharma & Gupta, 2003; 2006; Warschauer, 2003). A per-capita income variable utilized in some other studies (Baliamoune-Lutz, 2003; Dasgupta, Lall, & Wheeler, 2005) was not utilized in this research because of its lack of reliability or unavailability for many developing nations (World Bank, 2002; World Economic Forum, 2003). GNP includes an endogenous portion that is technology, so it was excluded as an independent variable for this research. However, GNP per capita was utilized to divide the sample of nations into subsamples of developed and developing.

The independent variables were tested for collinearity by analyzing correlation matrices for the whole sample, as well as for the subsamples of prosperous (developed) and poorer (developing) nations. Prosperous refers to nations with GNP per capita in 2001 of equal to or greater than 4,500 U.S. dollars/capita, while poorer refers to countries with GNP per capita in 2001 of less than 4,500 U.S. dollars/capita. The analysis of collinearity reduced the number of variables to nine, which are given in Table 1. In the list of independent variables, an asterisk indicates a variable eliminated by collinearity screening. However, one variable, natural log of science and technical journal articles per million population (STJA), remained highly correlated with seven of the other independent variables. Because of STJA's unique correlation status, two sets of regressions were run: (1) Stepwise regressions that included STJA and (2) Stepwise regressions that excluded STJA. Because the data sources had some missing data, the narrowing of variables reduced the size of the sample of nations with complete data to 71 for regression analysis. Because of constraints of degrees of freedom, we limited the number of independent variables allowed into the regressions to five for the full sample and three for the developed-nation and developing-nation subsamples.

TABLE 1. Correlation Matrix of Independent Variables, 1999–2001, International Sample

	PSOE	QMSE	GERATP	GOVRES	GPIT	PFLF	PPTR	FDI	STJA
Public Spending on Education (percent of GDP) (PSOE)	1								
Quality of Math and Science Education (QMSE)	−0.070 (0.535)	1							
Gross Enrollment Ratio, Primary Education (GERATP)	−0.070 (0.542)	−0.145 (0.203)	1						
Government Restrictions on Internet Content (GOVRES)	0.230* (0.039)	0.025 (0.822)	0.022 (0.848)	1					
Government Prioritization of Information Technology (GPIT)	0.199 (0.075)	0.106 (0.347)	−0.048 (0.672)	0.081 (0.475)	1				
Percent of Females in the Labor Force (PFLF)	0.345** (0.002)	0.094 (0.404)	−0.338** (0.002)	0.002 (0.987)	0.214 (0.055)	1			
Primary Pupil Teacher Ratio (pupils per teacher) (PPTR)	−0.199 (0.085)	−0.457** (0.000)	0.062 (0.598)	−0.184 (0.112)	−0.152 (0.191)	−0.242* (0.035)	1		
Foreign Direct Investment (per 1000 pop.) (FDI)	−0.027 (0.815)	0.029 (0.801)	0.017 (0.882)	0.063 (0.584)	0.239* (0.035)	0.164 (0.152)	−0.149 (0.208)	1	
LN of Science and Technical Journal Articles (per million pop.) (STJA)	0.357** (0.001)	0.235* (0.039)	−0.205 (0.075)	0.326** (0.004)	0.526** (0.000)	0.442** (0.000)	−0.523** (0.000)	0.366** (0.001)	1

Note. The numbers in parenthesis are the significance levels.
*signif. at 0.05.
**signif. at 0.01.
***signif. at 0.001.

Stepwise methodology was chosen because although some studies exist and have been discussed on socioeconomic correlates at the international level, there is insufficient prior research to narrow down the variables to only a few in a fixed model ahead of time. For (1), due to remaining collinearity, the maximum variables allowed to enter is three, while for (2), based on sample size, up to six variables were allowed to enter for the whole sample and up to three for the subsamples.

5. FINDINGS

Stepwise regression analyses were conducted for the five dependent variables. The first set of regressions was for the entire sample of 71 nations and included STJA. A maximum of three variables were allowed to enter. The overall regression results were very significant at the 0.000 level (five regressions on the left side of Table 2). The regression findings show that STJA is the most important correlate for all dependent attributes. The second most important correlate, for three dependent variables, is government prioritization of IT, while FDI relates to mobile phones. The quality of math and science education was inversely related to Internet hosts per capita, while gross enrollment ratio for primary education was associated with ICT expenditure.

Two control tests were done of the impact of global regional differences on the results. The first test, shown in the two regressions on the right side of Table 2, introduced a dummy variable ENA coded 1 for a European or North American nation and 0 for other nations. The regional effect was not present for the first three dependent variables. It was negative in value and significant at the 0.05 significance level for ICT expenditure and infrastructure quality, implying that the category of European and North American country reduces ICT expenditure/GDP and infrastructure quality for the model. The model impact is slight. The correlated independent variables remain the same as without inclusion of ENA, except that government prioritization of ICT becomes insignificant at the 0.05 level. A second regional control test for a regional dummy variable coded 1 for Latin American nations and 0 for other nations had no significant effect.

The second set of regressions was run for the subsample of 32 nations with GNP/capita greater than or equal to $4,500 and included STJA (Table 3). This subsample is referred to as "prosperous nation," while "poorer nation" refers to those with GNP/capita less than $4,500. For prosperous nations, STJA again dominates for all five regressions, with significance levels of 0.000. The only other significant variable for mobile phones was primary pupil teacher ratio, implying that fewer students per teacher is associated with more mobile phones. Results reinforce the significance of STJA for prosperous countries.

In the set of regressions for the subsample of developing nations, however, STJA was significant in the regression for PCs per capita. The most important correlate was FDI (Beta 0.442, signif. 0.003), followed by STJA (Beta 0.384, signif. 0.009). For the other four dependent variables, STJA was nonsignificant and did not enter the stepwise regressions. Those regression results are discussed later in Table 7. The reasons for STJA's reduced role relate to those nations' relatively smaller scientific R&D communities with lesser influence on IT usage, expenditure, and infrastructure, while governmental, FDI, and educational factors rise in relative importance.

As mentioned under methodology, a second set of regressions excluded STJA. They indicate the other factors beyond the dominant STJA that influence technology dependent variables.

TABLE 2. Standardized Regression Results for the Dependent Variables, 1999–2001, International Sample

											Standardized regression with Regional Dummy Variable ENA added			
	PCs per 1000 Pop.	signif.	Internet Hosts per 1000 Pop.	signif.	Mobile Phones per 1000 Pop.*	signif.	ICT Expenditure as Percent of GDP	signif.	Index of Overall ICT Infrastructure Quality	signif.	ICT Expenditure as Percent of GDP	signif.	Index of Overall ICT Infrastructure Quality	signif.
Public Spending on Education (percent of GDP)									0.148	0.063				
Quality of Math and Science Education			−0.255	0.034*										
Gross Enrollment Ratio, Primary Education							0.221	0.027*			0.239	0.022*		
Government Restrictions on Internet Content														
Government Prioritization of Information Technology			0.186	0.033*			0.243	0.031*	0.233	0.004**			0.191	0.022*
Percent of Females in the Labor Force											0.227	0.062		
Primary Pupil Teacher Ratio (pupils per teacher)														
Foreign Direct Investment (per 1000 pop.)					0.190	0.008**			0.151	0.057				
LN of Science and Technical Journal Articles (per million pop.)	0.791	0.000***	0.891	0.000***	0.755	0.000***	0.453	0.000***	0.540	0.000***	0.707	0.000***	0.836	0.000***
European or North American Nation—ENA (Control)											−0.362	0.011*	−0.222	0.023*
Regression adjusted R square	0.621		0.636		0.717		0.347		0.661		0.366		0.663	
Significance level	0.000***		0.000***		0.000***		0.000***		0.000***		0.000**			
Sample size (N)	70		71		71		71		71		71		71	

Note. ICT = information and communication technologies; LN = natural logarithm. ENA is included only for the two right-hand regressions.
*signif. at 0.05.
**signif. at 0.01.
***signif. at 0.001.

TABLE 3. Standard Regression Results for Dependent Variables, 1999–2001, International Subsample of Countries Having GNP per Capita in 2001 Greater Than or Equal to $4,500

	PCs per 1000 Pop.	signif.	Internet Hosts per 1000 Pop.	signif.	Mobile Phones per 1000 Pop.*	signif.	ICT Expenditure as Percent of GDP	signif.	Index of Overall ICT Infrastructure Quality	signif.
Public Spending on Education (percent of GDP)										
Quality of Math and Science Education										
Gross Enrollment Ratio, Primary Education										
Government Restrictions on Internet Content										
Government Prioritization of Information Technology										
Percent of Females in the Labor Force										
Primary Pupil Teacher Ratio (pupils per teacher)					−0.338	0.005**				
Foreign Direct Investment (per 1000 pop.)										
LN of Science and Technical Journal Articles (per million pop.)	0.807	0.000***	0.720	0.000***	0.665	0.000***	0.629	0.000***	0.751	0.000***
Regression adjusted R square	0.639		0.503		0.504		0.376		0.550	
Significance level	0.000***		0.000***		0.000***		0.000***		0.000***	
Sample size (N)	32		32		32		32		32	

Note. ICT = information and communication technologies; LN = natural logarithm. ENA is included only for the two right-hand regressions.

*signif. at 0.05.

**signif. at 0.01.

***signif. at 0.001.

Findings of regressions excluding STJA for the whole sample (Table 4) indicate three variables of large and about equal levels of significance, as follows: (1) FDI (significant for all the dependent variables; (2) quality of math and science education (significant for PCs, Internet hosts, mobile hones, and infrastructure); and (3) government prioritization of IT (significant for Internet hosts, ICT expenditure, and infrastructure quality). FDI consists of profit-seeking investments that influence broadly the uses for specific technologies, the overall spending on ICT, and betterment of technology infrastructure quality. Public spending on education is a less significant influence for PCs, ICT expenditure, and ICT infrastructure quality. This reflects an association of public educational investments mostly with factors of technology aggregated for the nation. For mobile phones, there is a significant relationship between reduced pupil-teacher ratio and mobile phones/capita that is unexplained.

For regressions excluding STJA for the whole sample, two control tests were again done of the impact of global regional differences on the results. As seen in Table 5, the dummy variable ENA for presence of European or North American nation has positive association with PCs, Internet hosts, and mobile phones. For each of the three specific technologies, there is somewhat greater prevalence in ENA nations, yet overall ICT expenditures and infrastructure quality are not affected. For PCs, Internet hosts, and mobile phones respectively, public spending on education, government prioritization of ICT, and quality of math and science education are no longer significant, but the most important findings on FDI and education variables persist. There is no regional control effect for the presence of a Latin American nation.

The results excluding STJA for the developed countries (Table 6) show significant relationship between public spending on education and PCs and mobile phones. There are significant associations between greater female labor force proportion and increased Internet hosts, ICT expenditure/GDP, and ICT infrastructure quality. The positive relationship of public educational spending and technology usage is one of many educational effects in the findings and will be discussed later in the context of the literature. In richer nations, women tend more to utilize technology, which contributes to increased Internet usage and ICT expenditure and adds to the need for improved ICT infrastructure. Its absence as an influence for poorer, developing nations (Table 7) may reflect that working women in poorer countries have lowered access to technology. However, that idea would need empirical investigation to corroborate. The association of women in the labor force with infrastructure quality needs explanation. The unexplained relationship of lower pupil-teacher ratio with more mobile phones/capita noted for the whole sample persists here.

For the poorer nations, excluding STJA, the regression findings sharply contrast to those for prosperous nations. Greater FDI is significantly related to increased usage of PCs, Internet, and mobile phones. The explanations given for FDI for the whole sample apply here even more strongly. Government prioritization of IT is significantly related to Internet usage, ICT expenditure/GDP, and infrastructure and is much more important for prosperous nations. For poorer nations, the government, relative to the private sector, has a greater role with technology, so governmental prioritization of it has increased relative impact. Primary pupil-teacher ratio is inversely associated with Internet usage and mobile phones, while quality of math and science education influences PCs. Gross enrollment ratio for primary education is associated with ICT expenditure/GDP. The widespread educational effects are covered in the next section. Altogether, these findings for poorer countries point to the dominant roles of foreign direct investment and public educational spending, in contrast to the leading attributes of women in the labor force and a variety of education factors for richer countries.

TABLE 4. Standard Regression Results for Dependent Variables, 1999–2001, International Sample, With Scientific and Technology Journal Articles per Capita Excluded

	PCs per 1000 Pop.	signif.	Internet Hosts per 1000 Pop.	signif.	Mobile Phones per 1000 Pop.*	signif.	ICT Expenditure as Percent of GDP	signif.	Index of Overall ICT Infrastructure Quality	signif.
Public Spending on Education (percent of GDP)	0.242	0.019*					0.244	0.020*	0.288	0.001***
Quality of Math and Science Education	0.343	0.002**	0.292	0.015*	0.336	0.001***			0.230	0.033*
Gross Enrollment Ratio, Primary Education										
Government Restrictions on Internet Content										
Government Prioritization of Information Technology			0.275	0.015*			0.342	0.002**	0.312	0.002**
Percent of Females in the Labor Force										
Primary Pupil Teacher Ratio (pupils per teacher)					−0.313	0.001***				
Foreign Direct Investment (per 1000 pop.)	0.295	0.006**	0.265	0.010*	0.304	0.007**	0.255	0.014*	0.272	0.003**
Regression adjusted R square	0.361		0.382		0.497		0.290		0.529	
Significance level	0.000***		0.000		0.000***		0.000***		0.000***	
Sample size (N)	71		72		72		72		72	

Note. ICT = information and communication technologies.
*signif. at 0.05.
**signif. at 0.01.
***signif. at 0.001.

TABLE 5. Standard Regression Results for Dependent Variables, 1999–2001, International Sample, With Scientific and Technology Journal Articles per Capita Excluded, Controlled for European/North American Region

	PCs per 1000 Pop.	signif.	Internet Hosts per 1000 Pop.	signif.	Mobile Phones per 1000 Pop.*	signif.	ICT Expenditure as Percent of GDP	signif.	Index of ICT Overall Infrastructure Quality	signif.
Public Spending on Education (percent of GDP)							0.216	0.044*	0.301	0.001***
Quality of Math and Science Education	0.27	0.027*	0.284	0.018*					0.225	0.038*
Gross Enrollment Ratio, Primary Education							0.232	0.029*		
Government Restrictions on Internet Content										
Government Prioritization of Information Technology					0.282	0.001***	0.298	0.006**	0.297	0.003**
Percent of Females in the Labor Force							0.202	0.074		
Primary Pupil Teacher Ratio (pupils per teacher)					−0.284	0.002**				
Foreign Direct Investment (per 1000 pop.)	0.239	0.025*	0.252	0.016*	0.282	0.001***	0.259	0.012*	0.282	0.002**
European or North American Nation (Control)	0.283	0.018*	0.277	0.019*	0.311	0.001***				
Regression adjusted R square	0.363		0.385		0.580		0.332		0.531	
Significance level	0.000***		0.000***		0.000***		0.000***		0.000***	
Sample size (N)	70		71		71		71		71	

Note. ICT = information and communication technologies.
*signif. at 0.05.
**signif. at 0.01.
***signif. at 0.001.

TABLE 6. Standardized Regression Results for Dependent Variables, 1999–2001, International Subsample of Countries Having GNP per Capita in 2001 Greater Than or Equal to $4,500, With Scientific and Technology Journal Articles Excluded

	PCs per 1000 Pop.	signif.	Internet Hosts per 1000 Pop.	signif.	Mobile Phones per 1000 Pop.*	signif.	ICT Expenditure as Percent of GDP	signif.	Index of ICT Overall Infrastructure Quality	signif.
Public Spending on Education (percent of GDP)	0.555	0.001***			0.297	0.036				
Quality of Math and Science Education					0.462	0.003**				
Gross Enrollment Ratio, Primary Education										
Government Restrictions on Internet Content										
Government Prioritization of Information Technology			0.333	0.037*						
Percent of Females in the Labor Force			0.418	0.010**			0.521	0.002**	0.517	0.002**
Primary Pupil Teacher Ratio (pupils per teacher)					−0.378	0.008**				
Foreign Direct Investment (per 1000 pop.)									0.312	0.045*
Regression adjusted R square	0.286		0.252		0.445		0.247		0.293	
Significance level	0.001***		0.001***		0.000***		0.002**		0.002**	
Sample size (N)	32		32		32		32		32	

Note. ICT = information and communication technologies.
*signif. at 0.05.
**signif. at 0.01.
***signif. at 0.001.

TABLE 7. Standard Regression Results for Dependent Variables, 1999–2001, International Subsample of Countries Having GNP per Capita in 2001 Less Than $4,500, with Scientific and Technology Articles Excluded

	PCs per 1000 Pop.	signif.	Internet Hosts per 1000 Pop.	signif.	Mobile Phones per 1000 Pop.*	signif.	ICT Expenditure as Percent of GDP	signif.	Index of Overall ICT Infrastructure Quality	signif.
Public Spending on Education (percent of GDP)									0.437	0.001***
Quality of Math and Science Education	0.292	0.024*								
Gross Enrollment Ratio, Primary Education							0.357	0.016*		
Government Restrictions on Internet Content										
Government Prioritization of Information Technology			0.267	0.016*	0.198	0.052	0.354	0.017*	0.480	0.000***
Percent of Females in the Labor Force										
Primary Pupil Teacher Ratio (pupils per teacher)			−0.248	0.028*	0.261	0.13*				
Foreign Direct Investment (per 1000 pop.)	0.561	0.000***	0.570	0.000***	0.634	0.000***				
Regression adjusted R square	0.478		0.585		0.641		0.218		0.501	
Significance level	0.000***		0.000***		0.000***		0.004***		0.000***	
Sample size (N)	38		39		39		39		39	

Note. ICT = information and communication technologies.
*signif. at 0.05.
**signif. at 0.01.
***signif. at 0.001.

6. DISCUSSION

The most important finding overall is that increased science and technical journal publication (STJP) is associated with greater technology use, expenditure, and infrastructure. Overall, after excluding STJP, the most significant positive influences are FDI, government prioritization, and quality of math and science education, with lesser influence of public spending on education. These will be discussed with reference to the research literature, and contrasting findings are examined between developing and developed nations.

An explanation of the importance of STJP is that a strong pool of scientific and technical talent, as reflected in high STJP, leads to more creative and productive industry, resulting in a greater prevalence of technology and its infrastructure, as well as a stronger economy in general. Creativity in nations sprouts from educated segments of the population referred to by Florida (2005) as the "creative class," which he defines as employees in science, engineering, health care, business law, architecture and design, entertainment, and the arts. The creativity of this class includes innovations in technology. This class is estimated at 40 million in the U.S. and 125 million worldwide (Florida). Besides the U.S., nations with high percentages of "creative class" are Ireland, Belgium, Australia, Netherlands, New Zealand, Estonia, the U.K., Canada, Finland, and Iceland (Florida). They can compete better economically in technology and other creative industries. Analogous to the rationale for communities, nations with high-quality scientific education attract foreign students and talented immigrants who add to the level of technology (Florida). Florida carries this argument further, suggesting that governments and businesses can be proactive in seeking talented students and top-skilled immigrants, as has occurred for example in Australia and Ireland.

The explanations of national results for STJP are tied to arguments for regions and localities. Florida (2002) pointed out that certain metropolitan areas within nations such as the Silicon Valley, southern California, and Route 128 in Boston have heightened effects from scientific creativity, leading to enhanced corporate productivity, and strong regional and local economies. In a more complex future research study, geographic submodels for the leading high-tech metropolitan areas of nations could be included, if consistent worldwide data were available. For African nations, Onyeiwu (2002) echoed this idea in his study, suggesting that there would be economies by concentrating ICT-intensive investment initially in one part of a subcontinental region forming a locus that could spread.

At the national level, effects of income and education on six dependent ICT variables (all per capita) were noted for a samples of 49 to 106 nations worldwide (Quibria et al., 2003). Although the intended focus was on Asia, the Asian dummy variable in the regression was found to be insignificant, so the full results can be compared to the present findings. In addition to the dominant correlate of income, tertiary education was a significant positive influence on Internet use and PCs; secondary education was positive for telephone, but primary education was insignificant (Quibria et al.). Education's prominence corroborates the present findings. At the same time, their total lack of effect for primary education differs from the present study's significant relationship of lower pupil-teacher ratio to higher use of cell phones. The discrepancy may stem from differing measures of primary education and country composition of samples.

For regional and metropolitan units of analysis, research has shown that education relates to technology (Azari & Pick, 2004, 2005; Florida, 2002). These studies indicate that the positive effects of education are not limited to science and technology but apply to general college attainment and primary education. In other words, local communities and metropolitan areas benefit by having an educated population with an abundance of scientists, engineers, and other technical professionals. The contribution to higher levels of technology stems from the capability of educated communities to conduct R&D, fill scientific and technical jobs, and attract in-migration of scientific talent. An example of such a community is Silicon Valley near San Jose in California: Technology firms in the Valley can fill jobs by the presence of talent-filled job pools; R&D can be accomplished in the Valley's cutting-edge companies and R&D-oriented universities; and new technological products and services are the outcome. In the present study, the quality of math and science education is associated with technological factors of nations in a somewhat analogous way.

The variable gross enrollment ratio for primary education reflects access to education, which is most likely to provide initial formal learning about technology. The ratio had limited association, but it was significant for ICT expenditure/GDP for the overall sample with or without SJTP included, as well as for developing nations, with or without SJTP. It is encouraging that educational accessibility is associated with national ICT expenditure. This finding is in concert with studies by Norris (2001) and Guillen (2005) that emphasized openness and democracy as correlates of growth and usage of the Internet at the national level. This relationship needs to be investigated further. It is an instance where causality could be argued both directions, i.e., at the national level, accessibility leads to ICT expenditures, or ICT expenditures lead to accessibility. It may, in reality, be not one direction of causality or the other but a positive feedback loop over a long period of time. This study limitation is discussed later.

When developing and developed nations are contrasted, for wealthier nations, technology factors are dominated by STJP, followed by labor force proportion of women and educational variables. For developing countries, technology factors, with the exception of PCs, are associated with FDI and government prioritization of IT, followed by educational variables. For them, the roles of government policy and foreign investment rather than education and demographic factors are more important, This can be considered as the "startup" stage of national ICT development, where technology must the "primed" to get started. These results resemble somewhat the findings of Baliamoune-Lutz (2003) who pointed to the importance for national ICT level of openness of government trade policies and the partial significance of political rights and civil liberties, while literacy was not important. Her finding on trade-openness is closely aligned with the present result for FDI.

6.1 Country Case Studies

This section analyzes and compares two brief case studies of countries in the present sample, drawn from the literature, that might shed light on the findings of this research with a focus on developing nations. Case studies have been utilized in several reports of the World Economic Forum (Dutta et al., 2006, 2007) to provide greater detail to support a larger data analysis and the Estonian case study is one of them (Dutta, 2007).

Estonia constitutes a case example of a developing nation from which technological development has benefitted by government leadership, foreign and domestic investment in technology, as well as government emphasis on education that emphasizes information technology and the Internet. The case essentially commenced in 1991 when Estonia regained its independence from the Soviet Union. The government leadership in the 1990s had a unifying theme of technology and the Internet (Dutta, 2007). One of the government's major steps was to replace aging Soviet infrastructure with cutting-edge infrastructure at the time. This was done by opening up telecommunications sector to private and foreign investment.

The bulk of this came from global Scandinavian firms such as Ericsson and Nokia (Dutta, 2007). There has been remarkable development of mobile services, stimulated by both foreign and Estonian companies. Local industry has been innovative and even world-class as seen by Estonian developers of Skype videoconferencing (Dutta, 2007).

The proactive stance of the Estonian government is shown by its innovation in government policies to the extent of achieving European recognition as an e-government leader, educational support and programs with the aim of an open and informed citizenry, especially the youth segment, and support for domestic Internet and technology companies and nonprofits. The federal government's multiple advances and innovations starting in the late 1990s included a portal linked to all government Web sites (introduced in 1998), paperless cabinet meetings (2000), constitutional right that guarantees Internet access to all citizens (2000), open citizen access to draft bills and amendments (2001), national electronic ID cards (2002), and development of a national option for electronic voting (2002), which was effected three years later. The federal government also supported the Tiger Leap program (1997) that aimed for all school children to have access and skills at the Internet, "Look @ the World" program (2001) with the goal of training and open access to reach 90% of citizenry as Internet users, and some joint government-university programs in technology (Dutta, 2007). The steps were especially remarkable for Estonia as a developing nation that had only a decade or so of independence.

Although great strides were achieved, challenges remain that include continuity of interest in technology by government top leadership, financial resources to replace the current infrastructure, deficits in national ICT workforce, and lack of success in the export of technological innovations from Estonian firms (Dutta, 2007). Many of these challenges stem from the country's small population and low GDP/capita.

The case corresponds to findings of the regression analysis for developing nations (Table 7). This includes an instance of the positive association of most of the dependent variables with government prioritization of ICT and with foreign direct investment. The association of public spending on education with ICT infrastructure is amply illustrated because the government emphasized e-education and technology in the schools, as well as by the Tiger Leap Program.

Egypt is a developing nation with very low levels of technology use and government expenditure per capita but above average ICT infrastructure quality. From the mid 1990s onwards, the Egyptian government emphasized high-profile programs for its public schools, but many of those programs were misdirected or inappropriate for achieving expanded skills and usage (Warschauer, 2003). Egypt's Ministry of Education invested in multimedia centers for selected government schools, computer labs for most schools, educational software developed by the Ministry, satellite educational TV programming, and a national multi-site videoconference system. Although the hardware and software were successfully installed, the programs were greatly hampered by rigid curricula dictated by the Ministry, bureaucracy, and a desire to "showcase" for outsiders rather than perform the essential teaching steps (Warschauer). Similar problems of under-utilization applied to several programs from prominent foreign government funding (Warschauer).

Although government investment in ICT was close to average levels for developing nations, FDI was very low (FDI per 1,000 population of 7.8 versus a mean of 74.9 for developing countries). Because it has a limited technology sector that can build the infrastructure inside the country, this implies that Egypt has reduced potential to develop broad technology utilization across the society. It corresponds to the regression findings (Table 7) of the association of reduced FDI with low prevalence of PCs, mobile devices, and Internet hosts. Egypt's prevalence levels for the PCs and mobile devices are about one-third of the average for developing nations, while Internet host prevalence is a sixth of the average.

Another issue has been the high extent of stratification of education in Egypt. In particular, the government has invested much more heavily in secondary and university education and much less at the primary levels. However, secondary levels and above are largely restricted to the richer segments of society. This has led to reduced access and openness of education and consequently to lessening of technology training and education.

In sum, the case studies of Estonia and Egypt illustrate contrasting ways that developing nations seek to develop technology use and expenditure and improve ICT infrastructure. Estonia has been a success story, and key elements of its success correspond to our regression findings for developing nations because the government emphasizes ICT, fosters education, encourages foreign investment. Egypt has trailed in technology usage and success at the national level due to governmental training programs that have not worked, reduced foreign investment, and other reasons. The key factors in this case also correspond to the developing-country regression results.

7. RECOMMENDATIONS AND POLICY IMPLICATIONS

The technology gap existing around the world cannot be left to the free market alone. To alleviate the gap and based on the present research findings, the following policies are recommended on all levels of international organizations, national governments, and particularly governments in developing countries:

- invest in stimulating, attracting, and growing creative technical and scientific workforce as measured by publications, patents, and research productivity
- increase the access to education and digital literacy
- reduce the gender divide and empower women to participate in the ICT workforce
- promote FDI, technology transfer, and openness of trade to stimulate, and build the domestic economy (Baliamoune-Lutz, 2003)
- encourage national policies of educational and workforce openness and tolerance in order to stimulate greater labor force participation of women, improve educational and training opportunities
- facilitate global circulation of talented people to supplement creative national labor force with outside workforce (Florida, 2003; Liu & San, 2006)
- emphasize investing in intensive-R&D for selected metropolitan areas and regions within nations (Florida, 2002, 2003) and, if cooperation can be achieved, for a particular nation within a continental subregion (Onyeiwu, 2002) in order to serve as a kernel for the subregion

The first two points on national policies—improve educational access and infrastructures with a focus on digital literacy at the primary level and research creativity—are especially important and strongly supported by the article's findings. Many developed nations have to struggle with finding the necessary budget and political support to broadly advance higher education. For developing nations, studies are mixed on what level of education has higher returns. Some indicate that, theoretically, primary education has higher returns on investment than secondary and higher levels (Psacharopoulos, 1994), whereas other studies point out that education above primary levels has enhanced returns stemming partly from complementary benefits between higher education and the new technologies (Quibria et al., 2003). No matter what the level, it becomes a question of national leadership in giving high priority to educational improvement programs and providing the necessary resources, expertise, and national educational leadership to succeed. Florida (2005) has emphasized the importance, even for the U.S., of political will and leadership to make the advances that are needed to improve creative talent, technology, and openness/tolerance. The question of political will and leadership applies broadly to nations that seek to improve their ICT. Multi-country studies such as this one have a growing consensus on certain steps to be taken, such as education, science and R&D, investment (foreign direct or governmental), and national policies favoring ICT. However, these improvements will not be made without concerted national leadership.

7.1 Lessons for Developing Countries

In developing nations, the problems are much more critical and difficult, and the relatively larger indirect benefits of ICT may be hard to measure (James, 2004, 2005). When literacy itself is a national challenge, such as in some African, Asian, and Latin American nations, digital literacy and creativity may be pushed aside by more fundamental needs and not receive as much attention or funding. There are other important initiatives competing for resources (Mariscal, 2005; Warschauer, 2003). For them, it is important not to think of providing the ICT equipment and infrastructure as alone the solution, but rather to emphasize a cluster of resource allocations working together synergistically to achieve economic and social development (Warschauer). On the other hand, one study (Dasgupta et al., 2005) emphasizes the importance of long-term phone infrastructure services in developing nations. The present study points to FDI, primary education, educational investment, access to education, and government prioritization of ICT as all important. They are elements that have the potential to work together in this synergistic way. The present model framework supports that those factors would lead to improved ICT infrastructure.

Also, developing nations may achieve better results by focusing funding for digital literacy and creativity in certain regions and metropolitan areas, the first steps in getting the whole nation started on an upward trajectory. The success of the state of Kerala in India is an example. Another approach, recommended by Florida (2005) is to form international consortia with the goal of advancing digital literacy worldwide.

7.2 Limitations of This Study

There are several limitations to the present research. The first is the application of multiple regression method. Regression results are estimates of the changes that would occur if the variables were entirely independent of one another. In complex social phenomena, such as those addressed in this study, single factor changes are rare. For example, income, education, and occupation are unlikely to change separately without inducing changes in the other components. Such cross-dependencies highlight the dangers of interpreting results as estimates of causal changes. A further study limitation of this research is a moderate sample size ($N = 71$) that stems from missing data for multiple nations in the World Bank and GITR data sets. This problem is the result of national governments' constraints and inconsistencies in their data collection and surveys, mostly in developing countries.

Another weakness is the adoption of a unidirectional model that does not include feedback mechanisms. A fuller model would include multistep simultaneous equations and bidirectional pathways. We are aware of the bidirectional impact of our model—i.e., the effect of technological change on socioeconomic factors. We intentionally planned a unidirectional model based on our review of literature (Baliamoune-Lutz, 2003; Dutta, 2003, 2006; James, 2004, 2005; Mariscal, 2005; Psacharopoulos, 1994; Sharma, 2003; Wallsten, 2005). Many authors tackle the problem of digital divide unidirectionally. In addition, as Rosenberg (1994) contends, a simple analysis of the science, technology, and production interface cannot capture the complex interrelationships between economic growth and technological change. To also measure the benefits of economic contribution and technological change on the socioeconomic characteristics of a country's population—the bidirectional impact—requires a broader survey beyond the scope of this study. However, technology by itself cannot influence and direct society and neither can society script the activities of technological innovation. Technological change and innovation depend on many complex patterns of interaction, including individual inventiveness and entrepreneurship (Castells, 1996). An expanded study could be based on a bidirectional, feedback model, mediated by intermediate factors.

8. CONCLUSION

In summary, this research on socioeconomic correlates of technology usage, expenditure, and infrastructure at the national level points to the dominant role of R&D capacity as represented by science and technical journal publication. We reason that the educated and creative workforce performing more R&D contributes higher levels of technology utilization and infrastructure. Other factors of importance are foreign direct investment, government prioritization of ICT, quality of math and science education, and access to primary education. They are also the factors that are associated with the large digital divide between the world's countries. The differences in correlates between developing and developed nations show that developing nation's technology level is more influenced by FDI and government initiatives, while richer nations' technology level is more associated with labor force participation of women and educational variables. We recommend the following steps for national governments to take to foster higher national levels of technology: (a) emphasize R&D and creative scientific workforce; (b) support access to education; (c) prioritize government initiatives in technology and education; (d) improve digital literacy; (e) upgrade skills; (f) promote foreign direct investment; (g) attract talent through migration both domestically and internationally; (h) reduce the gender divide in the workforce; (i) encourage societal openness and tolerance; and (j) support growth of the nation's highly creative cities and regions. Ultimately, beyond the resources and programs, the results for a single nation seeking improved ICT depends on political will and leadership that appreciates how multidimensional factors, including the ones highlighted in this article, need to be combined for development.

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