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Information and Communication Technologies Effects on Economic Growth

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Information and Communication Technologies Effects on Economic Growth

Complete Research Paper

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ABSTRACT

While Information and Communication Technologies (ICTs) are seen to be drivers of economic growth, it is unclear how this change takes place, especially since social and human factors are often seen to change as a result of ICTs. This paper investigates the effects of ICTs, and social and human factors in terms of skills, education, and labor, on economic growth. An augmented production function is used to quantify the effects that infodensity levels, defined as the combination of ICT networks and skills, education, and labor, have on the economic growth of high and low-to-middle income economies. This research draws upon data collected from the International Telecommunications Union (ITU) and the World Bank on a sample of 72 high and low-to-middle income economies covering the years 2000 to 2008. Panel data is used in this research to account for the time series factor present in the data range. The results indicate that while secondary levels of education are not significant, infodensity and tertiary levels of education have a significant contribution on the levels of economic growth per capita.

KEYWORDS

Information communication technology (ICTs), infodensity, panel data, the Arellano and Bond GMM estimator, economic growth.

INTRODUCTION

As a phenomenon that has reached a global scale in its effects, Information Technology for Development (ITD) has become an important tool to achieve long term levels of economic growth (Mankiw G. , 2003). Information and communication technologies (ICTs tools), such as the Internet or the Cell Phone, have shortened geographic distances by increasing the speed of communication. As a result, research efforts in information technology for economic development have focused in providing different insights into the ways in which information technology (IT) can be used as a tool for economic development (Becchetti & Adriani, 2005; Kamal and Qureshi, 2009). While many theories have recognized the importance of education and training as a tool for economic growth, other theories have recognized the importance of ICTs as a instrument for the modernization of economies (Kottemann and Boyer-Wright, 2009; Baliamoune-Lutz 2003; Kamal & Qureshi, 2009). A 2007 report from the International Telecommunication Union (ITU) found education enrollment and literacy levels as the main indicators to measure knowledge impact on ICTs access and usage (International Telecommunications Union, 2007). Additionally, broadband subscribers were found as the indicator that better reflects a country's ICTs consumption.

The majority of efforts undertaken in the analysis of ICT adoption worldwide have focused on access, infrastructure, diffusion and impact, which suggests that there is a relationship between IT adoption and economic development; however, other studies suggest that the ability to use ICTs in innovative ways is important in enabling sustained growth in developing regions (Sciadas G., 2003; Baliamoune-Lutz, 2003; Kottemann & Boyer-Wright, 2008). Information Technology for Development's success relies not only on its potential to enable a country to experience growth in the long term, but also on its usability. Other studies such as the one by Qureshi et al.(2009) have considered the role of entrepreneurs and their ability to access and use ICTs to gain knowledge and skills, which in turn contributes to the economic growth of a nation.

The overall objective of this research is to analyze the effects that infodensity levels, measured by capital and labor stocks, have on the economic growth of high and low to upper-middle income economies worldwide. Infodensity levels are represented by ICT networks including main telephone lines per 100 inhabitants, cell phones per 100 inhabitants, internet hosts per 1,000 inhabitants and skills measured by gross enrollment ratios for secondary education and tertiary education (Sciadas G. , 2003, p. 35). The data used in this research included a sample of seventy-two countries, between the years 2000 to 2008, that were classified based on gross national income (GNI) levels per capita as established by the World Bank (2011). Low income economies include those with a GNI equal or less than $1,025, whereas upper-middle income and high income economies have a GNI of $4,036-to-$12,475 and $12,476 respectively (The World Bank, 2011a; The World Bank, 2011b). In addition, Labor is taken into account in order to understand the effects of knowledge and skills on GDP per capita.

Solow's neoclassical growth model was used to account for the contribution that technological progress has on economic growth (Cavalcanti, 2010; Hernando & Nuñez, 2001; Papaioannou & Dimelis, 2007, p. 6)). In this study, we address the research question: how do ICT networks, skills and labor contribute to the growth of gross domestic product (GDP) on a per capita basis? This research is conducted by developing a panel data model to account for the time series factor present in the different countries in the data set (Chvosta & Erdman, 2007; Eigner, 2009). The next section presents a literature review on information technology and ICTs for economic development. The following sections present a description of the methodology used (econometric specification), results and conclusions.

THEORETICAL FRAMEWORK

The literature regarding information technology (IT) and economic development is extensive. Throughout the years, scholars and policy organizations, including the United Nations Development Programme (UNDP, 2012), the World Bank, and the OECD, have studied the impact of ICTs on the economic growth of both developed and developing nations. Directly, ICTs influence areas such as health, nutrition, education, culture and community; indirectly, ICTs generate economic growth by influencing some other areas of an economy, such as commerce and finance. As a tool that increases a country's productive capacity and international presence, ICTs have decreased the costs associated with the production and exchange of goods and services, enhanced management functions, and increased information access among enterprises. For instance, while the internet has removed physical distances between buyers and sellers, it has also created the demand for skilled workers. This demand for an educated workforce, and the subsequent economic growth, is analyzed in this research by considering the effects of secondary and tertiary education.

At the macroeconomic level, the impact of information technology differs across sectors and occupations. While some countries have engaged in the development, commercialization and trade of ICTs, other countries have become recipients of these technologies, hindering their possibilities to be technologically independent. ICTs in this case, are not being used by developing countries to "foster innovation and reduce poverty" (Yousefi, 2011, p. 3). Freeman (2004) mentions that one of the key elements in competitiveness is innovation. An innovation must be able to couple with changing technologies, products and markets; create new products, processes, systems and industries; and include new skills, new technologies, and new markets in order to keep up with international levels of competitiveness and economic development.

Most of the studies on the effect of ICTs on economic growth focus on developed nations, leaving room for the analysis of ICTs effects on developing nations (Papaioannou & Dimelis, 2007; Samoilenko & Osei-Bryson, 2011; Yousefi, 2011). Research findings arrive at the same conclusion: information technology has become one of the factors that has influenced the accelerated growth of many countries worldwide. While it is true that more and more people have access to ICTs due to a decline in their costs, the spillover effects of ICTs are not reaching equally to the citizens of developed and developing nations (United Nations Development Program, 2012). By including the effects of the accumulation of human and physical capital on economic growth, Mankiw, Romer and Weil (1992) study, analyzed the Solow Growth model on a sample of a hundred and twenty one countries from 1960 to 1985; their results explain why some countries have experienced higher levels of economic growth while others have not. The Solow-Swan model focuses on income levels and growth rates accounting for technological change as a factor to have a "positive growth rate of GDP per capita in the long-run" (Kosempel, 2007, p. 1256).

Other researchers have concluded that ICTs investment levels have grown disproportionately with the level of income "more than one for one with GDP growth" (Mann, 2005, p. 5). This fact is supported by the United Nations MDG Gap Task Force Report for 2012, which states that, regardless of a decrease in the costs of hardware and software, and an increased in access to ICTs worldwide, the digital divide between developed and developing nations still persists (Hernando & Nuñez, 2001; United Nations Development Program, 2012, p. 19). By using an augmented Cobb-Douglas production function, the Papaioannou & Dimelis (2007) study found that ICT impact, defined by the amount of money spent on hardware, software and communications is greater in developed than in developing countries. The data sample included 42 developed and developing countries between 1993 and 2001. Following this line of research, the first question that this study looks to answer is related to the effects of ICTs on the economic growth of high and low to upper-middle income economies as classified by the World Bank (2011).

From a political perspective, ICTs are influencing governments' regulations by causing them to implement new laws aim to protect their citizens from new forms of crime related to ICTs in the areas of "electronic content, cyber security, data protection and environmental issues" (United Nations Development Programme, 2012, p. xviii; UNCAD Secretariat (2009)). Therefore, policy makers need to create and facilitate the economic environment needed for the information technology sector to flourish -- an environment with accessible, affordable and good quality infrastructure. The context under which this research takes place considers Sciadas's (2003) ICTs dual nature: a consumable (info-use) and productive (info-density) side. From the productive side, ICTs are the aggregation of a nation's ICT stocks (capital and labor); from the consumption side they represent a nation's consumption of ICTs per period. In other words, networks (fixed telephone lines, internet host and mobile subscribers) and skills (school enrollment and literacy) are info-density indicators; uptake (computers, internet users, household TV) and intensity (broadband subscribers and international outgoing telecommunications traffic) are info-use indicators; with info-state being the aggregation of info-use and info-density (2003, p. 15).

METHODOLOGY

Econometric Specification - Production Function

At the aggregate level, the relationship between ICTs and economic growth has been studied by different scholars following Solow's (1957) neoclassical growth model (Kosempel, 2007; Mankiw, et al., 1992; Papaioannou & Dimelis's, 2007; Samoilenko, 2010; Samoilenko S. V., 2013). Solow's model uses as inputs the marginal products of capital and labor, while considering the rate of technological progress as an exogenous variable (Mankiw, et al., 1992; Samoilenko S. V., 2013). The dataset for this research consists of a time series between the period of 2000 to 2008 with a cross-section for each country in the sample (a total of seventy two were considered)
Assuming a Cobb-Douglas production function the Solow model as follows (Samoilenko, 2013):

$$Y_{it} = A * K_{it}^{\alpha} * L_{it}^{\beta} \quad \text{(Equation1)}$$

the subscripts *i* and *t* denote country and year respectively, Y_{it} is output, K_{it} is capital, L_{it} is labor's measure, and A is a constant that represents technology; α and β are the elasticities of capital and labor respectively.

Assuming constant returns to scale (CRS) and taking the natural logarithm, the production function of equation (1) is augmented by including human capital represented by gross enrollment ratios (Barro, 1997; Mileva, 2007; Papaioannou & Dimelis, 2007; Sciadas, 2003). Gross enrollment ratios are the "ratios of total enrollment, regardless of age, to the population of the age group that officially corresponds to the level of education" in upper secondary and tertiary levels (World Bank, 2012). This variable was included to account for the impact that an educated work force can have when adopting different technologies that can contribute to a nation's economic growth (Barro, 1997).

Equation (1) becomes:

$$\mathrm{Y_{it}} = \beta_1(\mathrm{Y_{i,t-1}}) + \beta_2(\mathrm{ID_{it}}) + \beta_3(\mathrm{L_{it}}) + \beta_4(\mathrm{TER_{it}}) + \beta_5\mathrm{Ln}(\mathrm{SEC}_{it}) + \mathrm{e_{it}} \quad \text{(Equation 2)}$$

- $\mathrm{Y_{it}}$ = GDP per capita (constant 2000 US$)
- $\mathrm{Y_{i,t-1}}$ = One year lag of GDP per capita
- $\mathrm{ID_{it}}$= Infodensity level of a country expressed by the number of main fixed telephone lines, cell phones, and internet hosts per 100 persons in a country (networks)
- $\mathrm{L_{it}}$ = Size of the labor force compromised of people ages 15 and older
- $\mathrm{SEC_{it}}$ and $\mathrm{TER_{it}}$= Gross enrollment ratios for secondary/tertiary education (skills)

After including the lag of the dependent variable, equation (2) is expressed as a function of the natural log (Ln) of ID, labor and, secondary and tertiary education (capital, in this research, is represented by a country infodensity levels (Sciadas, 2003). Taking into consideration Barro (1997) and Papaioannou & Dimelis, (2007), a maximum of three lags was used to obtain reliable estimates of the regression:

$$\mathrm{Ln}(\mathrm{Y_{it}}) = \beta_1\mathrm{Ln}(\mathrm{Y_{i,t-1}}) + \beta_2\mathrm{Ln}(\mathrm{ID_{it}}) + \beta_3\mathrm{Ln}(\mathrm{L_{it}}) + \beta_4\mathrm{Ln}(\mathrm{TER_{it}}) + \beta_5\mathrm{Ln}(\mathrm{SEC_{it}}) + \mathrm{u_{it}} \quad \text{(Equation 3)}$$

the natural log was implemented to evaluate whether the proposed linear regression was appropriate and also to examine the presence of constant variance in the error term (Kutner, Nachtsheim, & Neter, 2008, p. 107).

Following the World's Bank (2011) country classification, the seventy-two countries were analyzed based on their gross national income (GNI) levels as establish by the World Bank (2011) between high and low-to-middle income economies covering the years 2000 to 2008, along with the complete data sample this results in three different models:

- Model one all income level economies (high and low-to-middle income)
- Model two low-to- medium income economies
- Model three high income economies

Econometric Specification - Panel Data Models

When working with panel or longitudinal data it is necessary to consider the effects of unobserved factors over the dependent variable which either are constant or vary over time. In econometrics, two methods exist to evaluate whether unobserved factor it is correlated or uncorrelated with the dependent variable. When an unobserved effect does not vary over time, that is, it varies across cross-sections (country, firm, or city) it is called a fixed effect model. The goal of the fix effect model is to eliminate the unobserved effect because "it is thought to be correlated with one or more of the dependent variables." Contrarily, when it is though that an unobserved effect is uncorrelated with one or all of the explanatory variables across the sample's time it is called a random effects model. A random effects model does not allow arbitrary correlation between the unobserved effect and the dependent variables (Jeffrey, 2006, pp. 461, 494).

The Hausmann test was used to determine if a fixed effect or a random effect model suited better the different models postulated previously (Princeton University, 2012) *(See Table 1)*. The results showed that at 5% level of significance the null hypothesis is rejected (the coefficients estimated by the random effects estimator are similar to those obtained by the fix effect estimator (Princeton University, 2012)). Since the random effects model will produce inconsistent estimators, a fixed effects model is the best option to analyze models one *(all income level economies)* and two *(low-to- medium income level economies)*. Although for model three *(high income economies)*, the null hypothesis at the 5% level of significance is not rejected leading to the conclusion that a random effects model will be a more efficient estimator, with a p-value of .09 it is better to use a fix effect estimator (Princeton University, 2012).

Model Description

Estimation Method: RanOne	Model One	Model Two	Model Three
Number of Cross Sections	70	38	32
Time Series Length	9	9	9

Hausman Test for Random Effects

DF	5	5	5
m Value	21.47	14.26	9.32
Pr > m	0.0007	0.0141	0.0969

Random Effects Model (Table 1)

When calculating equation (*3*) some econometric problems may arise Mileva (2007). The first problem is related to endogeneity issues of the dependent variable (Y_{it}). In this case, endogeity problems arise when higher levels of economic growth may influence the independent variables ID_{it} and L_{it}, and vice versa. Causality may arise in both directions causing the regressors to be correlated with the error term. The second problem, in a fixed effect model, is the unobserved cross-sections (country-effects), v_i, and the specific errors, e_{it} are part of error term (Jeffrey, 2006, p. 494)

$$u_{it} = v_{it} + e_{it} \quad \text{(Equation 4)}$$

The third problem is related to the autocorrelation of the lagged level of the dependent variable, ($Y_{i,t-1}$) (Mileva, 2007, p. 1).

To correct the aforementioned problems, the Arellano and Bond GMM estimator, developed by Arellano and Bond (1991), was used. The nature of this estimator allows working with data samples that have a small time series (small-T) and a large data sample (large-N), as is the case of this paper (Mileva, 2007). To achieve unbiased and consistency, estimates of the dependent variables (problem No. 1 above), the Arellano-and-Bond estimator used three instruments. These instruments include the natural log of info-density, school enrollment at the secondary and tertiary levels and the lagged levels of the natural log of the dependent variable, making the endogenous variables pre-determined. The endogenous variables not only are pre-determined in the sense that "past values of the error term have some impact on future realizations," but also in the sense that they are not correlated with the error term defined in equation (2) (Mileva, 2007, p. 2 ;Papaioannou & Dimelis, 2007, p. 184). That is, higher level of economic growth per capita may lead to an increase in infodensity levels or school enrollment.

A limitation of the Arellano and Bond GMM estimator is that the use of "too many instruments bias the estimator to the within estimate" (SAS Institute Inc., 2013). To account for this problem the MAXBAND option is SAS for PANEL procedure was used to specify the number of time lags per instrument variable (SAS Institute Inc. , 2013). To deal with the cross-section or country effect problem (second problem), the GMM estimator transformed equation (1) to get the first-differences of it (Mileva, 2007, p. 2),

$$\Delta Y_{it} = \beta_1 \Delta(Y_{i,t-1}) + \beta_2 \Delta(ID_{it}) + \beta_3 \Delta(L_{it}) + \beta_4 \Delta(TER_{it}) + \beta_5 \Delta(SEC_{it}) + \Delta u_{it} \quad \text{(Equation 5)}$$

Since the country-specific effect does not vary with time, the previous step removed the fixed effect from equation (2) (problem No. 3). The new equation for the error term is:

$$\Delta u_{it} = \Delta v_{it} + \Delta e_{it} \quad \text{(Equation 6)}$$

To deal with the autocorrelation problem, the GMM estimator uses as an instrument the past levels of the first-differenced lagged of the dependent variable, $(Y_{i,t-1})$ (Mileva, 2007, pp. 1, 2).

RESULTS

Descriptive Statistics

Table 2 shows the descriptive statistics for the regression performed on the whole sample and also on low-to-medium and high-income economies. The results show that on average infodensity levels (ln ID) for the whole sample are above the levels of low-to-medium economies and below high-income ones. However, infodensity levels for low-to-medium economies is way lower than for high-income economies; this may be due to higher levels of infrastructure (networks) in developed nations, higher levels of GDP per capita (ln GDP per capita) and/or higher levels secondary and tertiary education (ln SEC and ln TER).

Model One (All income economies)

Simple Statistics

Variable	N	Mean	Std Dev
ln(ID)	630	4.251	0.918
ln (L)	630	15.654	1.673
ln (TER)	620	3.572	0.689
ln (SEC)	574	4.485	0.252
ln (GDP per capita)	630	8.500	1.404

Model Two (Low-to- medium income)

Simple Statistics

Variable	N	Mean	Std Dev
ln (ID)	342	3.695	0.882
ln (L)	342	15.997	1.6672
ln (TER)	332	3.283	0.684
ln (SEC)	304	4.350	0.254
ln (GDP per capita)	342	7.453	0.917

Model Three (High income)

Simple Statistics

Variable	N	Mean	Std Dev
ln (ID)	288	4.911	0.345
ln (L)	288	15.246	1.588
ln (TER)	288	3.9056	0.527
ln (SEC)	270	4.6366	0.140
ln (GDP per capita)	288	9.742	0.683

Descriptive Statistics (Table 2)

The correlation matrix, Table 3, shows that there is a strong positive correlation between infodensity levels (ln ID) and upper levels of education (ln TER and ln SEC), as well as infodensity levels and GDP per capita (ln GDP per capita) for the three models. An interesting finding is the level of correlation between GDP per capita and upper levels of education. Whereas for model one this one is above 0.5, for models two and three is below compared with model one. The table also shows those variables that are significant at the 5% level of significance.

Model One

	ln (ID)	ln (L)	ln (TER)	ln (SEC)	ln (GDP per capita)
ln (ID)	1				
ln (L)	-0.186 (<.0001)	1			
ln (TER)	0.649 (<.0001)	-0.007 (-0.864)	1		
ln (SEC)	0.687 (<.0001)	-0.153 (-0.0002)	0.739 (<.0001)	1	
ln (GDP per capita)	0.785 (<.0001)	-0.147 (-0.0002)	0.557 (<.0001)	0.616 (<.0001)	1

* P-values are reported in parenthesis

Model Two

	ln (ID)	ln (L)	ln (TER)	ln (SEC)	ln (GDP per capita)
ln (ID)	1				
ln (L)	-0.061 -0.260	1			
ln (TER)	0.596 (<.0001)	-0.099 -0.072	1		
ln (SEC)	0.561 (<.0001)	-0.142 -0.013	0.730 (<.0001)	1	
ln (GDP per capita)	0.604 (<.0001)	0.006 -0.900	0.470 (<.0001)	0.334 (<.0001)	1

* P-values are reported in parenthesis

Model Three					
	ln (ID)	ln (L)	ln (TER)	ln (SEC)	ln (GDP per capita)
ln (ID)	1				
ln (L)	-0.038	1			
	-0.519				
ln (TER)	0.347	0.434	1		
	(<.0001)	(<.0001)			
ln (SEC)	0.171	0.143	0.491	1	
	(-0.0048)	(-0.0186)	(<.0001)		
ln (GDP per capita)	0.518	0.152	0.159	0.307	1
	(<.0001)	(-0.0094)	-0.0067	(<.0001)	

* P-values are reported in parenthesis

Correlation Matrix (Table 3)

Panel Model Results

The panel results for models one and three for the fixed effect estimator (Table 4), all income and high-income economies, show the positive contribution that infodensity and tertiary education have on economic growth on a per capita basis, at the 5% level of significance. Contrary to expectations labor size and secondary education were found not to be statistically significant for either sample; this may be due to country differences. The fact that tertiary education has a significant contribution on the levels of economic growth per capita probes the initial assumption about the contributions that an educated workforce has on advanced economies that are capable of using the skills of their citizens. Similarly in model two, low-to-medium income economies, we can see the positive contribution of infodensity and tertiary education. Contrary to model one (all income level economies), and model three (high-income economies), the variable labor size has a significant negative effect on GDP per capita. Secondary education was found not statistically significant in this model.

To evaluate the consistency of the GMM estimator, the Sargan and the Arellano-Bond test for autocorrelation were used. While the Sargan test evaluates the null hypothesis whether the instruments used in equation number (4) are exogenous (or not correlated with the residuals), the Arellano and Bond test evaluates the null hypothesis that autocorrelation is not presented in the error term; this test is applied to the differenced residuals (Mileva, 2007). The reported results for the Sargan test for model one (all income level economies) is relatively low compared with the results obtained from model two and three (low-to-medium income and high-income countries). At the 5% level of significance, the Sargan test does not reject the null hypothesis for any of the models, meaning that the instruments used are valid. However, it is necessary to consider that for high-income economies, the value of the Sargan test is too high (Prob. ChiSq = 1.0). This can be due to the number of instrumental variables used in the regression and the sample size (n=32); an instrument denotes those variables that were used "in the moment condition of the dynamic panel estimator" (Arellano, 2009; SAS, 2012). After re-estimating the Sargan test using two lags instead of three, the value of the test decreased; the null hypothesis about the instruments is not rejected (Schaffer, 2012). On the other hand, no values were obtained for the Arellano and Bond test to evaluate whether any of the models exhibit serial correlation in first differences, AR(1). This can be due to the number of time periods per instrument, three in total that were used for the moment condition (SAS Institute Inc., 2012). Further research needs to be conducted in this regard.

The dynamic panel method GMM from Arellano and Bond (1991) was used to account for endogeneity problems that may arise from calculating equation (3). When considering all the countries in the data sample (model one), the effect of infodensity, labor size, and tertiary education is positive and significant at the 5% level. The positive contribution of infodensity to GDP per capita is lower on low-to-medium income economies (model two) compared to high-income economies (model three) where it is high (see table 4); this finding supports Papaioannou & Dimelis's (2007) study regarding the effects of technology on economic growth in developed and developing countries. The small impact that infodensity has on low-to-medium income economies (model two), can be attributed to the lack of skills present to use technology properly. Other variable that have a lower effect on economic growth on low-to-medium economies include tertiary education. Contrary to the contribution of the variables just described, secondary education had no influence on economic growth at all. For high-income countries, labor size was found to be insignificant. The main reason can be attributed to the size of the sample.

Model Description

Estimation Method	FixOne		
Number of Cross Sections	70	38	32
Time Series Length	9	9	9

	Fix Effects estimates			Arellano and Bond estimates		
Independent variables	Model One	Model Two	Model Three	Model One	Model Two	Model Three
ln GDP_per_capita_3	0.037973	0.0126	0.13576			
	(-0.3708)*	-0.833	0.0097			
ln GDP_per_capita_1				0.729123	0.78805	0.673605
				(<.0001)	(<.0001)	(<.0001)
ln (ID)	0.212424	0.2189	0.266305	0.060216	0.04091	0.106379
	(<.0001)	(<.0001)	<.0001	(<.0001)	(<.0001)	(<.0001)
ln (L)	-0.07873	-0.34	0.070877	0.08547	0.17221	-0.0281
	-0.382	-0.021	0.4426	(<.0001)	(-0.0005)	(-0.2852)
ln (TER)	0.156877	0.118	0.172944	0.087826	0.03759	0.086483
	(<.0001)	-0.003	<.0001	(<.0001)	(<.0001)	(<.0001)
ln (SEC)	-0.08463	0.0018	-0.03605	-0.22647	-0.01731	0.025138
	(-0.1115)	-0.985	0.4418	(<.0001)	-0.2956	(<.0001)
R-Square	0.9975	0.9915	0.9967			
F Stat.	12.21	10.7	19.59			
(p-value)	(<.0001)	(<.0001)	(<.0001)			
Number of Cross Sections	70	38	32	70	38	32
Time Series Length	9	9	9	9	9	9
Estimate Stage				2	2	2
Maximum Number of Time Periods (MAXBAND)				3	3	3
Sargan test				67.64	34.94	30.55
(p-value)**				-0.4894	0.9997	1

*p-values reported in parenthesis

** The null hypothes is that the instruments used in the equation number two are exogenous or not correlated with theb residuals

Panel data estimates Table 4

CONCLUSION

In order to study the relationship between ICTs and economic growth, this paper specified a Cobb-Douglas relationship between GDP per capita and infodensity, tertiary and secondary education, and labor in a sample of seventy-two countries including low-to-medium economies and high-income economies for a total of three models. Estimations were carried out by using the fix effect and the Arellano and Bond panel data estimators to account for possible endogeneity problems. The results point out some of the disparities present between developed and developing nations in terms of the contribution that ICTs, measured by infodensity, have on GDP per capita. The findings also support the fact that an educated workforce has a greater likelihood to contribute to the economic growth of a nation, especially at the tertiary level of education. The contribution of this research is in ascertaining that infodensity and tertiary education levels and in some cases, labor contribute to the economic growth of low-to-medium and high income economies in different proportions. This finding has implications for policy making when making decisions as to what ICT applications can drive change.

This research paper can be extended by analyzing the impact that the uptake and intensity of using ID can have on economic growth including expenditure levels in hardware and software. There are multiple policy implications of this research: 1)

Government need to invest in ICTs and education at the tertiary levels in order to see social change in their countries, 2) Low income countries stand to benefit from ICTs targeted at improving labor productivity and 3) the combination of ICT support for tertiary education increases the likelihood of social change through the ICT investments.

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