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Educational Levels and the Impact of ICT on Economic Growth: Evidence of a Cointegrated Panel

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ABSTRACT

The purpose of this paper is to analyze the long-run relation between economic growth and access to telecommunications services, comprising mobile telephony, fixed telephony, and broadband. We examine the differentiated impact on economic growth for a sample of twelve countries, divided according their educational level, i.e. high, medium, and low. The role of telecommunications alone on economic growth is limited unless is also accompanied by parallel investments in education; only this joint effort can provide a deep impact on growth due to a more efficient use of those technologies. Three panel data analysis are applied, one for each group of countries; the econometric analysis includes unit tests root tests, cointegration tests to examine the presence of long-term relationships, and an Ordinary Least Squares (OLS) panel model to estimate the impact of the of telecommunications and educational variables on economic growth. The evidence confirms the presence of a differential impact of telecommunications on economic growth related to educational levels.

Keywords: Education, economic growth, ICT, telecommunications.
JEL Codes: I25; L96; L86; J24.
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1.0 INTRODUCTION

During the 1990's, developed economies experienced significant productivity growth. This fact was attributed to the use of ICT by practitioners, scholars, and international institutions. Throughout the present decade the implementation of these technologies has increased in less developed nations; nonetheless, their impact on productivity has been limited; this has promoted research considering the presence of some other factors that can enhance the contribution of ICT on economic growth.

Nevertheless, international organizations still propose investment in ICT as a pre requisite (albeit not as a panacea) factor to further economic growth among developing nations (OECD/OECD, 2012; World

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Economic Forum (WEF), 2013; World Bank, 2012); these organizations recommend greater use of ICT, particularly telecommunications technologies as a condition to promote economic development, both for developed and developing economies; no prior differentials in some important factors like education are taken into consideration in their suggestions. Contrary to this view, this work stresses the fact that education and trainning of the labor force is a key factor for the application and optimal use of ICT, particularly telecommunications. Indeed, during the last two decades multiple studies contribute evidence about the importance of education on economic growth (Topel, 1999; Temple, 2001; Krueger and Lindahl, 2001; Sianesi and Reenen, 2003; Aghion *et al*, 2009¸ Pegtas, 2014). In this respect, the contribution of this work is linking educational levels with the use of telecommunications to test their impact on economic growth. Thus, considering that education directly affects the formation of human capital, this work sustains the hypothesis that countries with higher educational levels experience greater impact from telecommunications on economic growth because individuals with more education have more knowledge, creativity, skills and capacities which enables them to optimize the utilization of those technologies.

This hypothesis is tested using a sample of 12 countries divided into three groups according to their educational levels: High (Australia, Norway, Finland, The Netherlands); medium (Bolivia, Colombia, Mexico, Venezuela); and low (China, India, El Salvador, and Paraguay). Three panel data analysis are applied, one for each group of countries; the econometric analysis includes (a) unit tests root tests to verify the order of integration of the variables; (b) cointegration tests to examine the presence of long-term relationships; and (c) an OLS (Ordinary Least Squares) panel model to estimate the impact of telecommunications and educational variables on economic growth.

Our study presents some relevant findings. First, broadband impact on growth is positive for the three panel studies; its impact is greater the higher the degree of development and education is; thus, the least impact of broadband takes place in the group of countries with low education levels. Second, in the case of mobile phones, the results suggest that their impact on GDP per capita growth follows an asymptotic form in relation the level of education of the population when mobile phone penetration exceeds 100 phones per 100 inhabitants. Finally, fixed telephony results show a negative impact on growth per capita in two of the three panels, which confirms a fact rapidly taken place worldwide: the substitution of fixed telephony by mobile telephony in a first stage, and based on Internet protocols, in a second stage.

The evidence supports the hypothesis that the impact of telecommunications, particularly that most related to access and dissemination of knowledge, like internet, tends to be higher the more advanced is the educational level of a nation, by the following reasons:

1. Countries with higher levels of education incorporating ICT in their production processes, can increase efficiency, improve their practices and streamline their processes. This effect can be limited by educational level in countries with lack of qualified labor.
2. Governments can manage public services through Internet and improve communication with the citizenry, and people can connect with each other, increasing the exchange of information. This tends to happen more often in countries where there is greater citizen participation, typically the more educated.

To promote economic development strategic policies must be implemented enhancing the access to telecommunication services, particularly Broad Band, which should be accompanied with strong educational systems. Countries with low economic development and weak educationally systems must pursue more forcefully these policies.

The paper is organized as follows. Section 2 reviews the literature, first that dealing with the role and relationship between ICT, education and economic growth, and second with a review concerning ICT, telecommunications and economic growth. Section 3 deals with methodological issues; it describes the data, the construction of the panels to be examined according to differentials in educational levels; it also defines the econometric methodology; it ends highlighting some key differentials among the countries included in the panel analysis. Section 4 reports the evidence obtained. Finally, section 5 concludes the work.

2.0 RELATED STUDIES

2.01 ICT, EDUCATION AND ECONOMIC GROWTH

ICT have favored important positive productivity changes in economic, financial and commercial activities, enhancing socioeconomic development in many countries. Their applications have invigorated, automated and improved efficiency of many processes from the real and financial sectors; due to their multiple applications they are considered as general purpose technologies.[4]

The literature acknowledges three transmission paths concerning the effects of ICT on economic development:

1. Greater productivity within the ICT-producing sector;
2. Reductions in the prices of goods and services, which in turn benefit other sectors of the economy, derived from those reductions as well as from better quality of their inputs; and,
3. Derived from the previous changes, the use of ICT becomes widespread leading to greater impacts to overall corporate operations, not only because their processes also become more productive and efficient, but also because the release of previously entangled resources can be used to further investments; in short ICT enhance total factors productivity. (Jorgenson and Stiroh, 2007; Silva & Teixeira, 2011 ; World Bank 2012; ONTSI, 2013; Spiezia, 2011).

This view focus the problem partially because it ignores the initial conditions characterizing each individual country; it also ignores alternative development policies (Avgerou, 2010) assuming the existence of a common and undifferentiated impact of technology usage; it does not consider other variables among which must be mentioned the educational level and training of the national population, variables with considerable differentials between developed and developing nations. Moreover, the literature based on this perspective, implicitly assumes that lower costs lead immediately to a decrease in prices; however, without adequate regulatory mechanisms, it is possible that the reduction in costs will only lead to a redistribution of profit margins among companies within the same sector. In the absence of such mechanisms, it is possible that some of the potential resources for other investments are not released, and the effect described in item (iii) above is hampered.

Furthermore, the ICT-economic growth relationship is conditioned by the existence of certain characteristics; ICT generate impacts on competitiveness and subsequently, productivity, provided that firms have (a) a degree of maturity that allows them to incorporate new technologies into their business processes, and (b) employees and a labor force in general, with certain level of education to benefit from greater access to information and generation of innovations derived from ICT (Bárcena, Prado, Cimoli & Pérez 2011).

In this respect, research has identified leading mechanisms through which education impacts economic growth. Among the most important are:

1. education can increase labor productivity by increasing human capital of the workforce, resulting in a higher equilibrium level of output (Mankiw, Romer and Weil 1992; Hua, 2005; Berger and Fisher, 2005);
2. closely related to health; since higher levels of education promotes better hygiene, food and other behaviors that affect the well-being (Larrañaga, 1997; Brunello *et al*, 2011); e.g. children of more educated mothers tend to be healthier and more productive (Lockheed, 1991), and the fertility rate tends to decrease with education (Birdsall, 1990);

[4] General purpose technologies (GPT) are important new methods of producing and inventing whose impacts induce high aggregate economic changes nationally or even globally, and in society in general. Electricity and information technologies are frequently identified as the two more important GPT.

3. direct impacts on individual creativity, enabling technical and institutional innovations in mid sectors (Romer 1990; Becker, Murphy and Tamura, 1990; Benhabib and Spiegel, 1992; Fasko Jr., 2000-2001; Desh and Srisvastava, 2014);
4. increasing skills of human capital may affect other factors (like physical capital) and increase productivity of all factors of production (Lucas, 1990; Benhabib and Spiegel, 1992; Lebedenski y Vandenberghe, 2013).
5. higher education levels allows people access to higher revenues (Psacharopoulos and Patrinos 2004; Heckman, Lochner and Todd 2006; Hanushek and Zhang 2006) and better decision enabled by access to superior and more relevant information.

Summing things up, education promotes prosperity; additionally, linking education with the use of information and communication technologies increases their potential benefits on economic growth.

2.02 ICT, TELECOMMUNICATIONS AND GROWTH

The impact of ICT on economic growth has been widely studied since the 1990s, especially in developed economies. The neo-classical growth model advanced by Solow (1956) has become the point of departure for the development of more recent models; in a nut shell, growth is fostered not only by the addition of capital and labor inputs but also from innovation and new technologies. Jorgenson, Ho and Stiroh (2007) estimate a measurement of the change of 40 percent in factor productivity in the US, mainly due to a more intensive use of ICT. Along the same lines Strauss and Samkharadze (2011) using data from the EUKLEMS growth accounts show that ICT has made smaller contributions to labor productivity growth in 15 European countries, both at macro and economic individual sectors.

Research for the case of developing economies has also shed some light about the impact of ICT on their economic performance. Yousefi (2011) finds an insignificant impact of ICT on output growth for the case of these economies, Aravena, Cavada, and Mulder (2012) analyze the impact of ICT on the economies of Argentina, Brazil, Chile and Mexico for the period 1995-2008; their evidence concludes that non-ICT capital accounted for 38 percent of output growth, and ICT-capital for 12 percent. International financial and economic cooperation institutions have also advanced important studies which have become highly influential to policy making in the developing countries. The World Economic Forum (2013) suggests that increased investment in ICT improves the conditions under which competition (competitiveness) occurs, generating a series of elements that determine productivity growth. The World Bank (2012) holds that growth opportunities open to developing countries due to greater access to ICT devices and communication schemes enhance their development; the WB asserts that mobile communications offer greater opportunities to bring forward human development; they strengthen their potential for economic growth.

UNCTAD (2003) points out that the impact of ICT on economic activity derives from reorganization and restructuring of production processes and working methods in the sectors in which they are used; these technologies "... offer ample advantages to upgrade efficiency, share information, and generating a rapid accumulation, dissemination and application of knowledge." For the OECD, "... ICT act as promoters of innovation, particularly in products and marketing, both in manufacturing and in services" (Spiezia, 2011).

Avgerou (2010) calls into question the veracity of international organizations views. He pinpoints that the ICT-growth economic link is dubious and misleading, because it is based on a narrow economic theory, which ignores both the controversies surrounding the issue, as well as empirical evidence of alternative development policies (Avgerou 2010). At any rate, due to the low impact from the rapid adoption of ICT (particularly mobile phones and the internet) in developing countries, unlike the impact attained in developed countries, recent research has begun to consider additional factors which can deepen or else restrain the impact of ICT on growth. Examining the importance of other variables besides ICT, the works by Gordon (2000, 2010) and Vu (2005) must be mentioned. In addition, to examining the impact of ICT on total factor productivity Gordon measures the effect of falling prices generated in the area of ICT goods in the US; he finds that both effects are fed back, creating higher productivity growth around nine percent. Meanwhile, Vu assesses the impact of ICT on economic growth for a sample of 50 major ICT-spending countries. The author finds that the key determinants about the differentials of ICT contribution to growth include education, institutional quality, openness, and English fluency. Additionally, ICT investment has a significant impact on economic growth not only as traditional investment, but also as a boost to efficiency in growth: a higher level of ICT capital stock per capita allows an economy to achieve a higher growth rate for given levels of growth in labor and capital inputs. Finally, (Ngwenyama, Andoh-Baidoo, Bollou, and Morawczynski, 2006) analyze the impact that health, education and the use of ICT have on the development of 5 African countries; their findings suggest that ICT alone do not explain changes in development; but if education and health variables are included, the explanatory power increases significantly. From the perspective of Bárcena, et al (2011), integrating information and communication technologies into the dynamics of firms is achieved in four stages along an evolutionary path, intimately related to their size and maturity. Given the characteristics of most companies from developing countries they do not adopt ICT in production and organizational processes, so that potential impacts from their use is limited.

Considering the complexity of telecommunications, research has also dealt with particular aspects of such technologies, as is done in the present study. Lam & Shiu (2010) studies the impact of mobile telecommunications on economic growth and telecommunications productivity. She finds a bidirectional relationship between real gross domestic product and telecommunications development (measured by teledensity) for European high-income countries; assessing the effects of mobile phones alone, the bidirectional relationship is not restricted to those countries; her study also finds that countries in the upper-middle income group have achieved a higher average total factor productivity (TFP) growth than other countries. Using annual data from 192 countries over the period 1990–2007, Gruber and Koutroumpis (2011) find a positive impact of telecommunications on economic growth; however while in low income countries the impact of mobile telecommunications to annual GDP is 0.11%, for high income countries is greater, 0.20%. Their study also finds a positive impact on productivity growth due to the adoption of mobile phones. Dealing with the ASEAN region for the period 1992 – 2010, Mc Reynald (2013) finds that fixed-line and mobile phone telecommunications penetrations rates are positively related to GDP per capita growth. However, mobile phones seemingly are not associated with economic growth, apparently because mobile telecommunications were introduced later than fixed phones and a considerable length of time is needed to fully reach the benefits from mobile phones.

Similarly, Gyimah-Brempong and Karikari (2007) investigate the impact of telephone services on income growth for a sample of African countries. Using panel data and dynamic panel data estimation the authors find that telephone use has a positive impact on income growth, all things equal; they also find that mobile phones are substitutes for fixed phones. Lee and Gardner (2011) show evidence from South Asia and sub-Saharan African countries. Their empirical results show that mobile phones are positively correlated with economic growth; moreover, their marginal contribution is even greater while the conventional fixed-line telephony is poor. Finally, examining broadband impacts, for the case of emerging countries and African countries, Badran (2012) concludes that there is a positive impact of broadband uptake on economic growth.

Summing up, the literature on ICT and economic growth dealing with developed and developing nations acknowledges a positive effect, albeit the impact is greater for developed economies. Considering telecommunications, object of this study, the literature also finds positive influences from fixed telephony, mobile telephony and broadband on economic growth. Many studies, however, overemphasize the role of investment in ICT as the predominant factor contributing to economic development. This is particularly the case of international organizations; their view is limited because other factors that can enhance o restrict the role of ICT on growth are frequently disregarded. Education and socioeconomic differentials among countries constitute important factors that must be considered.

3.0 METHODOLOGICAL ISSUES

3.01 PANEL CONSTRUCTION Y VARIABLES

To test the impact of telecommunications on economic growth due to education, a sample of 12 countries was chosen from the educational level index published by the Office for Human Development from the World Bank (2013) which is reported for 187 countries and comprises average education levels for the 1980-2013 period. These economies were divided into three panels of study according to their educational level: Countries with high educational levels, index above 0.755 which includes Australia, Norway, Finland, The Netherlands; countries with medium educational level whose educational index ranges between 0.633 and 0.754 comprising Bolivia, Colombia, Mexico, Venezuela; and countries with low educational level which include China, India, El Salvador, and Paraguay; their educational index is below 0.622.

The variables used for the cointegrated panel analyses for the period 2003-2013 were gathered from the World Development Indicators of the World Bank (WDI, 2013). The corresponding per capita GDP in constant 2005 dollars annual data is used as a proxy for economic growth; telecommunications related variables include: subscriptions to fixed telephony, mobile telephony and broadband, each per hundred inhabitants. The variables used are transformed into natural logarithms.

3.02 ECONOMETRIC TESTS

Panel analysis is applied for each subgroup panel, according to the classification previously made in order to analyze the sensitivity of economic growth to changes in access to mobile services, fixed and broadband per hundred inhabitants. Previous to this analysis *de rigueur* unit root and cointegration tests are applied. Unit root tests are performed to determine the order of integration of each variable; three techniques are implemented in this paper: (a) Levin test (Levin, Lin, & Chu, 2002); (b) ADF-Fisher (Dickey Fuller Augmented) based on germinal ideas from Fisher; and c); and PP-Fisher (Phillips Perron) also based on observations made by Fisher (1932); these last tests advanced by (Maddala & Wu, 1999). The Levin test is based on the within dimension approach; this statistics pool the autoregressive coefficients across different members for the unit root tests on the estimated residuals. The other two tests are based on estimators that simply average the individually estimated coefficients for each member (Lee, 2005). In other words, the Levin test assumes the presence of a common unit root process crosswise for a panel data analyzed; the other two tests assume the presence of an individual unit root process tested with the pooled data.

The three tests are performed both in levels and in first differences. In addition cross sectional unit root tests have advantages over unit root tests for time series.

To test the null hypothesis of non cointegration, Pedroni (1999, 2004) proposes seven cointegration tests of two types: Four within the model and three between models; this study employs the ADF statistic and the ADF statistic for groups since Pedroni (1999) shows that the ADF tests work better than others when applied to small samples, such as the present panel.

Following Pedroni (1999), the heterogeneous panel and heterogeneous group mean panel cointegration statistics are calculated as follows (Lee, 2005)
Panel ADF-statistic:

$$\tilde{Z}_t^{\,*} = \left(\hat{s}^{*2}\right)\sum_{i=1}^{N}\sum_{t=1}^{T}\hat{L}_{11i}^{-2}\,\hat{e}_{it-1}^{*2}\Big)^{-1/2}\sum_{i=1}^{N}\sum_{t=1}^{T}\left(\hat{L}_{11i}^{-2}\,\hat{e}_{it-1}^{*}\Delta\hat{e}_{it}^{*}\right) \qquad (1)$$

Group ADF-statistic:

$$\tilde{Z}_t^{\,*} = \sum_{i=1}^{N}\left(\sum_{t=1}^{T}\hat{s}_i^{2}\hat{e}_{it-1}^{*2}\right)^{-1/2}\sum_{t=1}^{T}\left(\hat{e}_{it-1}^{*}\Delta\hat{e}_{it}^{*}\right) \qquad (2)$$

Where, e_{it} is the estimated residual from Eq. (1) and $\hat{L}_{11i}^{2}$ is the estimated long run covariance matrix for $\Delta\hat{e}_{it}$. Likewise, $\hat{\sigma}_i^2$ and $\hat{s}_i^2$ $(\hat{s}^{*2})$ are, respectively, the long run and contemporaneous variances for individual *i*. The other terms are appropriately defined in Pedroni (1999) with the property lag length determined by the Newey-West method.

Despite the fact that co-integrated test was already proposed more than one decade ago, its use is still in force. The reasons are that the principles at the base of the survey, the design of the seven co-integration tests in their two types, between and within the models, entail a certain strength in its results, due to the fact that they combine time series and cross sectional data obtaining more degrees of freedom, which improves properties of the estimators and in addition correct non observer heterogeneities (Robledo and Olivares, 2013). Panel Cointegration technique is still active and it is used in several studies as the main method (Cetin, Gunaydın, Cavlak & Topcu, 2014) or in a complementary way (Adhikari, & Chen, 2012 & Jebli & Youssef, 2015).

3.03 SOCIOECONOMIC AND TELECOMMUNICATION DIFFERENCES AMONG THE SAMPLE COUNTRIES

Prior to the *ad hoc* econometric tests to be carried out, it is important to highlight some differentials among the sample countries included in the cointegrated analysis. Table 1 identifies differences in key economic variables, educational levels, and deepness of telecommunications use among these 12 countries. Great disparities can be observed; notoriously, Norway GDP per capita is 50 times higher than the one corresponding to countries like India, Bolivia and Paraguay. The rate of economic growth is another variable showing huge differences; in countries like China and India average GDP growth rates over the last decade have been 10.2 and 7.5 percent, respectively, while in countries like Mexico, this variable has not surpassed 3.0 percent. Concerning the level of economic development, the differences are also marked; life expectancy is almost 16 years between Australia and India.

Regarding variables directly related to the present study, Table 1 reports ICT spending as a percentage of GDP; significant differences are present between developed countries, like Finland (7%), Netherlands (6.4%), as well as emerging countries characterized by high economic growth. i.e., China and India (6.6% and 5.9%, respectively), vis-à-vis other countries which present lower investment rates in ICT, such as in the case of Venezuela (2.3%).

Table 1: Key socioeconomic indicator for the sample countries

Country	GDP per cápita 2013 (USD 2005)	Average GDP per capita growth (2003-2013)	Average GDP growth, PIB (2003-2013)	Area thousand sq. km 2013	Life expectancy de vida (years)*	Population (millions inhabs.) 2013	Expenditure in ICT (% PIB) 2013**
Australia	37,492.9	1.5	3.0	7,682.3	82.1	23.1	4.8%
Bolivia	1,323.1	2.9	4.7	1,083.3	66.9	10.7	4.9%
China	3,583.4	9.6	10.2	9,327.5	75.2	1,357.4	6.6%
Colombia	4,376.4	3.2	4.7	1,109.5	73.8	48.3	5.5%
El Salvador	3,063.0	1.4	1.9	20.7	72.1	6.3	…
Finland	37,676.6	0.9	1.3	303.9	80.6	5.4	7.0%
India	1,165.0	6.1	7.6	2,973.2	66.2	1,252.1	5.9%
Mexico	8,519.0	1.3	2.5	1,944.0	77.1	122.3	5.2%
Netherlands	40,187.1	0.6	1.0	33.7	81.1	16.8	6.4%
Norway	65,188.5	0.4	1.5	304.3	81.5	5.1	3.8%
Paraguay	1,917.7	2.9	4.8	397.3	72.2	6.8	…
Venezuela	6,401.9	2.9	4.7	882.1	74.5	30.4	2.3%

Source: Data from World Development Indicators 2013. World Bank. * Data for 2012. ** Data calculated based on the Digital Planet series "Total Information and Communications Technology Spending" and Gross Domestic Product both in US $ millions.

The case of education is no exception. To stress this situation, as previously mentioned the sample is based on the average rate of education (1980-2013) based on the education index published by the Office for Human Development (2013) for 185 countries; twelve representative countries were selected according to their educational level, high, medium and low as shown in Table 2. These economies share some common but differentiated characteristics associated with investment in telecommunications, type of government, economic indicators, average expenditure on education as a percentage of GDP, and average percentage of the population with higher education, all reported for the period 1990-2012.

For the group of countries with high level of education the education index is greater than 0.755; for the medium educational level group the index varies between 0.623 and 0.754, finally, countries ranked with low education levels show indexes below 0.622.

This classification is enhanced with information about two other variables: (a) the average expenditure on education as a percentage of GDP (1990-2012); the following ranges are present for each group: the top group increased this expenditure by five percent; the medium group averaged between 4 and 4.9 percent; and the low group, less than 3.9 percent; and (b) the percentage of labor force with higher education; this coefficient is above 25 for the top group, between 15 and 24.9 percent for the medium group, less than 15 percent for the lower group. Bolivia is the only country for which spending on education as a percentage of GDP generally increased within this group.

Table 2: Educational Index for the sample countries

	Country	Educational level index (average, 1980-2013)[5]	Expenditure in Education (% PIB, (avererage 1990-2012)	Work Force with higher education (% from the total, (average 1990-2012)
High	Australia	0.992	4.994	32.175
	Norway	0.920	7.116	32.359
	Finland	0.912	6.466	31.600
	Netherlands	0.902	5.359	27.559
médium	Venezuela	0.709	4.325	25.400
	Bolivia	0.700	6.153	14.657
	Colombia	0.672	4.168	22.011
	Mexico	0.668	4.219	19.987
Low	Paraguay	0.617	3.821	12.650
	China	0.611	1.835	ND
	El Salvador	0.611	3.019	13.357
	India	0.548	3.442	7.225

Source: Data from Human Development Report Office and World Development Indicators, World Bank, 2014.

In this context it can be affirmed that those societies with higher educational levels and higher training are able to engage more effectively in different productive and communication processes impacting favorably competitiveness. For businesses, the core of all economies, the impact of ICT in growth will depend more on the way in which they incorporate them into their production processes by trained personnel accessing these technologies.

The opposite must be true for economies and businesses dominated by low education levels; in their case the use of these technologies may be limited, mainly for recreational use, even generating negative effects on productivity. Indeed a deficient use of ICT could lead to widening gaps in development.

[5] Annual average from 1980 a 2012 because investment in education takes from 20 to 30 years to become reflected in productivity, in consonance with educational reforms (Hanushek, 2005; Hanushek and Wößmann, 2007).

Finally, to test whether there is or there is not a long-term equilibrium relationship between the variables of access to ICT (fixed, mobile and broadband telephony) and economic growth, a model of OLS (Ordinary Least Squares) is applied. This approach allow us to obtain robust information, because it is possible to analyze crosswise and over time the data dynamics, providing greater degrees of freedom in the analysis; another gain consists in lessen multicollinearity problems of our model vis-á-vis time series models.

4.0 EMPIRICAL EVIDENCE

To analyze the relationship between telecommunications and economic growth three panels were employed, as previously identified.[6] First, it is necessary to test stationarity of the variables included in each panels. This is accomplished employing three panel unit root tests for panel. As previously stated, these tests are the Levin, Lin and Chu test (2002); Fisher test criteria including the Dickey Fuller; and the Phillips Perron (Maddala & Wu, 1999). Results are shown in Table 3. The null hypothesis sustains the presence of unit root.

Table 3: Unit root tests

		Common unit root process		Individual unit root process			
		Levin, Lin & Chu t*		ADF-Fisher chi-cuadrada*		PP-Fisher chi-cuadrada*	
	Variables	Levels	First Diff.	Levels	First Diff.	Levels	First Diff.
Panel countries with high educational level	lnPIB	0.81489	-3.51591***	2.54012	21.8746***	1.01679	28.3776***
	lnMOBILE	1.81189	-5.10276***	2.44568	33.9193***	0.16113	43.0356***
	inFIXED	-3.39987***	-2.91025***	18.6588**	13.7788**	51.9743***	13.9662**
	lnBBAND	-0.65621	-11.5911***	5.08925	55.8659***	0.70162	60.3505***
Panel countries with medium educational level	lnPIB	0.82502	-1.43887*	10.8773	17.5359**	20.8127***	21.152***
	lnMOBILE	1.61601	-6.17887***	2.76801	18.141**	0.41707	14.3898*
	inFIXED	-1.17018	-3.74317*	10.6575	26.5757*	8.69696	28.2933*
	lnBBAND	1.41407	-2.47011***	1.27454	13.2169*	0.44637	14.9985*
Panel countries with low educational level	lnPIB	2.41063	-3.10596***	2.26375	23.3435***	2.26194	29.6706***
	lnMOBILE	-1.35851*	-4.1932***	5.72105	16.7203**	2.87169	3.4817**
	inFIXED	-2.19462**	-4.45535***	12.6619	37.2108***	7.11578	34.1236***
	lnBBAND	-0.75872	-4.25433***	4.47026	26.4689***	3.67067	29.2359***

Null hypothesis: unit root presence (non-stationarity). *** indicates statistical significance at them1% level; ** indicates statistical significance at the 5% level; and *indicates statistical significance at the 10%. Probabilities for the ADF (Fisher Chi-square) and PP (Fisher chi-square) are computed using a χ^2 asymptotic distribution. For the Levin, Lin and Chu test a normal asymptotic distribution is employed.

The evidence is presented both in levels and in first differences. Tests in levels reveal that the series are not stationary; however, considering first differences, results indicate that the variables are stationary with significance levels of 1%, 5%, and 10%; an essential condition for the existence of long-term relationships. The statistical evidence is robust in 70% of the cases the significance level is 99%, 16% of the results has a significance level of 95% and in only 14% of the cases the significance level is of 90%. Cointegration test must follow, to identify the presence of linear combinations for each of the panels, which can be described as stationary. The Pedroni (1999) test of cointegration is used. This technique is analogous to the Engle and Granger (1987) test for time series, i. e. based on a regression of residuals. Seven cointegration tests are applied to each panel; four are applied within the model and three between models. Of the 7 tests, two were selected for analysis: the ADF statistic and the ADF statistic for groups. (Pedroni 1999) shows that ADF tests work better than others when applied to small samples, as in our case. The results are shown in Table 4.

[6] E-Views 8.0 was used for all econometric analyses.

The null hypothesis is not rejected, i.e. the variables are cointegrated; there is a significant long term equilibrium relationship between selected variables. Therefore, the estimation of a model that measures the impact of the variables number of mobile phone subscriptions, landlines and broadband links per 100 inhabitants on the GDP per capita growth, is possible and results are robust. In five of six cases the significance level is 1%; in the remaining case 5%, still very representative. Hence, the next step was to estimate the following model using ordinary least squares for each of the three models of panel, as follows:

$$\ln GDP = \alpha_{oi} + \beta_{1i}\ln mobile + \beta_{2i}\ln fixed + \beta_{3i}\ln bbanda + \varepsilon_{it} \quad (3)$$

Table 4. Cointegration Tests for each Panel

Panel	Test	Statistic	Probability
Panel with high educational level	Panel ADF statistic	-6.233437	0.0000
	Group ADF statistic	-3.471627	0.0003
Panel medium educational level	Panel ADF statistic	-3.296404	0.0005
	Group ADF statistic	-2.520903	0.0059
Panel with low educational level	Panel ADF statistic	-1.885321	0.0297
	Group ADF statistic	-3.997646	0.0000

Data source: World Bank (2014) and World Development Report, FMI (2014). Statistical tests follow a normal asymptotic distribution. ** and *** show rejection of the null hypothesis of no cointegration at significance levels of 5% and 1%, respectively.

The null hypothesis is not rejected, i.e. the variables are cointegrated; there is a significant long term equilibrium relationship between selected variables. Therefore, the estimation of a model that measures the impact of the variables number of mobile phone subscriptions, landlines and broadband links per 100 inhabitants on the GDP per capita growth, is possible and results are robust. In five of six cases the significance level is 1%; in the remaining case 5%, still very representative. Hence, the next step was to estimate the following model using ordinary least squares for each of the three models of panel, as follows:

$$\ln GDP = \alpha_{oi} + \beta_{1i}\ln mobile + \beta_{2i}\ln fixed + \beta_{3i}\ln bbanda + \varepsilon_{it} \quad (3)$$

Where *ln* indicates the natural logarithm for each of the variables. Results are reported in Table 5. The impact of the number of mobile phone users and the number of broadband subscriptions on per capita GDP is positive, while the number of fixed telephones may impact differently because it is a variable that for all selected countries in the last five years has steadily decreased both in absolute terms and in relative terms (telephones per 100 inhabitants).

Table 5. Model estimations

PANEL	Variable	Coefficient	t Statistic	Probability
Panel countries with high educational level	MOBILE	-1.345035	-2.543068	0.0150
	FIXED	-0.546391	-2.134926	0.0389
	BBAND	0.315118	3.270737	0.0022
	C	18.00061	5.738500	0.0000

	F-statistic	3.777287	Probability F	0.017750
	R-squqre	0.220757	R-square adjusted	0.192314
Panel countries with medium educational level	MOBILE	-1.000373	-6.770625	0.0000
	FIXED	1.016441	7.285695	0.0000
	BBAND	0.0526645	7.370059	0.0000
	C	9.299577	11.89391	0.0000
	F-statistic	119.2271	Probability	0.000000
	R-square	0.899417	R-square adjusted	0.891873
Panel countries with low educational level	MOBIL	0.317751	7.985363	0.0000
	FIXED	-0.462068	-10.35735	0.0000
	BAND	0.041749	1.713655	0.0943
	C	5.218882	25.23253	0.0000
	F-statistic	99.17632	Probability	0.000000
	R-square	0.881492	R-square adjusted	0.872604

Data source: World Bank (2014) and World Development Report, FMI (2014). ***; **; * indicate significance levels at the 1%, 5% and 10%, respectively.

4.01 EVIDENCE FOR COUNTRIES WITH HIGH EDUCATIONAL LEVEL

The empirical evidence shows that for all countries considered with a high educational level, the model has a low goodness of fit, documented by a 0.22 R square. The F test shows that the model is statistically representative as a whole to a significance level of 0.05. At the level of individual variables, all are statistically representative at a level of 0.05. However, not all variables show the expected sign. In the case of mobile telephony, the sign is negative. This could be attributed to the fact that between 2005 and 2007 access to cell phones in these countries increased to 100 per 100 inhabitants; the greatest impact of this variable on growth takes place with the first device per capita; penetration levels equal to 100 mobile lines per capita imply that the entire population (or at least that segment able to afford it) owns mobile phone line; any rate above that implies that part of the population has more than one. However, the contribution of a second line is marginal in proportion to the first, since the number of applications per capita that can be realized from a mobile line does not increase, but is divided between two lines.

In the case of the broadband variable, a positive and significant sign is obtained. This shows that the variable in this group of countries has contributed positively to GDP growth per capita. This is in line with the view that an increase in the penetration of broadband services, offers an increased infrastructure for people and businesses; this allows them greater access to information and knowledge generated elsewhere, advertise and market their products through internet, and so on.

Finally, concerning fixed telephony, the evidence supports a negative impact on per capita growth. This fact is related to the substitution of fixed telephony by mobile telephony; consequently fixed telephony has declined in most countries, both in absolute terms, as well as per 100 inhabitants. Further, in a second stage, fixed phones began to be replaced at an accelerated way by mobile telephony based on internet protocols, which does not require of the traditional fixed telephony infrastructure. Moreover, fixed phones were the first telecommunications service developed; in these group of countries of highly educated countries, fixed telephony has decreased annually during the period 2003-2013. Hence, it is quite feasible that the impact of this variable on growth occurred in previous periods to the one specified for the present period.

4.02 EVIDENCE FOR COUNTRIES WITH MEDIUM EDUCATIONAL LEVEL

The explanatory power of medium educational level model is better; the R-square registered is 0.89. Both F-statistic for the overall model, and the t-statistic for the individual variables are statistically significant.

In the case of the independent variables, similar results were obtained for mobile phones, a negative sign for the coefficient β. Like in the case of high educational level, countries that closer to, or exceeding the threshold of 100 phones per 100 inhabitants, the impact of the variable on growth begins to decrease; the contribution of the second line per capita tends to split with first, instead of adding up effects.

Considering fixed telephony, the impact on GDP per capita growth was positive. This is likely due to the fact that for 3 of the 4 countries in the group, this variable continues increasing (particularly for Venezuela where during the 2003-2013 period this variable more than doubled), i.e. this technology continues affecting production processes; to this one could add, that the substitution effect with mobile telephony was lower in this group, albeit both variables increased.

The impact of broadband on economic growth was also positive, although with a lower coefficient with respect to the one corresponding to the panel of highly educated countries. This result highlights the importance of education, considering that broadband, besides being a means of communication (like fixed and mobile telephony) is a medium that allows greater access to information flows and the creation and dissemination of knowledge.

4.03 EVIDENCE FOR COUNTRIES WITH LOW EDUCATIONAL LEVEL

For the group of countries with low education levels, the corresponding panel shows a high goodness of fit (R-squared of 0.89); overall is also statistically representative (F probability of 0.000). However, at the level of individual variables, the model shows statistically significant levels of 0.05 for both mobile and fixed telephony; in the case of bandwidth, this variable is only representative at a 0.10 level.

For mobile telephony, unlike the previous two panels, the impact found for this group of countries is positive; consistent with the above explanation, most countries belonging to this group have not reached rates above 100 telephones per 100 inhabitants; hence, the contribution to GDP growth per capita can continue to be positive.

For the variable fixed telephony, the evidence shows a negative impact; this can be explained by the fact that fixed phones in China and India have decreased during the period here analyzed; this change has occurred both in absolute terms and per 100 inhabitants, while their GDP per capita have been the most dynamic in the world; during the period under study this variable increased at rates of 10 percent and 8 percent, in China and India, respectively. For this group of countries, the effect of substitution of fixed by mobile telephony is still in force, which aids explaining the direction of the signs.

In the case of broadband, although the impact is positive, it is also proportionally smaller than that found for groups of countries with better education levels; this finding supports the hypothesis that the impact of telecommunications, particularly that most related to access and dissemination of knowledge, tends to be higher the more advanced is the educational level of a nation. Yet, the variable is statistically representative only a 0.10 significance level.

5.0 CONCLUSIONS

This study analyzed the differential impact of telecommunications on economic growth, taken as a point of departure the educational level of societies. A representative sample of twelve countries was selected and divided in three groups according to their educational levels: high, medium and low. An

OLS cointegrated panel model was employed to test the impact of telecommunication services on economic growth. Previous to this test unit root analysis and cointegration analysis was performed. Unit root tests confirmed the absence of unit root in the series; subsequently, cointegration tests proposed by (Pedroni, 1999), confirmed the presence of long term equilibrium between the variables of each panel. In the case of mobile phones the panel analysis evidence shows their impact on GDP per capita growth follows an asymptotic form in relation the level of education of the population when mobile phone penetration exceeds 100 phones per 100 inhabitants. This stems from the fact that functionality derived from mobile phones, can generate growth in the product as the user population grows; however, a second or third phone per inhabitant, have a marginal impacts on growth. In the case of broadband, the impact on growth is positive for the three panel studies; its impact is greater the higher the degree of development and education is; thus, the least impact of broadband takes place in the group of countries with low education. This evidence supports the hypothesis that to exploit more efficiently the potential benefits of telecommunications, the workforce must have educational levels that allow them to do so; otherwise, the impact of this technology on growth will tend to be limited.

In the case of fixed telephony, in two of the three panels its impact on growth per capita was negative, which confirms a fact rapidly taken place worldwide: the substitution of fixed telephony by mobile telephony in a first stage, and based on Internet protocols, in a second stage.

In short, to promote economic development strategic policies must be implemented aiming at enhancing the penetration of and access to telecommunication services, which should be accompanied with strong educational systems. Countries with low economic development and weak educationally systems must pursue more forcefully these policies. At any rate, future research is necessary to shed further light on the importance of telecommunications on economic growth. Further studies, particularly in the case of developing countries research should include longer periods, and more variables to detect the contribution of telecommunications on economic growth.

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