ARTÍCULO

AN APPROACH TO THE BROADBAND EFFECT ON LATIN AMERICAN GROWTH: A STRUCTURAL MODEL

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Alderete, M. V. (2017). An approach to the broadband effect on Latin American growth: A structural model. ***Cuadernos de Economía, 36*****(71), 549-569.**

This paper analyses the fixed broadband penetration effect on Latin American economic growth. The methodology employed consists of using a simultaneous equation model based on Koutroumpis (2009) and Katz and Callorda (2013). To aid this process, we use country level data from the World Bank and the Regional Dialogue about the Information Society-DIRSI for the 2010-2014 period. The results obtained stress the importance of broadband penetration for economic growth in Latin America.

Keywords: Broadband, economic growth, Latin America.
JEL: O3, O4, C3, L9.

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Alderete, M. V. (2017). Un planteamiento acerca del efecto de la banda ancha sobre el crecimiento de América Latina: un modelo estructural. *Cuadernos de Economía*, *36*(71), 549-569.

Este artículo analiza el efecto de la penetración de la banda ancha fija sobre el crecimiento económico de América Latina. La metodología consiste en el uso del modelo de ecuaciones simultáneas con base en Koutroumpis (2009) y Katz y Callorda (2013). Para contribuir a este proceso, utilizamos información a nivel de país del Banco Mundial y del Diálogo Regional sobre Sociedad de la Información (DIRSI) para el período 2010-2014. Los resultados obtenidos resaltan la importancia de la penetración de la banda ancha para el crecimiento económico en América Latina.

Palabras clave: banda ancha, crecimiento económico, América Latina.
JEL: O3, O4, C3, L9.

Alderete, M. V. (2017). Une analyse de l'effet du haut débit sur la croissance de l'Amérique latine : un modèle structurel. *Cuadernos de Economía*, *36*(71), 549-569.

Cet article analyse l'effet de la pénétration du haut débit sur la croissance économique de l'Amérique latine. La méthodologie se base sur l'utilisation du modèle d'équations simultanées de Koutroumpis (2009) et Katz et Callorda (2013). Pour contribuer à ce processus, nous utilisons au niveau de pays une information de la Banque mondiale et du Dialogue Régional sur la Société de l'Information, DIRSI, pour la période 2010 – 2014. Les résultats obtenus soulignent l'importance de la pénétration du haut débit pour la croissance de l'Amérique latine.

Mots-clés : Haut débit, croissance économique, Amérique latine.
JEL : O3, O4, C3, L9.

Alderete, M. V. (2017). Uma aproximação sobre o efeito da banda larga no crescimento da América Latina: Um modelo estrutural. *Cuadernos de Economía*, *36*(71), 549-569.

Este artigo analisa o efeito abrangente da banda larga fixa sobre o crescimento econômico na América Latina. A metodologia consiste no uso do modelo de equações simultâneas baseadas em Koutroumpis (2009), Katz e Callorda (2013). Para contribuir com esse processo, utilizamos informação no âmbito de país do Banco Mundial e do Diálogo Regional sobre Sociedade da Informação, DIRSI, no período 2010-2014. Os resultados obtidos ressaltam a importância da penetração da banda larga no crescimento econômico na América Latina".

Palavras chave: Banda larga, crescimento econômico, América Latina.
JEL: O3, O4, C3, L9.

INTRODUCTION

Technological revolutions have reconfigured the industrial production and became an instrument for economic growth in the long term. Since the end of the 80's, the role of Information and Communication Technologies (ICT) in determining productivity has been an important focus of debate in the literature.

ICT have some advantageous characteristics such as: a) low trading cost of goods and services, which leads to gains through specialization, scale economies and comparative advantages (Harris, 1995); b) low transaction costs and efficient information management, with complementary organisational changes and skills training; c) positive network effects as the value of ICT increases with the number of users; d) efficient control of distribution channels and reduced inventory holdings, and e) fast and efficient reallocation of inputs.

Several studies have shown that ICT increase firms' productivity (Alderete & Gutiérrez, 2012; Aral, Brynjolfsson & Wu, 2006; Balboni, Rovira & Vergara, 2011; Brynjolfsson, Malone, Gurbaxani & Kambil, 1994; Brynjolfsson & Hitt, 2003; Paunov & Rollo, 2016 among others). However, currently, findings about the ICT impact on nations' GDP are not conclusive. In fact, some papers have found a negative ICT effect on GDP (Strassman, 1999). These ambiguous results have promoted the development of a more disaggregated analysis using micro level data. Moreover, the availability of time series data and the employment of more adequate methodologies to deal with endogeneity between ICT and economic growth could help to identify the impact.

In particular, broadband is a key and decisive element in a new system characterized by structural complementarities that are fundamental for economic and social development. In developed countries, recent studies have emerged addressing the existence of causality between broadband and economic growth. The results evidenced a positive impact of broadband on GDP growth.

From an economic perspective, the broadband contribution is settled within a multiplicity of effects (Katz, 2012). Firstly, broadband infrastructure and telecommunications networks are sources of employment, and therefore, lead to several multiplicative effects on the economy. ICT provides market information (especially on prices and competitors) and knowledge about production techniques to farmers and fisheries (Jensen, 2007; Ogutu, Okello & Otieno, 2014).

Secondly, broadband has spill-over effects on the whole economic system, affecting both firms and households. Broadband's impact on the productive sector is reflected in firms' increase in productivity, which is one source of GDP growth. Paunov and Rollo (2016) found that industries' Internet use positively impacts the performance of the individual firm. These Internet-enabled knowledge spillovers are stronger in less innovative firms.

Alternatively, households can achieve a real income increase by reducing the poverty levels and therefore, promoting economic growth. By using broadband,

household consumers have access to fast, always-on and un-metered Internet (Oh, Ahn & Kim, 2003). Broadband can change a household's lifestyle, making it more flexible and producing more convenient circumstances. For instance, many people are able to work at home instead of travelling to the office, and children can use broadband Internet to do homework and research activities (Choudrie & Lee, 2004; Oh, Ahn & Kim, 2003; Spiezia, 2010). Advances in broadband can lead to higher productivity levels, competitiveness and social inclusion provided that broadband Internet makes access to services such as education, health and government management easier (Peres & Hilbert, 2009).

In Latin America, studies on the impact that ICT has on economic growth are still scarce. One of the possible reasons for this is the lack of ICT data with both a longitudinal and cross-section dimension. In many Latin American countries, it is difficult to obtain access to micro level data or data on a regional/local level due to lack of official statistics, the large informal sector, and budget constraints to finance micro-data projects, among others. These problems hinder the development of micro-data models, which explains the existence of only a small amount of research. Several of the countries for which there is information available include Ecuador (Katz & Callorda, 2013), Panamá (Katz & Koutroumpis, 2012), and Colombia (Katz & Callorda, 2011).

The Latin America region presents a digitalization[1] level of 34.63 (Katz, Koutroumpis & Callorda, 2013). The Digitization Index represents an attempt to quantitatively measure a country's progress that is on the path to digitization development. This index, which is a composite index that ranges from 0 to 100, allows for an initial ranking and, subsequently, a more meaningful clustering of national economies into different categories (Constrained, Emerging, Transitional and Advanced). Norway is one of the top 20 countries in the world rankings with 73.69 in 2011. On average, the Latin American region is on the border between emerging and transitional economies, which encompass those countries with a digitization score in the range of 35 to 50. While Chile is the best-positioned country in the region, there are countries such as Cuba, Bolivia and Nicaragua that pertain to the constrained category (with less than 20). The region has been improving its digitalization level at a compound annual growth rate of 6.48 per year since 2004: a rate that has drastically risen since 2010.

In Latin America, the first analyses of broadband's economic impact were deve loped by Katz (2009, 2010). Due to lack of a larger time window, an ordinary least squares model was estimated using a sample of countries for the years 2004 and 2009 separately. The main limitation of this methodology is the endogeneity between per capita GDP and broadband penetration. The author found that a 1% increase in broadband penetration leads to a 0.0158% increase in GDP growth. This result is similar to Koutroumpis (2009)'s findings who employed a simul-

[1] The digitalization index consists of six elements that capture the scope, level of access, reliability, speed, use and capabilities; and 24 sub-indicators that measure digitalization.

taneous equation model to control for endogeneity for OECD countries. According to the author, a 1% increase in the broadband penetration (in countries with a penetration level below 14%), contributes to a 0.008% growth in GDP.

The objective of this paper is to examine the impact of fixed broadband penetration on the economic growth in Latin America. This is the first attempt to update Katz's (2009, 2010) study in the region by using updated information and controlling for endogeneity. To achieve this goal, a simultaneous equation model is estimated based on Koutroumpis (2009) and Katz and Callorda (2013).

The paper is organised as follows: primarily we present the state of the art in order to describe the contribution of broadband to economic growth with special focus on Latin America. Secondly, we develop a theoretical framework about the importance that ICT has on economic growth. We then undertake a literature review in order to show the findings of the relationship between broadband and economic growth. Thirdly, a simultaneous equation model is described and estimated. Lastly, we explain the results obtained and make some final remarks.

STATE OF THE ART: FIXED BROADBAND PENETRATION IN LATIN AMERICA

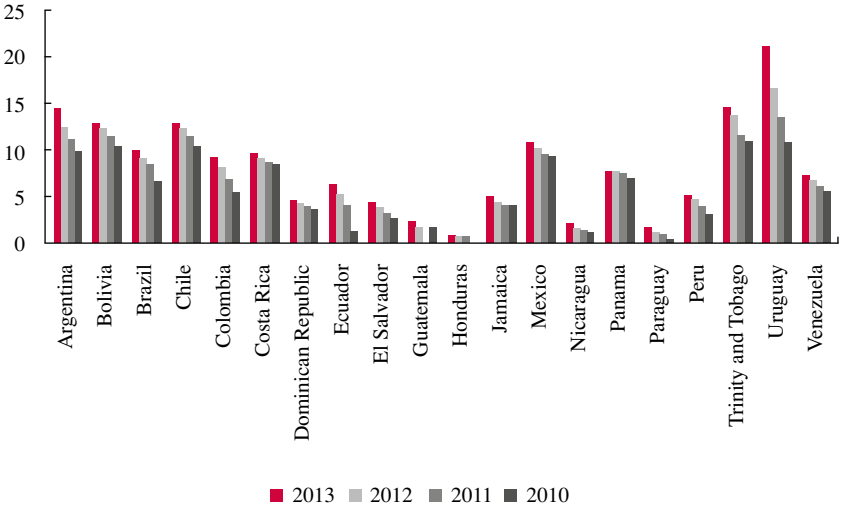
Broadband infrastructure contributes to economic growth since it improves the distribution of ideas and information, increasing both labour productivity and market competition. Besides, it promotes the development of new products and processes, which lead to new, labour practices, and entrepreneurial activities and innovation.

Broadband aids the development of new markets by facilitating innovation in new network-based products and services and the enlargement of the existing market (Czernich, Falck, Kretschmer & Woessmann, 2011). As a result, it is usual to refer to broadband as a General Purpose Technology (GPT) (Majumdar, Carare & Chang, 2009).

However, in many developing countries broadband access is still limited (ITU, 2013). Besides, the percentage of households that can actually access a fixed broadband service, but choose not to, is significant (Katz, 2012). This is an indicator of the broadband demand gap. Countries with the lowest broadband coverage are Bolivia and Perú. Excluding the aforementioned cases, the demand gap varies from 88% (Ecuador) to 38% (Chile); Chile is the best positioned country in terms of broadband penetration. Figure 1 shows the evolution of fixed broadband penetration during the 2010-2013 period for Latin-American countries.

In the year 2010, developing countries had to pay around five times more than developed countries to have access to broadband. Broadband services in Latin America are usually expensive and of low quality when compared to OECD countries. Besides, Latin American countries performed worse than OECD countries in terms of broadband development once wealth, education and demographic factors are controlled (Galperín & Ruzzier, 2010).

Figure 1.
Evolution of fixed broadband penetration



Source: Authors' elaborations based on data from the World Bank.

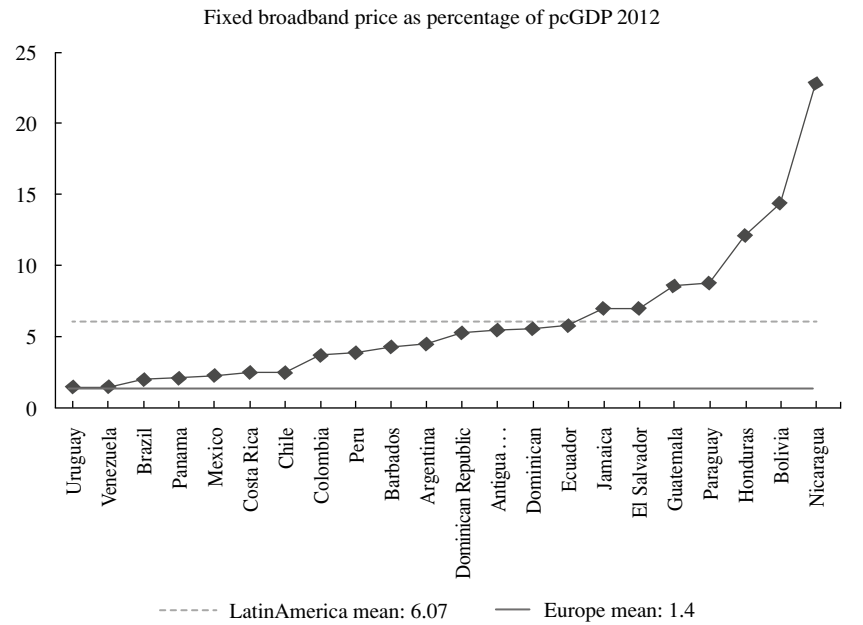
Since there is a strong link between broadband penetration, prices and affordability, the Broadband Commission for Digital Development has defined a specific goal in terms of broadband affordability: "By 2015, broadband basic services should become affordable for developing countries through adequate regulation and market forces (broadband prices should represent less than 5% of monthly incomes)."

In Latin America, based on 2012 data, the cost of a basic fixed broadband subscription varies from a 1.5 per cent of per capita GDP in Uruguay to 386.9 per cent in Cuba. Figure 2 presents the data, excluding Cuba and Haití (with 81.9%), which are outliers.

Residents in Bolivia, Guatemala and Nicaragua must pay on average a higher share of their monthly incomes for access to technology, which leaves an important part of the population outside the information society. This increases the gap across countries.

Recently, the economic sectors have required more broadband services due to cloud services, and the increasing number of devices, machines and personal equipment.Thus, there is a constant need for high speed data transmission. A high speed broadband bandwidth is needed to perform more complex activities through the internet. For instance, electronic commerce requires a broadband of at least 3 Gb to buy and sell products, pay online, and offer post-sale services, etc.

Figure 2.
Broadband affordability



Source: Authors' elaboration based on data from the International Telecommunication Union (ITU) 2013.

These transactional activities are more complex than the mere informational ones, such as searching profiles or product information that do not require high levels of connectivity. Hence, if people are convinced about the benefits of ICT, they need an adequate broadband infrastructure to fully exploit the digital advantages.

In Colombia, broadband diffusion policies search to find solutions to dynamize the broadband market. However, the existence of several market imperfections or failures means that there are problems in solving these inefficiency issues. The regulatory system must guarantee competitive conditions, the protection of users and transparency to properly estimate the temporal horizon of connectivity diffusion (Martínez, 2013). In Latin America and the Caribbean, Internet penetration increased by 142 per cent between 2006 and 2014 going from 20.7 to 50.1 per cent, respectively. However, average Internet penetration is still inferior to the OECD region, which has an 81.1 per cent coverage.

In Latin America and the Caribbean, advancement of the Internet has been very heterogeneous. During the period 2006-2014, the growth experienced in the most laggard countries in the region was not enough to close the gap. There are very different cases in the region that have diverging patterns. On the one side,

Nicaragua has the lowest number of Internet users and was unable to change its position over the period despite having the second largest average growth rate per year. On the other, Chile has the largest number of internet users. The gap between both countries, that had yielded a 31 percentage points difference in 2006, increased to a 56.6 point difference in 2014 (CEPAL, 2015).

Between 2005 and 2010, broadband was able to allow access to a higher speed for data transmission; this lead to the convergence in networks, devices and content. In 2014, there were 3600 million mobile telephone subscriptions, 2923 million internet users (nearly 40.4 per cent of the total population), and more than 3000 million subscriptions to fixed and mobile broadband. In 2013, the region reached a fixed broadband average penetration (number of active subscriptions per 100 inhabitants) of 9%, inferior to the 29% OECD penetration.

THEORETICAL FRAMEWORK

The endogenous growth theory models the creation and distribution of ideas and information as a key factor for economic growth (Aghion & Howitt, 1998; Lucas, 1988; Romer, 1990). In this setting, access to broadband infrastructure can have an impact on the economy's innovative capacities through the development of new products, processes and business models that promote economic growth.

Simultaneously, the lower costs of information diffusion can facilitate the adoption of new technologies that promote economic growth (Benhabib & Spiegel, 2005; Nelson & Phelps, 1966). Hence, the spill-over effects of the codified knowledge among agents represent a channel between the deployment of broadband and economic growth.

From an organizational perspective, ICT and the development of broadband enhances the productivity of firms (Alderete, 2013 Alderete & Gutiérrez, 2012; Gutiérrez, 2011; Jones, Alderete & Motta, 2013) since the performance of any productive activity depends on specific forms of knowledge. However, the presence of complementary inputs such as qualified labour, innovations and organizational changes are critical to ensure that these expected ICT effects actually happen (Arvanitis, 2005; Bloom & Van Reenen, 2007; Bloom, Kretschmer & Van Reenen, 2011; Bresnahan, Brynjolfsson & Hitt, 2002). From a households perspective, the broadband penetration also contributes to economic growth. This technology impacts on several aspects of everyday life. Broadband enhances the heritage of knowledge and information of individuals and society in general. ICTs are an instrument to develop new labour practices, such as telework, new forms of employment search (Stevenson, 2009) and new forms of entrepreneurship (Alderete, 2014; Audretsch, 2007).

There are different perspectives and methodologies to examine ICT's impact on economic growth. First of all, growth accountability, which separately analyses the contribution of each factor (labour and capital) to growth. Secondly,

the evolutionary approach focuses on the evolution of the labour productivity. In spite of their methodological differences, both agree with the positive impact that the ICT paradigm has had on the economic dynamic of Latin America.

The discussion towards ICT impact on economic growth still remains open since there is no consensus as to whether the impact is positive or statistically significant (Campos, 2007). Madden and Savage (1998) found that telecommunication infrastructure investments have had a positive impact on economic growth. The authors argue that although the direction of causality between telecommunication investments and GDP growth is usually in both directions, telecommunication penetration rates (in terms of the service use) more directly precede economic growth than do telecommunication investments. Therefore, the use of telecommunication penetration rates as independent variables may be less problematic than investment measures.

Jorgenson and Khuong (2007) claim that there is a positive effect of ICT on growth. By witnessing the drop of the input costs and the ICT investments, the authors stressed that ICT investments have been the engine of the world's economy since 1995. The accelerated reduction of ICT equipment prices offers a strong incentive to incorporate new technologies and to use them as a substitute of other forms of capital and labour. The ICT capital contribution more than doubled between 1995 and 2000 varying from 0.14 percentage points in 1995 to 0.28 in 2000. After 2000, it stabilized at 0.27 percentage points. Thus, the region has not witness the "Solow Paradox" (Peres & Hilbert, 2009). This phenomenon, known as the Productivity paradox was identified by Solow in 1987 in a New York Times article that stated "you can see the computer era everywhere except for the productivity statistics".

However, many studies have found a positive relationship between the firm's productivity and ICT investments (Alderete & Gutiérrez, 2012; Aral *et al*., 2006; Balboni *et al*., 2011; Brynjolfsson & Hitt, 2003; Brynjolfsson *et al*., 1994; Dedrick, Gurbaxani & Kraemer, 2003; Lichtenberg, 1995). The Latin America problem in this field has more to do with the low level of total investment than it does with the reduced participation of ICT.

Other papers are more sceptical about the causality direction. This doubt has emerged since it is likely that countries with a strong per capita GDP growth would invest more in ICT, and at the same time, countries that heavily invest in ICT would achieve better results in terms of growth.

To address reverse causality, Roller and Waverman (2001) built a multiple structural model for fixed telephony. This model was later modified for fixed broadband (Koutroumpis, 2009) and mobile broadband (Gruber & Koutroumpis, 2011). The model is made up of four equations: a production function that represents an economy's aggregate functioning, and three demand, supply and output functions. These last three functions model the broadband market and control by reverse causality.

Roller and Waverman (2001) argue ICT investment is an important explanatory factor in the long run economic growth of a group of OECD countries. This ICT effect is substantially lower in developing than in developed countries (Sridhar & Shridar, 2004; Waverman, Meschi & Fuss, 2005).

Koutroumpis (2009) analysed 15 countries from the European Union for the 2003-2006 period. The authors found a positive and significant relationship between broadband and economic growth, especially when there is a baseline infrastructure.

Furthermore, Czernich, Falck, Kretschmer and Woessmann (2011) estimated the effect of the broadband infrastructure on economic growth for an OECD panel during the 1996-2007 period. Based on a logistic diffusion model in which the pre-existent TV cable network and voice telephony predict broadband penetration, the authors find that a 10 percentage point increase in broadband penetration increases the yearly per capita growth from 0.9 to 1.5 percentage points.

Greenstein and McDevitt (2009) found very small positive impacts of broadband for the U.S. economy. According to the authors, conventional accounting of the broadband effect mismeasures the true economic impact. Households' broadband use has generated 20 to 22 billion dollars of broadband revenue. However, additional revenue is associated with consumer surplus, which is not measured via GDP.

In Latin America, Katz (2009, 2010) performed the first analysis of the economic impact of broadband. As a result of missing data, the author could not use panel data techniques, but instead relied on ordinary least squares. This was based on a survey of countries for the years 2004 and 2009, separately. Results show that a 1 per cent increase in broadband penetration explains a 0.0158 per cent growth in GDP.

This result is similar to the results found in Koutroumpis (2009), who estimates a simultaneous equation model for the OECD countries. A 1 per cent increase in the broadband penetration (in countries with a penetration that is less than 14%) generates a 0.008% growth in GDP.

In Latin America, the availability of disaggregated data or micro data allowed studies to be undertaken on a national level in Colombia, Panamá and Ecuador. In Colombia, Katz and Callorda (2011) examined the impact of the fixed broadband on the regional GDP, controlling by using the economic development level, the population growth and the human capital. They were able to reach the following conclusion: that a 10% increase in broadband penetration would increase GDP by 0.037%.

Katz and Koutroumpis (2012) employ a multiple structural model for Panamá. The average economic contribution of broadband was estimated to be 0.045% for each 1% increase in penetration. Following the same methodology, Katz and Koutroumpis (2013) estimated the broadband contribution in Ecuador. Results show that a 1% increase in broadband penetration leads to a 0.052% increase in the regional GDP.

METHODOLOGY AND DATA

Since broadband penetration can be endogenous to economic growth, a simultaneous equation model is estimated. The model consists of a set of two or more equations where the number of equations is equal to the number of endogenous variables. These models are useful when interdependence exists between two or more variables (bidirectional relationship) and there is a simultaneous influence between variables and equations. Parameters are estimated based on the information provided by the systems equations.

The model is composed of four equations: a production function, a demand function, a supply function and an output function. These three last functions model the broadband market, taking into account reverse causality.

Following Katz and Callorda (2013), the aggregate production function links the GDP to the fixed capital gross formation excluding telecommunication investment in the private sector,[2] the skilled labour (measured as the percentage of the economically active population with at least secondary education) and the fixed broadband infrastructure that uses penetration as a proxy (number of fixed broadband subscriptions). The production function is represented by a Cobb Douglas function. According to this function, expressed in log terms, the GDP growth depends on the variations of the physical capital, the qualified labour and the fixed broadband infrastructure.

The demand function links the broadband penetration with the price of the basic broadband service, in this case, the cheapest plan for fixed broadband, and the per capita consumption of households. Following Katz and Callorda (2013), the per capita GDP is not considered an adequate indicator of income, especially in Latin-American countries that have inconsistencies with official statistics and high degrees of informality. Hence, per capita consumption is used instead.

The supply function expresses the relationship between the aggregate incomes from broadband sales, the households' consumption level and the urbanization rate of a given country.[3] Since fixed broadband deployment is correlated with urban concentration, the broadband supply must show this structural tendency (Katz & Callorda, 2013).

The output equation links the yearly change in the fixed broadband penetration with the incomes from broadband sales; that change is used as an indicator of the yearly investment in broadband capital.

[2] To distinguish between the physical capital and the ICT capital, the authors subtract the private sector's telecommunication investment from the gross capital formation, using the World Bank data.

[3] The dependent variable is the income coming from the broadband sales (broadband subscriptions or penetration). Unfortunately, there is no information available in the region about the fixed broadband infrastructure investment. Hence, income is calculated as the product between the price and the number of subscriptions.

As Roller and Waverman (2001) and Koutroumpis (2009) describe, this equation assumes a stable and constant relationship between sales and investment, which may not hold. It would be better to have data on fixed broadband infrastructure investment; however, it is not available yet.

Functions:

1) ln PBI = $\alpha 0 + \alpha 1$ ln non-ICT physical capital pc + $\alpha 2$ ln qualified labour + $\alpha 3$ broadband + $\varepsilon 1$
2) ln Broadband = $\beta 0 + \beta 1$ ln consumption pc + $\beta 2$ ln broadband price + $\varepsilon 2$
3) ln Broadband income = $\delta 1$ ln consumption pc + $\delta 2$ ln urbanization + $\varepsilon 3$
4) ln Broadband penetration = $\gamma 1$ ln broadband incomes + $\varepsilon 4$

Table 1.
Description of the variables

Variables	Abbreviation (in ln)	Description	Source
GDP	lgdp	Domestic Gross Product expressed in constant 2005 prices	World Bank
Physical capital	lcapital	Capital gross formation	World Bank
	lnonictcapital	Capital gross formation excluding telecommunication investments from the private sector	World Bank
Qualified Labour	labour	Economically active population with secondary education	World Bank
Broadband	lfbb	Percentage of Fixed broadband subscriptions	World Bank
	lfixedbb	Number of fixed broadband subscriptions	World Bank
Consumption	lcomsumption	Households final Consumption expenditures per capita in constant 2005 prices	World Bank
Broadband price	lpricebb	Cheapest fixed broadband price (in US dollars)	DIRSI
Urbanization	lurban	Urban Population	World Bank

Source: The author.

The model is estimated for a set of Latin American countries: Argentina, Bolivia, Brazil, Chile, Colombia, Costa Rica, Dominican Republic, Ecuador, El Salvador, Guatemala, Honduras, Jamaica, Mexico, Nicaragua, Panamá, Paraguay, Peru, Trinity and Tobago, Uruguay, and Venezuela. Data corresponds to the 2010-2014 period because broadband prices have been published by DIRSI since 2010. The rest of the variables included are provided by the World Bank.

Descriptive statistics correspond to the variables in logarithmic terms and are shown in the Table 2.

Table 2.
Descriptive statistics

Variable	Name	Obs.	Mean	Std. Dev.	Min.	Max.
GDP	lgdp	93	25.60557	1.386531	23.83782	28.76686
Labour	llabour	27	3.530878	0.3674261	2.351375	4.043051
Physical capital	lnonictcapital	62	23.48191	1.557456	21.41839	26.29061
	lcapital	84	24.11335	1.457348	22.22261	27.1823
Fixed Broadband	lfixedbb	99	13.20836	1.810425	6.907755	16.82074
	lfbb	99	1.608372	1.088349	-4.333519	3.050769
Consumption	lconsumption	85	25.23809	1.309466	23.51043	28.17008
Fixed Broadband price	lpricebb	99	2.865452	0.4097323	1.565946	3.855486
Urbanization	lurban	100	4.152862	0.4929733	2.145931	4.555476

Source: The author.

Figure 3 examines the correlation between the percentage of fixed broadband subscriptions and per capita GDP in the year 2013. A clear pattern can be seen in the Latin American countries where countries with low rates of fixed broadband penetration exhibit low levels of GDP per capita. This description pretends to enrich the causal analysis between broadband penetration and economic growth.

RESULTS

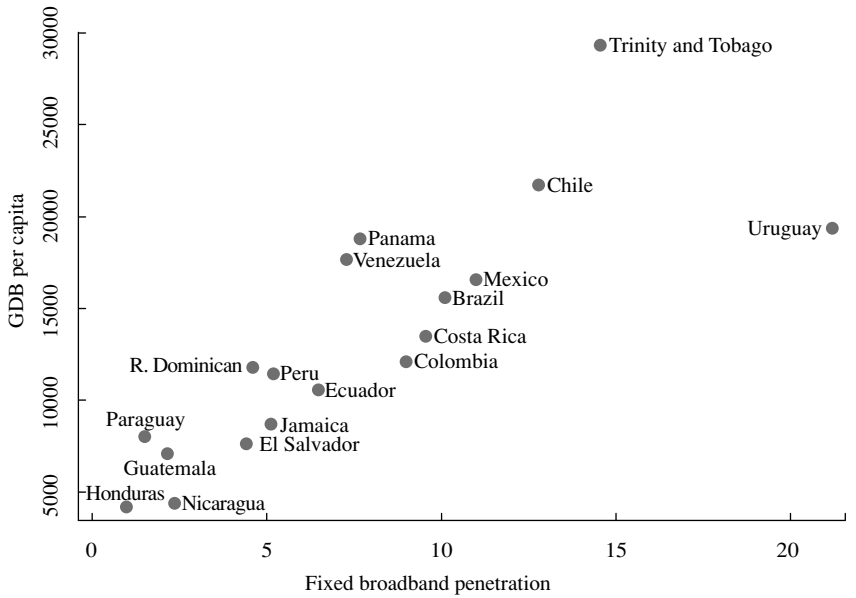
Firstly, Model 1 is estimated including the four equations from Koutroumpis' (2009) simultaneous equation model (Table 3). The diagnostics show that for three of the four functions there is an adequate goodness of fit (R2 reaches values of around 0.90). However, the R2 from the supply function can be seen to be unsatisfactory. One possible explanation of this poor goodness of fit is that the dependent variable was built as a combination of other variables included in the system; hence, it could be redundant. Therefore, Model 2 estimates the system excluding this function.

Table 3.
Estimated model results

Functions		Independent Variables		Model 1	Model 2	Model 3
				Coefficient	Coefficient	Coefficient
GDP Growth	lgdp	Labour	llabour	-0.24741***	-0.24758***	-0.17929***
		Fixed capital	lcapital	0.974860***	0.95501***	
			lnonictcapital			0.691011***
		Broadband penetration	lfbb	0.0876792*	0.11312**	
			lfixedbb			0.184318**
Demand	lfbb	Broadband price	lpricebb	-0.2906013 *	-0.15852	-0.197308**
		Households consumption	lconsumption	1.521527***	1.535461***	1.30209***
Supply	linco-mebb	Households consumption	lconsumption	1.464077		1.373544***
		Urbanization	lurban	1.936103		0.334192
Output	lvar-fbb	Broadband incomes	lincomebb	0.07678	0.0545172	
		Laggard roadband	lfbblag	-0.607361***	-0.594540***	
	lfbb	Broadband incomes	lincomebb			0.912542***
Year effects				yes	yes	yes
Observations per function[a]				13	13	20
R^2		GDP growth		0.9879	0.9874	0.9754
		Demand		0.8757	0.8784	0.8349
		Supply		0.3436		0.8159
		Output		0.9004	0.9001	0.92

*, ** and *** significant variables at 10, 5 and 1% respectively.
[a] The sample has missing data for the following countries and variables: GDP for Argentina (over the 2010-2014 period), Trinidad & Tobago and Jamaica (in 2014); labour for Bolivia and Brazil (over the 2010-2014 period) and for the rest of the countries in at least one year. The 3SLS method uses the cases for which there are no missing data for any variable in the system.
Source: The author.

Figure 3.
GDP per capita vis a vis fixed broadband penetration



Source: The author.

According to model 1, a one-percentage point increase in fixed broadband penetration generates a GDP growth increase of 0.087 percentage points. This result is significant at a 10% level, and is similar to previous studies that have been conducted in the region (Katz, 2012; Katz & Callorda, 2013).

Estimated parameters from the aggregate production function show that production factors have a significant and positive effect on economic growth: except from qualified labour, which has a negative sign. This unexpected sign could be the result of missing data for the economically active population that have secondary education in the region.[4]

With respect to the demand equation, as the theory predicts, an increase in broadband prices reduces the quantity demanded. For a one per cent increase in the price, the quantity of broadband subscriptions decreases by 0.29%. This result is significant at a 10% level. Moreover, the per capita consumption that is used as a proxy variable of the available income has a significant and positive incidence on broadband demand. For a one per cent income increase, the demand increases by 1.5%. Hence, broadband demand is more elastic in terms of income than it is to price.

[4] In order to examine whether it is a missing data problem, an alternative model was estimated using expenditures on research and development instead of EAP with secondary education. In this case, the variable was insignificant in explaining economic growth.

According to the broadband penetration equation, income from broadband sales is not significant. Besides, to estimate the broadband penetration function, a lagged term for broadband was included: that is, broadband from the previous year (broadband in $t-1$), which is significant as it captures the broadband penetration rate.

Based on model 2, broadband has a statistically significant impact on economic growth. A one per cent increase in broadband penetration generates an increase in the output growth of 0.11%, which is significant at a 10% level. Similar to model 1, labour results in a negative effect. However, the broadband price is not a significant variable in the demand function while income significantly and positively affects broadband demand. With respect to the output and the broadband penetration functions, the results are similar to those shown in model 1.

Lastly, model 3 is estimated including a pair of modifications. Firstly, the production function uses non-ICT capital instead of total capital. To distinguish physical capital from ICT capital, investments in telecommunications from the private sector were excluded from the gross capital formation. This variable is only a proxy (there is no information about broadband infrastructure investment) since telecommunication is a wider concept than broadband as it includes other technologies. Besides, the variable only refers to private sector investments while, in many countries in the region, broadband infrastructure is also the result of public investments.

Secondly, the fourth equation is estimated following Katz and Callorda (2013), using broadband penetration instead of broadband variation or the penetration rate. Results show that broadband significantly explains the output growth more effectively than in the first models. A one per cent increase in broadband increases GDP growth by 0.18%.

FINAL REMARKS

This study has analysed the fixed broadband effect on Latin America's economic growth. The main contribution of this paper was to extend the results already obtained in previous studies.

The broadband penetration impact on regional economic growth has been studied by Katz (2009, 2010). At the date of publication, the available data on the subject hindered the development of econometric models to control for endogeneity. The author found that a one per cent increase in broadband penetration increases GDP growth by 0.0158%. Subsequent studies using regional microdata confirm that the average broadband effect is about 0.04% for each percentage point increase in GDP growth.

Using a more robust control for endogeneity in order to validate the broadband impact on the Latin-American economic growth, this paper estimates simultaneous equations model following Koutroumpis' (2009) methodology for OECD countries. Additionally, the model uses Katz and Callorda (2013) as a reference. Results obtained in model 1 indicate that a one percentage point increase in fixed

broadband penetration generates an output increase of 0.087 percentage points. This result is similar to the results from previous studies in the region (Katz, 2009, 2012; Katz & Callorda, 2013).

Moreover, two alternative models that enhance the significance and contribution of fixed broadband to economic growth are also estimated. According to these models, on average, a one per cent increase in broadband increases economic growth by 0.14 percentage points.

In terms of policy, the significant and negative impact of broadband prices on the demand function stresses the need to promote more competition in the broadband sector in order to lower prices. Results suggest that broadband demand is not very elastic with respect to price. This information can help operators examine their policies to increase broadband incomes.

Fixed broadband contributes to economic growth in the Latin American region. This finding supports the broadband plans that are already in place. If broadband penetration does indeed have a significant impact on economic growth, it would be useful to promote policies that increase the broadband penetration in the region. Even though fixed broadband is an important part of the information society, its promotion must be accompanied by complementary resources such as digital skills, digital alphabetization, and inter-platform compatibility, etc. If fixed broadband is not part of a complementary set of resources (tangible and intangible) that enhance and promote its adoption and use, economic growth will not achieve its potential level. As a result, the fixed broadband contribution to economic growth, although significant, will remain limited.

Nowadays, mobile broadband is becoming one of the main ways that broadband internet is accessed. In terms of future research, it would be interesting to analyse mobile broadband penetration as a complement to fixed broadband.

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