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Socio-economic impact of broadband in LAC countries

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Content

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1 Abstract

This paper summarizes first the current situation in terms of broadband in the Latin American and Caribbean (LAC) Region, showing the differences among countries, the existing low broadband penetration and high prices, and the fulgurant deployment of mobile technology in the last decade.

Secondly, the paper analyzes the existing literature that evidences how broadband plays a key role in society, impacting GDP, Productivity and Employment and in fact, how one major goal to be achieved by Governments is that broadband becomes universal not only in terms of access, which is a connectivity issue, but also in terms of usage.

In the third place and more importantly, the paper provides two major contributions to the existing literature: the first contribution revolves around the conception of an econometric model, specific for the LAC countries, which forecasts that, on average, an increase of 10% in the number of broadband subscriptions has associated increases of 3.19% in GDP and 2.61% in Productivity, and 67,016 new jobs created. Complementary to this, the model proves that the network economies effect is also a reality for broadband, or to put it another way, the greater the broadband penetration rate, the greater the multiplicative effect of an additional increase of broadband penetration on GDP, Productivity and Employment. The second contribution consists of the definition of a genuine model that helps governments to determine the levers they have available to shape the broadband status of their respective countries.

2 Introduction

2.1 Broadband status in the Region

As shown in Figure 1, fixed and mobile broadband penetration for LAC countries is considerably low in comparison with other regions of the world such as the OCDE **[1]**.

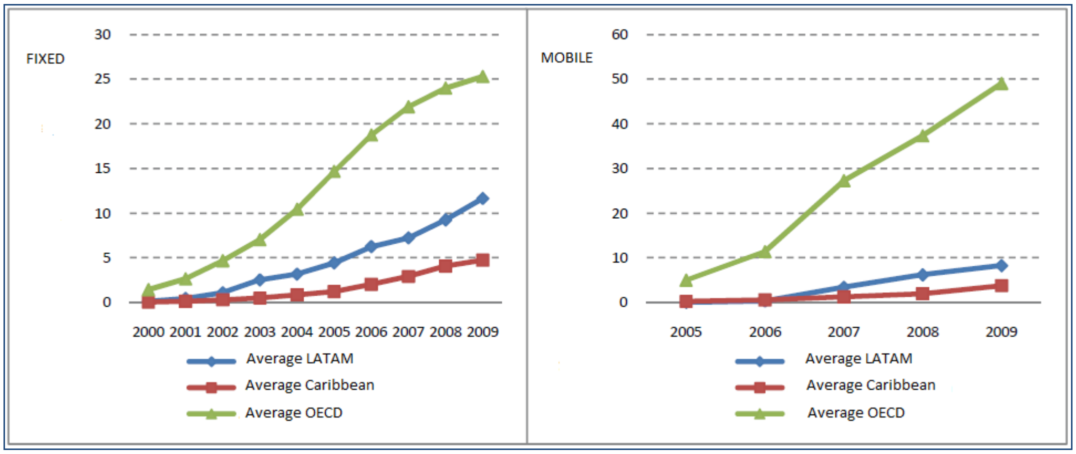

Figure 1.- Fixed and mobile broadband penetration worldwide
Source: ITU (2011)

Apart from being low, as shown in Figure 2, broadband penetration in LAC countries is quite unequal. The main reasons for this inequality are the different socio-economic conditions of the LAC countries, the special orographic conditions of the Region and the high investments that the deployment of infrastructure requires **[2]**. However, and despite the moderate broadband penetration in LAC countries, mobile broadband has evolved at a very quick pace in the last years (see Figure 1).

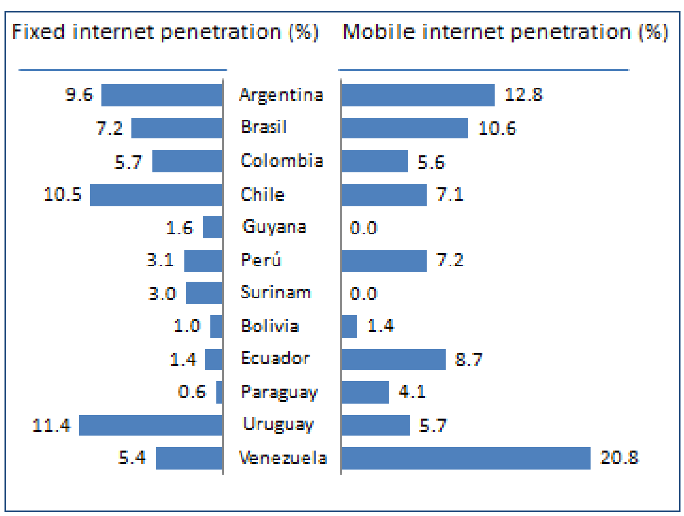

Figure 2.- Broadband penetration in LAC countries
Source: ITU (2011)

Indeed, the Internet penetration in LAC countries is towards mobile and, if the mobile internet penetration maintains its growth pace of the last years, the number of mobile subscriptions is expected to double the number of fixed subscriptions by 2012-2013 **[1] [2]**.

Additionally, as shown in Figure 3, in comparison with other regions such as OECD, the Region not only presents a quite moderate quality in terms of connection speed but it has also considerably higher broadband prices **[1]**. These factors make very difficult to reduce the existing technological gap.

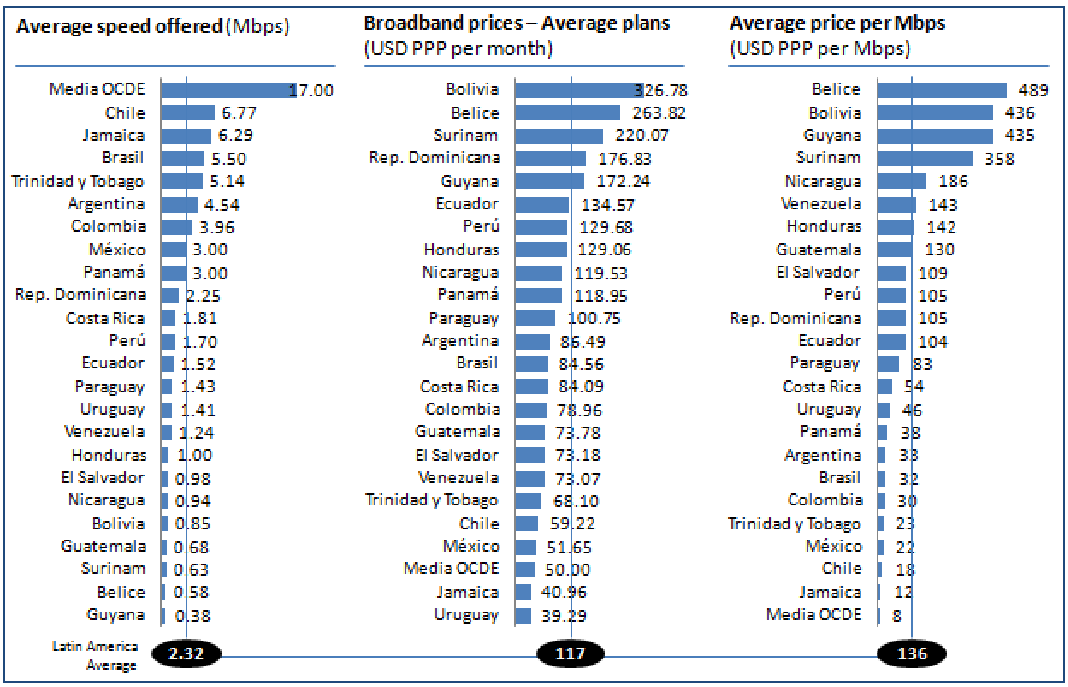

Figure 3.- Broadband quality and prices, LAC and OECD countries
Source: ITU (2011)

2.2 Existing literature

The impact of telecommunications and more specifically of internet and broadband on the socio-economic development of countries has already been proven by numerous studies. In year 2009, for instance, Koutrompis, based on an analysis over 22 OECD countries, established that a 1% increase in the number of broadband subscriptions implied a 0.025% economic growth **[3]**. In a similar way, Czernich, also in 2009 over a sample of OECD countries, pointed out that a 10% increase in the broadband penetration implied between 0.9% and 1.5% increase on GDP **[4]**. Raúl Katz, in the same year, in reference to the Latin-American region, affirmed that the deployment of broadband infrastructure had important direct and indirect effects on Employment and Productivity **[5]**. Finally, Zhen-Wei Quiang and Rosotto, also in 2009, published a World Bank report, which maintained that a 10% broadband increase implied, for some developing countries, an additional 1.3% increase in GDP **[6]**.

The aforementioned studies are all of great value to understand the relevance of broadband for the socioeconomic wealth of a country; however, as Charles Kenney **[7]** highlights, we find that somehow they attempt to simplify the underlying models that represent the relation among broadband penetration and GDP, Productivity and Employment, relying on linear regressions and on data and regression coefficients that are not entirely specific for LAC countries as well as using regressions that are not subject to robustness tests.

For these reasons, distinctively from these valuable reports, we focus specifically on LAC countries, for which we count on customized data from years 2003-2009, using a non-linear approach, testing the assumptions and providing a genuine model in the literature to determine the explanatory variables that help explain the broadband status of a country.

3 Contributions

This paper presents two major contributions. Basically, the first contribution revolves around the conception of an econometric model which determines, specifically for the LAC countries, what is the impact that an increase in the number of broadband subscriptions has on GDP, Productivity and Employment for these countries; concretely, an increase of 10% in the number of broadband subscriptions per capita, on average, has associated increases of 3.19% in GDP and 2.61% in Productivity, and a generation of 67,016 new jobs. As a follow-up to this fact, the model evidences that network economies are in force for broadband and therefore, the greater the broadband penetration of a country, the greater the effect of an additional increase of broadband penetration on GDP, Productivity and Employment. Finally, the second contribution centers upon the definition of the specific variables that a government may control to help increase the number of broadband subscriptions per capita more effectively and therefore, improve the socio-economic conditions of the country it represents.

The rationale that moves us to study the impact on GDP, Productivity and Employment is the macroeconomic and social relevance of these variables for a given country and their measurability. GDP is the monetary value of the final goods and services produced by an economy or put it another way, the representation of the economic activity and prominence of a country. Productivity relates the amount of goods and services produced with the resources utilized to produce them and consequently, it is strongly affected by technology and innovation, among other factors. Finally, Employment measures the percentage of working population that is in fact working. As a matter of interest, all these variables are interrelated, and the Employment level is determined as the ratio between GDP and Productivity.

In the following, we will explore the analytical impact of broadband on GDP, Productivity and Employment. To proceed, we will develop a non-linear multivariate least-squared regression model for each macroeconomic variable and prove the significance and validity of every model for explanatory and forecasting purposes.

To do so, for each model, we will use the following steps: 1.- we will select the most significant variables[1] that explain each macroeconomic variable; 2.- we will show, through the p-values and T_{obs} statistics, that all the explanatory variables are significant and that the model is significant as a whole; 3.- we will show the goodness[2] of the model (R^2 and F_{obs} statistics) or in other words, how much of the fluctuations of the independent variable are explained by the variations of the explanatory variables; 4.- we will show the forecasting validity (coefficient of variation statistic[3]); 5.- we will get rid of heteroscedasticity by performing a left hand side algebraic stabilizing transformation (and proving then homoscedasticity by observing the random pattern of the residuals); 6.- we will show that the model does not present

[1] We will define that a model is significant when p-values of all explanatory variables and of the whole model is less than 0.05 (95% significance).

[2] We will disregard any regression model with an explanatory power (R^2) less than 80%.

[3] We will define that a model is valid for forecasting purposes when its coefficient of variation is less than 25%.

autocorrelation (Durbin-Watson statistic[4]) nor multicolinearity (low variance inflation factors[5], expected signs in the regression coefficients and not strong correlations between the explanatory variables[6]) and finally 7.- we will show that residuals are normally distributed and do not follow any pattern (Anderson-Darling statistic[7]).

Once all the previous steps are satisfied, we will use the resulting non-linear model (valuable for explanatory and forecasting purposes) for each macroeconomic variable to effectively determine the impact of an increase in broadband penetration on GDP, Productivity and Employment for LAC countries.

3.1 Impact of broadband on GDP, Productivity and Employment

3.1.1 Impact of broadband on GDP

According to economic theory, GDP= C+ I+ G+ (X-M), where C represents private consumption, I gross investment, G public spending, X exports and M imports. Additionally, GDP can be also expressed as GDP= f(A, L, K)= f(A, L, K_{BA}, K'), where A represents technology, L labor, K_{BA} capital associated with broadband (networks and connected devices), and K' any other capital. In a non-linear approach, GDP= f(A, A^2, L, L^2, K_{BA}, K_{BA}^2, K', K'^2), and $\Delta GDP/\Delta K_{BA} = \alpha_0' + \alpha_1' \cdot K_{BA} + f(A,K',L)$[8]. In other words, theoretically, firstly, variables that explain consumption, investment, public spending or trade surplus/deficit, such as those associated with capital markets, lead also to explain variations in GDP; secondly, the greater the broadband capital of a country, the greater the effect of an additional increase in the broadband capital on its GDP.

Empirically, to determine the impact of broadband on GDP, we formulate a non-linear multivariate regression model where, as illustrated in Figure 4, the dependent variable is the GDP per capita (Y1) and there are five independent explanatory variables, including the number of fixed broadband subscriptions per 100 inhabitants (Y)[9].

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[4] We will consider that the model does not present autocorrelation if the Durbin-Watson statistic is between 1.5 and 2.5.

[5] We will consider low variance inflation factors when VIF<7 (with the exception of squared variables).

[6] We will consider strong correlations when any correlation coefficient, in absolute value, is greater than 0.75.

[7] We will consider that residuals are normally distributed when the p-value of the A-D statistic is greater than 0.05.

[8] $GDP= f(A, A^2, L, L^2, K_{BA}, K_{BA}^2, K', K'^2)= \alpha_0 + \alpha_1 \cdot A + \alpha_2 \cdot A^2 + \alpha_3 \cdot L + \alpha_4 \cdot L^2 + \alpha_5 \cdot K_{BA} + \alpha_6 \cdot K_{BA}^2 + \alpha_7 \cdot K' + \alpha_8 \cdot K'^2 + \alpha_9 \cdot A \cdot L \cdot K_{BA} \cdot K' + \alpha_{10} \cdot A \cdot L \cdot K_{BA} + \alpha_{11} \cdot A \cdot L + \alpha_{12} \cdot A \cdot L \cdot K' + \alpha_{13} \cdot L \cdot K_{BA} \cdot K' + \alpha_{14} \cdot L \cdot K_{BA} + \alpha_{15} \cdot L \cdot K' + \alpha_{16} \cdot K_{BA} \cdot K'$ [all variables in logs]

$\Delta GDP/\Delta K_{BA}= \alpha_5 + 2 \cdot \alpha_6 \cdot K_{BA} + \alpha_9 \cdot A \cdot L \cdot K' + \alpha_{10} \cdot A \cdot L + \alpha_{13} \cdot L \cdot K' + \alpha_{14} \cdot A \cdot L + \alpha_{16} \cdot K'= \alpha_0' + \alpha_1' \cdot K_{BA} + f(A, K', L)$

[9] We concentrate on the number of fixed broadband subscriptions per 100 inhabitants since for mobile broadband subscriptions, there is no data available from 2003-2009 (mobile booming has been relatively recent).

The formulation of a non-linear model instead of a linear one is key and a salient point of differentiation with current models. The reason for this choice is that the relation between the explanatory variables and the dependent variable is non-linear, as we verified first formulating a linear model for GDP[10] whose explanatory power (R^2) was considerably more limited than that of its equivalent non-linear model, and second, verifying that scatter plots of the residuals versus some of the independent variables presented a quadratic form.

To proceed with the model development, we count on data relied by the World Bank and the ITU. Specifically, our regression variables' samples come from the WB Development Indicators and ITU World ICT Indicators databases. As we have previously mentioned, to finally select the ultimate five key explanatory variables, we followed an extensive procedure in which we proved up to 87 different variables associated with consumption, investment, public spending and trade.

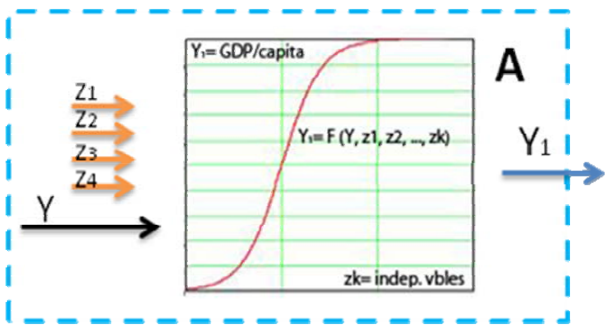


Figure 4.- Regression model vignette

As we can see in Figure 5, the independent variables are: the interest rate spread (Z1), the interest on new debt (Z2), the multilateral debt (Z3), the net official development aid (Z4), the fixed broadband penetration per 100 inhabitants (Y) and the fixed broadband penetration per 100 inhabitants squared (Y-sq.), all of which are significant, as we can notice regarding its p-values (see Figure 5 for independent variables and Figure 6 for the model as a whole). All these Z variables have a direct effect on the investment and public spending of any given country, although some of them, such as Z3 or Z4, apply in a greater way to poorer countries.

We study fixed broadband penetration instead of other variables such as mobile broadband penetration, broadband speed or broadband coverage, due to a lack of data available for LAC countries in the period under consideration.

Non-Linear Multivariate Regression Equation

Y1^0.6 = 193 - 0.891 Z1 + 4.32 Z2 - 1.06 Z3 - 573 Z4 + 20.8 Y - 0.872 Y-sq.

Predictor	*Coef*	*SE Coef*	*T*	*P*	*VIF*
Constant	193.48	11.59	16.69	0.000	
Z1-Interest Rate Spread	-0.8912	0.2586	-3.45	0.001	1.090
Z2-Interest on New Debt	4.322	1.323	3.27	0.001	1.910
Z3-Multilateral Debt	-1.0574	0.2087	-5.07	0.000	3.691
Z4-Net ODA/GDP PPP	-572.7	141.9	-4.04	0.000	2.531
Y-Broadband Penetration/100inh	20.817	2.999	6.94	0.000	12.936
Y-squared	-0.8718	0.3200	-2.72	0.007	10.534

Figure 5.- Model equation, P-values and T_{obs} and VIF statistics

10 We performed the same analysis for Productivity and Employment with exactly the same findings.

To establish the sense of causality, we worked with the variables lagged one period and we attained very similar results. Indeed, since broadband deployment is a progressive process and requires large fixed investments, broadband penetration rate is very similar from one year to the following one. With this lagged model, we verified that as expected, causality applies in both directions and not only do increases of broadband penetration imply increases in GDP but also increases in GDP imply increases in broadband penetration. The same findings apply for Productivity and Employment.

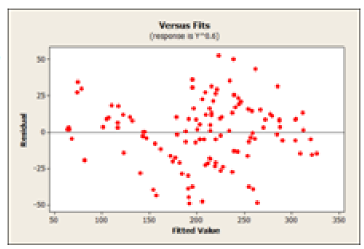
As shown in Figure 6, the regression model is not only robust for explanatory purposes, with the independent variables explaining 89.8% of the fluctuations in the GDP/capita and a F_{obs} of 166.84, but it is also valid for forecasting purposes, with a coefficient of variation of 9.1783%. Apart from that, as we can see with the Arlinson-Darling statistic, residuals are normally distributed and the model, which is based on 121 samples from years 2003-2009, does not present heteroscedasticity (random residuals plot), multicolinearity (expected signs[11] in regression's coefficients, reduced VIFs and uncorrelated independent variables) nor autocorrelation (Durbin-Watson statistic).

R-Sq = 89.8%   C.V.= 9.1783%   S = 21.9655   R-Sq(adj) = 89.2%
PRESS = 60561.3   R-Sq(pred) = 88.74%

ANOVA

Source	*DF*	*SS*	*MS*	*F*	*P*
Regression	6	482976	80496	166.84	0.000
Residual Error	114	55003	482		
Total	120	537979			

Source	*DF*	*Seq SS*
Z1-Interest Rate Spread	1	30789
Z2-Interest on New Debt	1	146565
Z3-Multilateral Debt	1	214886
Y-Broadband Penetration/100inh	1	79153
Y-sq.	1	3719
Z4-Net ODA/GDP PPP	1	7862



Durbin-Watson statistic = 2.41340
Arlinson-Darling Normality Test P-value= 0.201

Figure 6.- ANOVA table, R^2, C.V., Durbin-Watson, and A-D statistics

Finally, as we can see in Figure 7, independent variables are not strongly correlated to each other and therefore, they provide an accurate explanation of the fluctuations of the dependent variable.

[11] The positive sign associated with the interest on new debt (Figure 5) seems counterintuitive, since it implies that the higher is the interest rate, the greater is the GDP for a given country. However, this finding is not caused by multicolinearity problems in the regression model and indeed, it is sustained by the original World Bank data, which shows a positive correlation between interest rate on new debt and GDP. Interest on New Debt is measured by the World Bank as the average interest rate on all new public and publicly guaranteed loans contracted during the year and to obtain the average, the World Bank weights the interest rates for all public and publicly guaranteed loans by the amounts of the loans. The explanation of the positive correlation could reside in that countries with greater investments and public spending (higher GDP) borrow greater amounts and this in turn, imply greater interest rates on new debt.

Correlation Matrix				
	Z1	Z2	Z3	Y
Z2	-0.026			
Z3	0.179	-0.600		
Y	-0.218	0.113	-0.554	
Z4	0.069	-0.608	0.730	-0.314

Figure 7.- Correlation matrix of explanatory variables

Once we have the regression model, ceteris paribus, we use it to estimate the impact in GDP associated with a 10% increase in the number of broadband subscriptions in three different periods of time for LAC countries (see Figure 8): in 2005, the model proclaims a 1.34% increase in GDP; in 2007, a 2.29%; and in 2009, a 3.19%. These findings corroborate that the greater the number of broadband subscriptions per capita a country has over time, the greater impact that an additional increase in the number of broadband subscriptions will have on the GDP of the country.

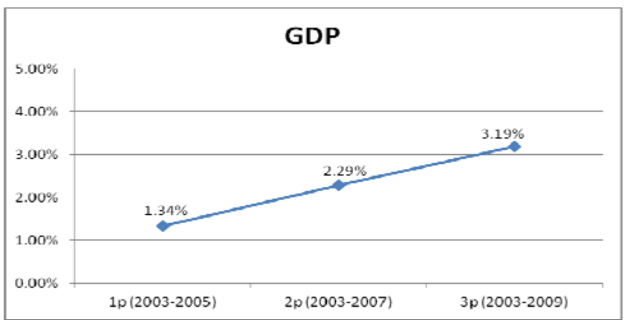


Figure 8.- Impact on GDP over time of a 10% increase in Broadband penetration

Although there is not enough data available for LAC countries to analyze the effect of broadband speed on GDP, existing literature points out that the higher the broadband speed, the higher its effect on GDP –a report by Ericsson, Arthur D. Little and Chalmers University of Technology in 33 OECD countries quantifies the isolated effect of broadband speed, showing that doubling the broadband speed for an economy increases GDP by 0.3% (Sept. 2011).

3.1.2 Impact of broadband on Productivity

According to economic theory, Productivity (P) measures the efficiency of a country in production terms: P= Y/L= f(A, L, K)= f(A, L, K_{BA}, K'), where A represents technology, L labor, K_{BA} capital associated with broadband, and K' any other capital. In a non-linear approach, Y/L= f(A, A^2, L, L^2, K_{BA}, K_{BA}^2, K', K'^2), and $\Delta(Y/L)/\Delta(K_{BA}/L)= \alpha_0' + \alpha_1' \cdot K_{BA}/L + f(A,K',L)$. Similarly to what happened with GDP, the greater the broadband capital per person of a country, the greater the effect of an additional increase in the broadband capital per person on its Productivity level.

Empirically, to determine the impact of broadband on Productivity, we formulate a non-linear multivariate regression model where, as illustrated in Figure 9, the dependent variable is the

Productivity level[12] (Y2) and there are six independent explanatory variables, including the number of fixed broadband subscriptions per 100 inhabitants (Y).

To proceed with the model development, we count on data relied by the World Bank, the ILO and the ITU. Specifically, our regression variables' samples come from the WB Development Indicators, ILO and ITU World ICT Indicators databases. As we have previously mentioned, to finally select the ultimate six key explanatory variables, we followed an extensive procedure in which we proved up to 92 different variables associated with production inputs.

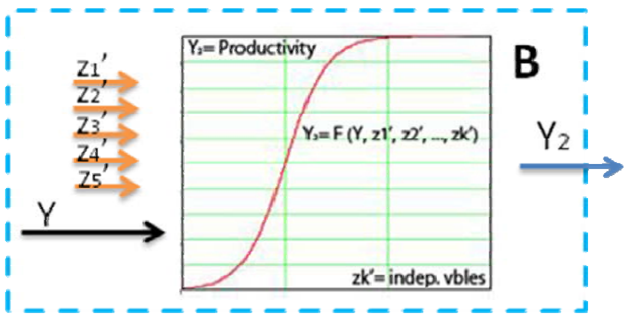


Figure 9.- Regression model vignette

As we can see in Figure 10, the independent variables are: the Gini coefficient (Z1'), the ILO 131 minimum wage fixing convention (Z2'), the percentage of urban population (Z3'), the percentage of primary school enrollment (Z4'), the percentage of primary school completed for students with 15 years or more (Z5'), and the fixed broadband penetration per 100 inhabitants (Y), all of which are significant, based on the calculated p-values (see Figure 10 for independent variables and Figure 11 for the model as a whole). While Z1' and Z3' are associated with the geographic distribution of production inputs, Z2', Z4' and Z5' are associated with the quality of the labor force, which is influenced by the regulatory environment, the salary conditions and the education received, among other factors.

Non-Linear Multivariate Regression Equation

Y_2^0.5 = 236 - 1.31 Z_1' - 11.3 Z_2' + 0.422 Z_3' - 0.758 Z_4' + 0.883 Z_5' + 3.93 Y_2

Predictor	Coef	SE Coef	T	P	VIF
Constant	236.12	20.78	11.36	0.000	
Z_1'-Gini	-1.3075	0.4017	-3.25	0.002	2.343
Z_2'-ILO 131	-11.260	3.019	-3.73	0.001	1.268
Z_3'-Pop urban (%)	0.4216	0.1869	2.26	0.029	1.299
Z_4'-1ary school enrolment(%)	-0.7581	0.2504	-3.03	0.004	2.254
Z_5'-Age15+Primary compl. (%)	0.8833	0.1643	5.38	0.000	1.236
Y_2-Broadband Pen./100 inh.	3.9286	0.8049	4.88	0.000	1.132

Figure 10.- Model equation, P-values and T_{obs} and VIF statistics

As shown in Figure 11, the regression model is not only robust for explanatory purposes, with the independent variables explaining 82.8% of the fluctuations in the Productivity level and

[12] The Productivity level is measured as the GDP generated per each person employed (in constant 1990 PPP USD).

a F_{obs} of 33.12, but it is also valid for forecasting purposes, with a coefficient of variation of 6.8023%. Apart from that, as we can see with the Arlinson-Darling statistic, residuals are normally distributed and the model, which is based on 50 samples from years 2003-2008, does not present heteroscedasticity (random residuals plot), multicolinearity (expected signs in regression's coefficients[13], reduced VIFs and uncorrelated independent variables) nor autocorrelation (Durbin-Watson statistic).

```
R-Sq = 82.2%    C.V.= 6.8023%    S = 9.41138    R-Sq(adj) = 79.7%
PRESS = 6031.68   R-Sq(pred) = 71.83%

ANOVA
Source          DF        SS       MS      F      P
Regression       6   17603.0   2933.8  33.12  0.000
Residual Error  43    3808.7     88.6
Total           49   21411.7

Source                               DF  Seq SS
Y-Broadband Penetration/100 inh.      1  3651.0
Z1'-Gini                              1  8232.1
Z2'-ILO 131                           1  1892.6
Z3'-Pop urban (%)                     1   924.2
Z4'-1ary school enrolment(%)          1   341.6
Z5'-Age15+Primary completed (%)       1  2561.6

Durbin-Watson statistic = 1.78832
Arlinson-Darling Normality Test P-value = 0.08
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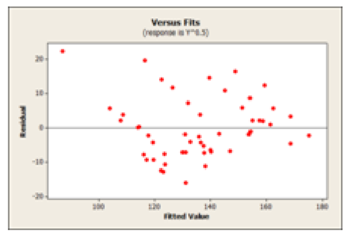

Figure 11.- ANOVA table, R^2, C.V., Durbin-Watson, and A-D statistics

Finally, as we can see in Figure 12, independent variables are not strongly correlated to each other and therefore, they provide an accurate explanation of the fluctuations of the dependent variable.

Correlation Matrix

	Y	Z1'	Z2'	Z3'	Z4'
Z1'	-0.120				
Z2'	-0.147	-0.117			
Z3'	0.393	-0.184	-0.047		
Z4'	-0.169	0.627	0.311	-0.056	
Z5'	-0.197	-0.195	0.073	0.117	0.366

Figure 12.- Correlation matrix of explanatory variables

Once we have the regression model, ceteris paribus, we use it to estimate the impact in Productivity associated with a 10% increase in the number of broadband subscriptions in three different periods of time for LAC countries (see Figure 13): in 2004, the model proclaims a 0.49% increase in Productivity; in 2006, a 1.16%; and in 2008, a 2.61%. These findings corroborate again that the greater the number of broadband subscriptions per capita a country has over time, the greater that an additional increase in the number of broadband subscriptions

[13] The negative sign associated with the percentage of children that enrolls in primary education (Figure 10) seems counterintuitive, since it implies that the greater is the percentage of primary school enrolment, the lower is the Productivity for a given country. However, this finding is not caused by multicolinearity problems in the regression model and indeed, it is sustained by the original World Bank data, which shows a negative correlation between primary school enrolment and Productivity. The explanation could reside in that less developed/productive countries tempt to have younger population pyramids and also in that more students per class could lead to a worse education and this, in turn, to lower productivity.

will impact the Productivity level of the country. Additionally, we notice that Productivity grows at a faster pace than GDP as the number of broadband subscriptions increase over time.

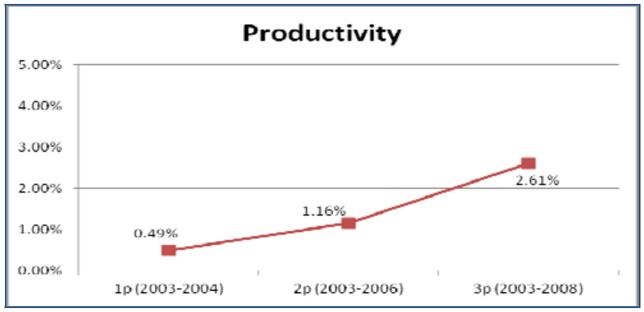

Figure 13.- Impact on Productivity over time of a 10% increase in Broadband penetration

As a final remark, according to the model presented, policies whose goal is to decrease inequality are associated with an increase in productivity for any given country. Therefore, policies focused on inclusion issues that consider aggregating demand in municipalities (health care centers, police and fire-men departments, guild of agriculture producers) will have an associated increase in the productivity level. In the same way, policies focused on quality (broadband speed) will have a positive effect in productivity since, as we mentioned before, a greater broadband speed increases output (GDP) and consequently, since inputs remain constant, productivity grows.

3.1.3 Impact of broadband on Employment

According to economic theory, the Employment level is the ratio between GDP and Productivity. Empirically, to determine the impact of broadband on Employment, we formulate a non-linear multivariate regression model where, as illustrated in Figure 14, the dependent variable is the Employment level (Y3) and there are seven independent explanatory variables, including the number of fixed broadband subscriptions per 100 inhabitants (Y).

To proceed with the model development, we count on data relied by the World Bank and the ITU. Specifically, our regression variables' samples come from the WB Development and Doing Business, and ITU World ICT Indicators databases. As we have previously mentioned, to finally select the ultimate seven key explanatory variables, we followed an extensive procedure in which we proved up to 89 different variables.

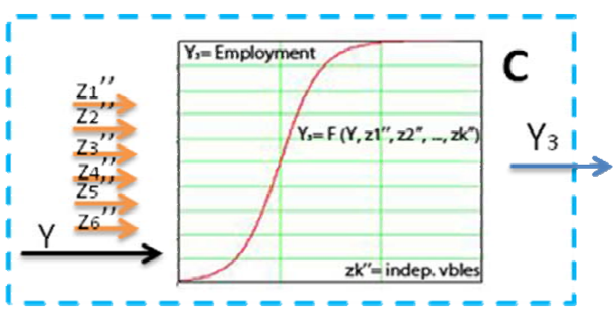

Figure 14.- Regression model vignette

As we can see in the Figure 15, the independent variables are: the days to start a business indicator (Z1''), the percentage of the population with 15 or more years (Z2''), the interest rate (Z3''), the cost of start-up procedures (Z4''), the new business density (Z5''), the new business density squared (Z5'' sq.), the value added of the industry sector as a percentage of the GDP (Z6'') and the fixed broadband penetration per 100 inhabitants (Y), all of which are significant, based on the calculated p-values (see Figure 15 for independent variables and Figure 16 for the model as a whole). While Z1'', Z3'', Z4'' and Z5'' are associated with the conditions to generate new employment, Z2'' relates to the working-age population and Z3'' with the importance of the industrial sector in the economy.

Non-Linear Multivariate Regression Equation

```
1/Y3 = 0.00973 + 0.000009 Z1'' + 0.000102 Z2'' - 0.000083 Z3'' - 0.000015 Z4''
      + 0.000269 Z5'' - 0.000023 Z5''-sq. + 0.000032 Z6'' - 0.000154 Y
```

Predictor	Coef	SE Coef	T	P	VIF
Constant	0.009725	0.001751	5.55	0.000	
Y-BB subscriptions/100 inh	-0.00015412	0.00004984	-3.09	0.003	1.867
Z1''-DaysToStartBus	0.00000926	0.00000088	10.50	0.000	2.089
Z2''-Pop 15+(%)	0.00010246	0.00002677	3.83	0.000	2.397
Z3''-Interest Rate	-0.00008326	0.00000907	-9.18	0.000	1.185
Z4''-Cost start-up procs (%GNI)	-0.00001547	0.00000328	-4.72	0.000	2.646
Z5''-New biz density (per th)	0.0002690	0.0001327	2.03	0.047	17.836
Z5''-squared	-0.00002315	0.00001057	-2.19	0.032	16.548
Z6''-Industry, value added (%GDP)	0.00003228	0.00001543	2.09	0.040	1.304

Figure 15.- Model equation, P-values and T_{obs} and VIF statistics

As shown in Figure 16, the regression model is not only robust for explanatory purposes, with the independent variables explaining 82.1% of the fluctuations in the Employment level and a F_{obs} of 38.52, but it is also valid for forecasting purposes, with a coefficient of variation of 4.6812%. Apart from that, as we can see with the Arlinson-Darlington statistic, residuals are normally distributed and the model, which is based on 76 samples from year 2003-2009, does not present heteroscedasticity (random residuals plot), multicolinearity (expected signs[14] in regression's coefficients, reduced VIFs and uncorrelated independent variables) nor autocorrelation (Durbin-Watson statistic).

[14] The negative signs associated with the interest rate and the cost of registering a business (Figure 15) seem counterintuitive, since it implies that the greater is the interest rate and the more expensive it is to set up a business the higher is the Employment level for a given country (the regression equation is in terms of 1/Y and not in terms of Y). However, these findings are not caused by multicolinearity problems in the regression model and indeed, they are sustained by the original World Bank data, which shows a positive correlation between both Interest Rate and Cost of Start-Up procedures with Employment. The explanation for the positive correlation between the Interest Rate and the Employment level could reside in that the higher the interest rate, the higher the FDI for a given country and this, in turn, might lead to the creation of more jobs. Finally, the explanation for the positive correlation between the cost of registering a business and the Employment level could reside in that the newly created businesses might be not profitable enough and generate less new jobs than the traditional businesses and consequently, the more expensive it is to enter a new business, the more probable it is that entrepreneurs focus on looking for and finding a job in a traditional business.

```
R-Sq = 82.1%    C.V.= 4.6812    R-Sq(adj) = 80.0%    S = 0.000789417
PRESS = 0.0000519721    R-Sq(pred) = 77.77%

ANOVA
Source          DF          SS            MS       F      P
Regression       8   0.000192062   0.000024008   38.52  0.000
Residual Error  67   0.000041753   0.000000623
Total           75   0.000233815

Source                               DF      Seq SS
Y-BB subscriptions/100 inh            1   0.000000031
Z1''-DaysToStartBus                   1   0.000099075
Z2''-Pop 15+(%)                       1   0.000032801
Z3''-Interest Rate                    1   0.000043092
Z4''-Cost start-up procs (%GNI)       1   0.000012272
Z5''-New biz density (per th)         1   0.000000262
Z5''-sq.                              1   0.000001802
Z6''-Industry, value added (%GDP)     1   0.000002729

Durbin-Watson statistic = 1.93151
Anderson-Darling Normality Test P-value = 0.124
```

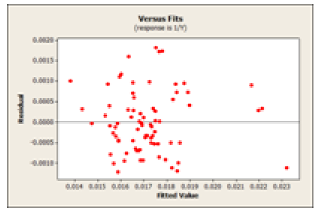

Figure 16.- ANOVA table, R^2, C.V., Durbin-Watson, and A-D statistics

Finally, as we can see in Figure 17, independent variables are not strongly correlated to each other and therefore, they provide an accurate explanation of the fluctuations of the dependent variable.

Correlation Matrix

	Y	Z1''	Z2''	Z3''	Z4''	Z5''
Z1''	-0.187					
Z2''	0.697	0.038				
Z3''	0.000	0.003	-0.020			
Z4''	-0.487	0.410	-0.547	-0.048		
Z5''	-0.016	-0.160	0.137	0.087	-0.299	
Z6''	-0.120	0.183	0.211	-0.246	-0.140	-0.236

Figure 17.- Correlation matrix of explanatory variables

Once we have the regression model, ceteris paribus, we use it to estimate the impact in Employment associated with a 10% increase in the number of broadband subscriptions in three different periods of time for LAC countries (see Figure 18).

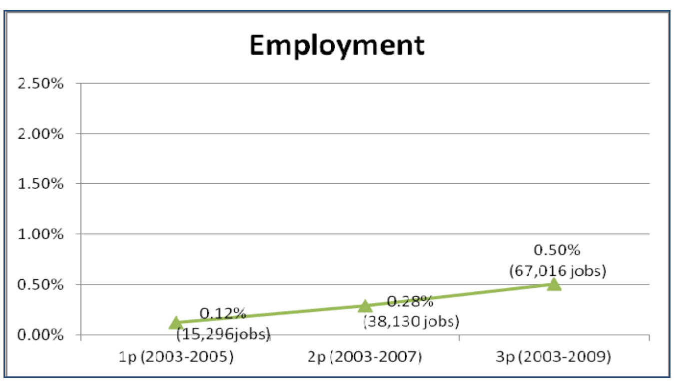

Figure 18.- Impact on Employment over time of a 10% increase in Broadband penetration

As shown in Figure 18, in 2005, the model proclaims, on average, 15,296 new jobs created; in 2007, 38,130 new jobs; and in 2009, 67,016 new jobs (Figure 19 shows the estimation of new jobs generated in 2009 per country associated with a 10% increase in broadband penetration).

These findings corroborate again that the greater the number of broadband subscriptions per capita a country has over time, the greater that an additional increase in the number of broadband subscriptions will impact the Employment level of the country.

Country	New Jobs (2009)
Argentina	244,441
Bolivia	20,077
Brazil	725,513
Colombia	106,089
Costa Rica	8,962
Dominican Republic	23,002
Guatemala	7,234
Jamaica	6,336
Mexico	536,736
Panama	11,718
Peru	44,603
Uruguay	16,547

Figure 19.- Estimation of jobs generated per country associated with a 10% increase in broadband penetration (2009)

3.1.4 Broadband Network Economies Effect

As we have analyzed through this chapter, since broadband is a cross cutting service enabler with clear socio-economic benefits, it is a must for Governments to intervene proactively to effectively accelerate the broadband penetration in the Region.

As we have already presented for GDP, Productivity and Employment and as it is shown in Figure 20, the models verify the existence of a broadband network economies effect and thus, the more broadband subscriptions a country has over time, the greater the impact of an additional increase in the number of broadband subscriptions on GDP, Productivity and Employment. This leads to the conclusion that the more maintainable the broadband policy of a country is, the better this policy will be for the country.

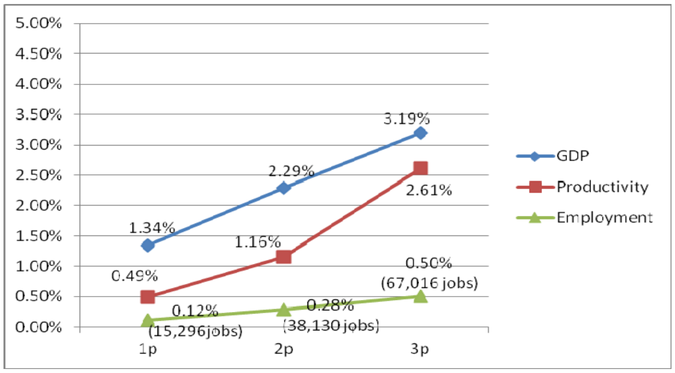

Figure 20.- Impact on GDP, Employment and Productivity over time of a 10% increase in Broadband penetration

However, these findings are not enough for our purposes and the nagging question now turns into how governments can increase broadband subscriptions by 10%. To proceed and solve this dilemma, we move on to the last contribution of the paper, which addresses the variables a government might effectively control to help shape the broadband policy of its country.

3.2 Levers to determine a country's broadband policy

In this chapter, we focus on the econometric model that defines the specific variables that will help a government to effectively increase the number of broadband subscriptions per capita and as a result, improve the socio-economic conditions of the country it represents.

3.2.1 Econometric model to shape the Broadband status of a country

Technology becomes cheaper over time and as a result, broadband penetration is expected to experience vegetative growth, but there is not a theoretical model in the literature that explains the broadband penetration for a given country. However, we believe that broadband penetration is explained by the following four dimensions: 1.- Public Policies & Public Private Partnerships (PPPs); 2.- Strategic Regulation; 3.- ICT Infrastructure; and 4.- Capacity Building & Applications (see Figure 21).

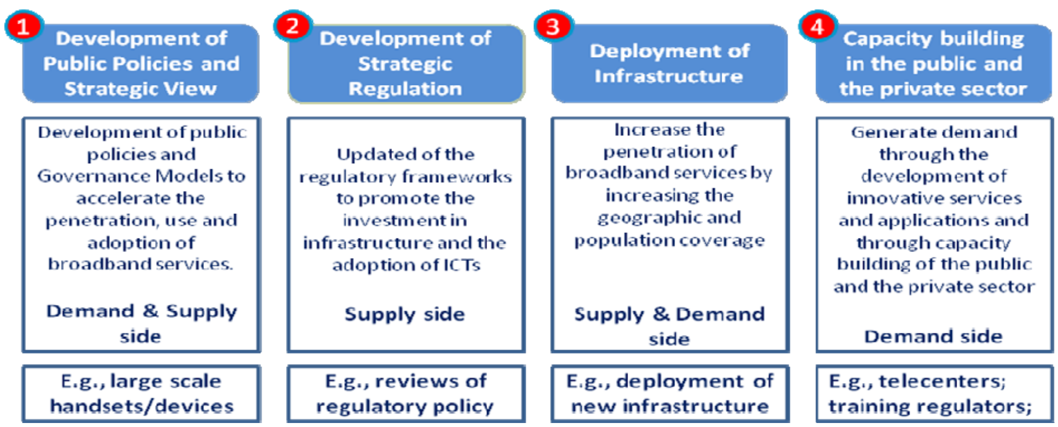

Figure 21.- The Four Pillars that explain Broadband Penetration

These pillars will be our base to define an econometric model that is genuine in the literature. As in the previous chapter, we will develop a non-linear multivariate least-squared regression model for the broadband subscriptions and prove the significance and validity of the model for explanatory and forecasting purposes.

To do so, we will repeat the same process as before and use the following steps: 1.- we will select the most significant variables that explain each macroeconomic variable; 2.- we will show, through the p-values and T_{obs} statistics, that all the explanatory variables are significant and that the model is significant as a whole; 3.- we will show the goodness of the model (R^2 and F_{obs} statistics) or in other words, how much of the fluctuations of the independent variable are explained by the variations of the explanatory variables; 4.- we will show the forecasting validity (coefficient of variation statistic); 5.- we will get rid of heteroscedasticity by performing a left hand side algebraic stabilizing transformation (and proving then homoscedasticity by observing the random pattern of the residuals); 6.- we will show that the model does not present autocorrelation (Durbin-Watson statistic) nor multicolinearity (low variance inflation factors, expected signs in the regression coefficients and not strong correlations between the explanatory variables) and finally 7.- we will show that residuals are normally distributed and do not follow any pattern (Anderson-Darling statistic).

To determine the variables that explain the broadband status of a country, we formulate a non-linear multivariate regression model where, as illustrated in Figure 22, the dependent variable is the number of fixed broadband subscriptions per 100 inhabitants (Y) and there are seven independent explanatory variables.

To proceed with the model development, we count on data relied by the World Bank and the ITU. Specifically, our regression variables' samples come from the WB Development and Education, and ITU World ICT Indicators databases. As we did for GDP, Productivity and Employment, to finally select the ultimate seven key explanatory variables, we followed an extensive procedure in which we proved up to 105 different variables associated mainly with Public Policies & PPPs, Strategic Regulation, ICT Infrastructures and Capacity Building & Applications.

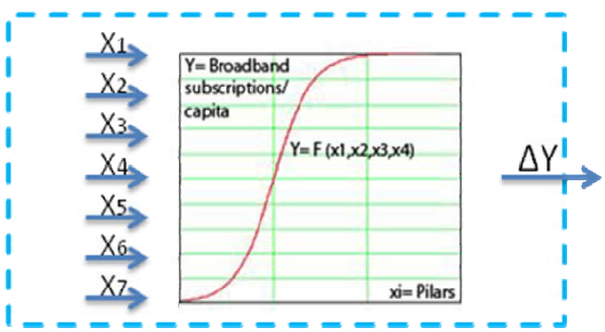

Figure 22.- Regression model vignette

As we can see in Figure 23, the independent variables are: the number of cellular subscriptions (X1), the percentage of the population between 15 and 65 years (X2), the percentage of households with PC (X3), the monthly cost per business fixed telephone line (X4), the existence of IP telephone regulations (X5), the ending age of compulsory education (X6) and the time to start a business (X7), all of which are significant, as we can notice regarding its p-values (see Figure 23 for independent variables and Figure 24 for the model as a whole).

Non-Linear Multivariate Regression Equation

$\sqrt{Y} = -4.08+0.00951\,X_1+0.0532\,X_2+0.0327\,X_3+0.0129\,X_4-0.295\,X_5+0.0628\,X_6-0.00116\,X_7$

Predictor	*Coef*	*SE Coef*	*T*	*P*	*VIF*
Constant	-4.0794	0.6950	-5.87	0.000	
X1-cellulars/100 inh	0.009510	0.001190	7.99	0.000	1.395
X2-Pop.age 15-64	0.05317	0.01288	4.13	0.000	2.228
X3-Households% with PC	0.032660	0.004430	7.37	0.000	2.109
X4-Monthly$/biz teleph. service	0.012924	0.005197	2.49	0.015	1.371
X5-IP Telephony regulations?	-0.29460	0.08832	-3.34	0.001	1.340
X6-End.Age compulsory Education	0.06275	0.02262	2.77	0.007	1.266
X7-TimeToStartBus	-0.0011571	0.0003169	-3.65	0.000	1.218

Figure 23.- Model equation, P-values and T_{obs} and VIF statistics

Apart from these seven variables, one of which is exogenous (X2) and not directly controlled by the government and another one (X1) that has achieved almost a saturation point by 2012[15], we observed other variables that according to international evidence **[8] [9] [10]** play a key role for broadband penetration; however, they have not been included in the analysis because data is not available. Examples of these variables are: X1'- Spectrum management, X2'- Interconnection issues, X3'- Tariffs affordability policies, X4'- Infrastructures sharing, X5'- Access' and infrastructure's market competitiveness, X6'- Regulation for the inclusion of ICTs in infrastructures, X7'- Effective use and endowment of a broadband universal access fund, X8'- Percentage of population with IT knowledge, X9'- Number of innovation centers and tele-centers per country, X10'- Number of universities that include IT for teaching purposes or X11'- Number of SW applications generated per country.

As shown in Figure 24, the regression model is not only robust for explanatory purposes, with the independent variables explaining 86.9% of the fluctuations in the number of broadband subscriptions and an F_{obs} of 78.62, but it is also valid for forecasting purposes, with a coefficient of variation of 23.3267%. Apart from that, as we can see with the Arlison-Darlington statistic, residuals are normally distributed and the model, which is based on 91 samples from year 2003-2009, does not present heteroscedasticity (random residuals plot), multicolinearity (expected signs in regression's coefficients, reduced VIFs and uncorrelated independent variables) nor autocorrelation (Durbin-Watson statistic).

[15] We predict a substitution effect among voice mobile subscriptions and data mobile subscriptions, but we expect the total number of mobile subscriptions to remain stable. In our model, we used the total number of mobile subscriptions instead of the total number of data mobile subscriptions because there was not enough available information for data mobile subscriptions in the period considered (2003-2009).

```
R-Sq = 86.9%   C.V.= 23.3267%   R-Sq(adj) = 85.8%   S = 0.277009
PRESS = 7.81588   R-Sq(pred) = 83.92%

ANOVA
Source          DF      SS      MS      F      P
Regression       7  42.2298  6.0328  78.62  0.000
Residual Error  83   6.3689  0.0767
Total           90  48.5987

Source                                DF   Seq SS
X1-cellulars/100 inh                   1  23.3511
X2-Pop.age 15-64                       1  10.1161
X3-Households% with PC                 1   3.8339
X4-Monthly$/biz teleph. service        1   2.1019
X5-IP Telephony regulations?           1   0.5625
X6-End.Age compulsory Education        1   1.2412
X7-TimeToStartBus                      1   1.0231

Durbin-Watson statistic = 1.97978
Anderson-Darling Normality Test P-value = 0.391
```

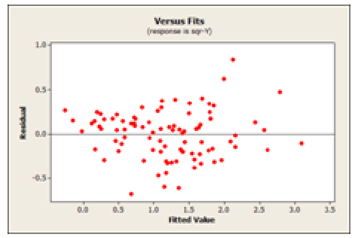

Figure 24.- ANOVA table, R^2, C.V., Durbin-Watson, and A-D statistics

Intuitively, to have an idea of the sense of causality, while it is clear that actions in any of the four dimensions considered for the selection of the explanatory variables (Public Policies & PPPs; Strategic Regulation; ICT Infrastructures; and Capacity Building & Applications) explain variations in broadband penetration, the opposite is not necessarily true.

Finally, as we can see in Figure 25, independent variables are not strongly correlated to each other and therefore, they provide an accurate explanation of the fluctuations of the dependent variable.

Correlation Matrix

	X1	X2	X3	X4	X5	X6
X2	0.410					
X3	0.549	0.747				
X4	0.287	0.485	0.364			
X5	-0.004	0.275	0.415	0.121		
X6	0.049	0.133	0.060	0.050	0.117	
X7	-0.046	0.080	-0.008	-0.109	-0.112	-0.293

Figure 25.- Correlation matrix of explanatory variables

Once we have the regression model, we can analyze the weight of every independent variable in explaining the dependent variable by looking at the T_{obs} statistic. If we do so, we have the following weights (Figure 26):

Key Variable	$\lvert T_{obs} \rvert$	Weight
X1- Cellular subscriptions	7.99	* * * * * * *
X2- Population 15-64 years	4.13	* * * * *
X3- Households % with PC	7.37	* * * * * *
X4- Monthly $/business line	2.49	*
X5- IP telephone regulations	3.34	* * *
X6- Ending age of compulsory education	2.77	* *
X7- Time to start a business	3.65	* * * *

Figure 26.- Relative weight of explanatory variables

3.2.2 Findings of the Model

The model specifies that according to the data, changes in any of the explanatory variables have an associated change in the broadband penetration; or more precisely, that fluctuations in the explanatory variables explain 86.9% of the variability in the number of broadband subscriptions.

However, the model does not conclude that the explanatory variables are the direct causes of broadband penetration. Thus, although the increase in the number of cellular subscriptions is expected to have an associated increase of broadband penetration, the real cause for the increase in the number of cellular subscriptions and in the number of broadband subscriptions might be a decrease in the import tariffs for smart phones and computers[16] (a public policy measure). Notwithstanding, even if the relation between the explanatory variables and the dependent variable is not of direct causation, this is still a strong and not a casual relation, as we have proven in different periods of time (2003-2005, 2003-2007 and 2003-2009), where the model has always proven to preserve its validity.

We present all significant variables to have a greater insight of their meaning:

X1-Cellular subscriptions: this variable accounts for the number of existing cellular subscriptions in a given country. From a user perspective, cell phones, especially smart phones usage, goes hand in hand with fixed broadband usage, because when customers get used to using cell phones to connect with the internet, they are more likely to use fixed broadband, and vice versa. In a similar way, when import tariffs are reduced, it is common that they are reduced for smart phones and computers at the same time. For these reasons, public policies that promote a greater use of cell phones (with internet connectivity) are beneficial for a greater usage of fixed broadband.

X2-Population 15-64 years: this variable, which accounts for the percentage of people between 15-64 years, who are the most willing to use the internet, is exogenous to any direct measurable government action. Although the government cannot easily alter the percentage of people between 15-64 years in the country, we need to take this exogenous variable into account in the regression model since it has significant explanatory power of the existing number of broadband subscriptions of a country.

X3-Percentage of households with PC: this variable accounts for the percentage of households with a PC and, since owning a PC is a pre-requirement to use broadband, this variable obviously matters. Measures that lead to the massif availability of PCs, since they are normally accompanied by a decrease in prices, stimulate the demand and as a consequence, lead to a greater broadband penetration.

X4-Monthly price per business phone line: this variable accounts for the price of a supplementary service such as setting up a business phone line. As we see in the regression model, the higher the price of the supplementary service, the greater the number of broadband

[16] It is common that measures concerning import tariffs affect cell phones and computers in the same way.

subscriptions. This rationale applies also for other variables, but in the case of broadband penetration in the LAC countries, the price of a fixed line, compared to other variables, has proven its greater significance in determining the number of additional broadband subscriptions.

X5-Existence of IP telephone regulations: this is a dummy variable, which measures whether there are IP telephone regulations in force in a given country. As we can see in the regression model, the lack of IP regulations leads to a greater number of broadband subscriptions.

X6-Ending age of compulsory education: this variable accounts for the ending age of the compulsory education in a given country. Since a longer education facilitates a greater capability in the use of the internet, it leads to a greater demand for broadband services.

X7-Time to start a business: this variable accounts for the number of days required to start a new business in a given country. As we can see in the regression model, the easier it is to set up a business, the greater the number of broadband subscriptions.

In Figure 27.a, we summarize the variables that prove to be significant in our model, classified by supply/demand variables and by dimension/pillar; and in Figure 27.b, we summarize the variables that are also relevant for broadband penetration purposes, but whose data is not available.

X_i	Key Variable	End/Ex.	Weight	Supply/Demand	Pillar	Pillar Description	Pillar weight
X_1	Cellular Subscriptions	Endog.	*******	Supply/Demand	1 – 3	P1: Public Policy and PPP	***
X_3	Households % with PC	Endog.	******	Supply/Demand		P3: ICT infrastructure	***
X_7	Time to Start a Business	Endog.	****	Supply	2	P2: Strategic Regulation	**
X_5	IP telephone regulations	Endog.	***	Supply			
X_4	Monthly$/business phone line	Endog.	*	Supply			
X_6	Ending Age Compulsory Education	Endog.	**	Demand	4	P4: Capacity Building	*
X_2	Population 15-64 years	Exog.	*****	—	—	—	—

Figure 27.a.- Summary of measurable significant variables

Xi'	Key Variables
X1'	Spectrum Management
X2'	Interconnection Issues
X3'	Tariffs Affordability Policies
X4'	Infrastructure Sharing
X5'	Access' and Infrastructure's Market Competitiveness
X6'	Regulation for the Inclusion of ICTs in Infrastructures
X7'	Effective Use and Endowment of a Broadband Universal Access Fund
X8'	Percentage of Population with IT Knowledge
X9'	Number of Innovation Centers and Tele-Centers per Country
X10'	Number of Universities that include IT for Teaching Purposes
X11'	Number of SW Applications generated per Country

Figure 27.b.- Summary of non-measurable relevant variables

3.2.3 Considerations about the Model

The econometric model presented in this paper to explain the fixed number of broadband subscriptions per 100 inhabitants of a country is subject to the existing data, which as we have mentioned, is scarce.

As a consequence, and although as shown in Figure 27.a, variables associated with Public Policy & PPPs and ICT Infrastructure seem to have had a more relevant role in determining the broadband status of any LAC country in the past few years, we could expect a greater relevance than the one presented by our model for other variables associated with Strategic Regulation or Capacity Building & Applications. Despite the constraints in data availability, our findings show that, according to the weights of Figure 27.a, there seem to have been a relative lack of governmental support in Strategic Regulation and Capacity Building for LAC countries.

Therefore, according to the World Bank **[8]** and the OECD **[11]**, strategic regulation and capacity building policies have proven to be essential to reducing the digital divide (incidentally, the countries ranked at the top of the OECD broadband ranking have promoted capacity building initiatives more proactively in the last few years), it is clear for us that it is time for LAC governments to prioritize and focus their efforts on Capacity Building and Application development initiatives.

Having said this, the unquestionable relevance of variables associated with Public Policies & PPPs and ICT Infrastructure in determining the broadband status of a country is strongly evidenced by some real examples that have taken place recently in LAC countries.

For instance, in Colombia, the Ministry of Information and Communication Technologies announced in October 2011 the complete suppression of import tariffs for computers, mobile phones, tablets and PC parts **[12]**; this measure, according to Intel, has made Colombia the Latin-American country with the cheapest PC prices and with the greatest growth in PC sales in the whole Region, accompanied by a formidable growth in broadband subscriptions. Also in Colombia, the government launched its *Compartel* program in 1999 in an effort to ensure access to telecommunications even in its most rural locations, deploying broadband Internet access to 3,000 public schools, 624 city halls, 120 public hospitals and 30 military facilities, and it extended the program in 2011 to provide internet services to an additional 6,852 rural area schools, which will benefit approximately 1,130,000 children **[13]**.

Another example of the role of infrastructure deployment in determining the broadband status of a country can be found in Chile, where the continuous flow of investments in infrastructure (including ICT) by private and public stakeholders have allowed a continuous growth of broadband penetration and a progressive reduction in the social gap; as it is affirmed in the book “Inversión en Infraestructura Pública y Reducción de la Pobreza en América Latina” where according to some econometric measures, good infrastructures in LAC countries imply low poverty indexes **[14]**. Also in Chile, in 2011, the government, in a PPP with Ericsson and Entel, a Chilean mobile services provider, extended broadband services to remote areas of Chile, resulting in broadband service in Chile’s rural communities on par with large urban areas like Santiago and Valparaiso; as a matter of interest, extension of broadband service improved the provision of critical services in rural Chile from expanded education opportunities to improved health care to better public services and, at the same time, the new network allowed local businesses to leverage the benefits of connectivity to create new opportunities for themselves and for their communities by connecting them to national, regional, and global markets **[15]**.

An additional example of the relevance of infrastructure for broadband penetration is found in Peru, where in 2010 the *Intégrame* initiative represented a successful example of Telefónica’s strategy in practice. Specifically, Telefónica partnered with local governments to facilitate communication access to thousands of people in the most isolated locations of Peru. Telefónica and its Peruvian partners have, thus far, connected 217 towns and over 58,000 people via broadband and fixed, mobile and public wireless telephony to improve the delivery of public services, promote local economic development and build stronger public-private alliances.

Finally, an example of the relevance of the creation of PPPs for broadband penetration outside the LAC region can be found in Sweden. In 2010, Sweden’s *Rural Development Program* helped finance local investments in broadband infrastructure through a novel approach. This program relied on local residents and enterprises to form cooperatives or economic associations to partner with service providers in building out local infrastructure and providing service. The organizations contributed both financial support and support in kind (often doing much of the digging to install new ducts). In the end, the local cooperative owned the resulting infrastructure and was responsible for its maintenance, but the network itself was run by an independent telecom operator as a condition of the initial community development grant. Sweden realized three distinct advantages from relying on the cooperative structure. One was the effect of organizing local stakeholders and encouraging their participation, which paid off in terms of planning and implementing the projects. The other advantage also flowed from the nature of the structure, which implied local cooperation. That paid in cost savings from easier access to the needed rights of way across private land, which was often owned by a member of one of the cooperatives. The third was the extent to which the structure also encouraged cooperation among Swedish government agencies with very different responsibilities, in that it involved both Sweden’s telecommunications regulator, which was enlisted for its technical know-how, and its Department of Agriculture, which contributed much of the financial support **[16]**. By July 2011, these measures allowed Sweden to occupy the sixth position in the OECD broadband penetration ranking **[17]**.

4 Conclusion

LAC governments can improve the broadband status of their respective countries by controlling some key variables. However, as we have shown in this paper, although some of these variables can be directly measured and therefore, their significance analytically proven, other variables are not easily measured even though they are internationally recognized.

Of the measurable variables that we have identified in our model, we have verified that those associated with Public Policies & PPPs and ICT Infrastructure have played a key role in determining the broadband status of any LAC country in the past few years, showing the active role of governments on these fronts and evidencing that a greater focus in Strategic Regulation and Capacity Building & Applications is required. This in turn, through the generation of additional broadband subscriptions, will originate a greater effect on GDP, Productivity and Employment.

Specifically, as we have shown in this paper, on average, an increase of 10% in broadband penetration has associated increases of 3.19% in GDP and 2.61% in Productivity, and a generation of 67,016 new jobs for LAC countries.

5 Citations

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