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> Economic Impact of Broadband Deployment in Ecuador

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Abstract

The purpose of this paper is to determine the economic impact of broadband deployment in Ecuador. First, to structure the theoretical framework, the study presents two models based on aggregate macroeconomic data, where the contribution of broadband to GDP growth and the creation of jobs in Ecuador are estimated. Both models **confirm** that **broadband deployment** has a **directionally positive** socioeconomic impact. According to a structural model, fixed broadband significantly contributed to the Ecuadorian GDP growth between 2008 and 2012. For every 1% increase in penetration, the average annual contribution to GDP growth was estimated at 0.052%. In addition, a model based on microeconomic data was specified to understand the contribution of broadband to average income levels. The microdata model shows that broadband deployment increases average income by 3.67% annually, **confirming broadband's impact on poverty reduction**.

1. INTRODUCTION

Research on the economic contribution of broadband conducted to date has targeted three issues:

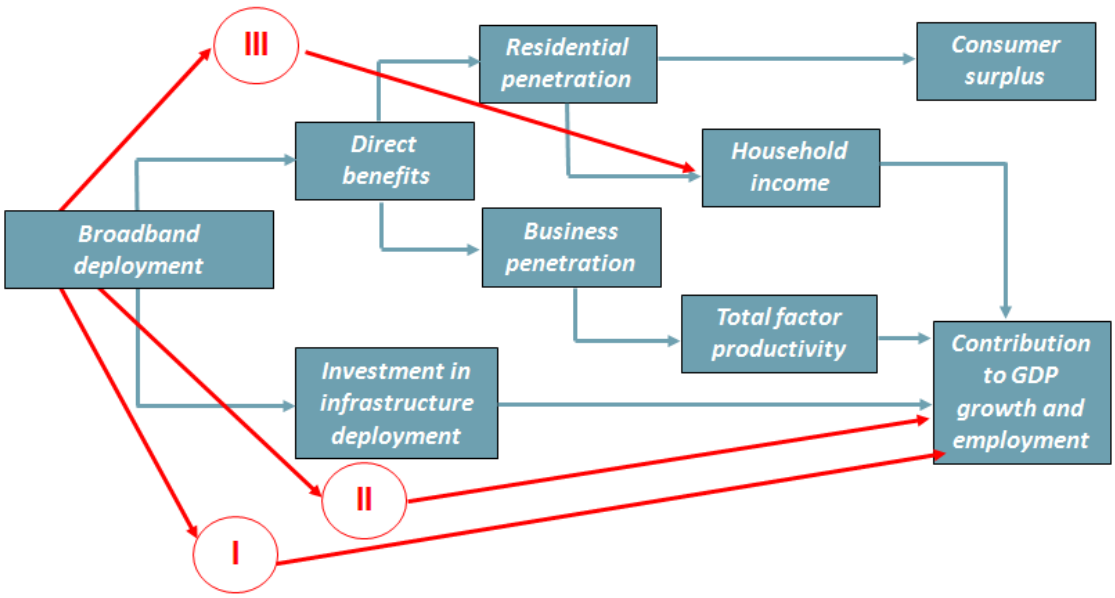
I. What is the causal link between increased broadband penetration and gross domestic product (GDP) growth?

II. How does increased broadband penetration impact job creation?

III. What is the relationship between broadband deployment and the rise in average household income?

These three relationships[1] are shown below (Exhibit 1) through the following causal chain:

Exhibit 1. Analysis of the economic contribution of broadband



However, until recently, broadband economic impact analysis has been based on *macro*-economic data. Studies like those of Crandall et al. (2007), Thompson and Garbacz (2008), Czernich et al. (2009), and Qiang et al. (2009) are based on samples of countries with data aggregated at the national or county level. These efforts have limited control over possible effects of reverse causality, which have been partially addressed through structural models (Koutroumpis, 2009, Katz and Koutroumpis, 2012).

[1] *In addition, studies to estimate consumer surplus carried out by Shane Greenstein from Northwestern University should be taken into consideration. See Greenstein, S. and McDevitt, R. 2019, 2011*

In recent years, the implementation of national household surveys that now include ICT modules has allowed to research the impact of broadband based on *micro*-economic data. For example, using information from Peruvian households between 2007 and 2009, De Los Rios (2010) found that, during this time period, Internet adopters experienced significant income growth relative to those households that did not have the service. Similarly, Atasoy (2011) analyzed the impact of expanding broadband access in the United States over the period of 1999-2007 and its impact on the job market, finding that access to broadband service had a positive impact on the employment rate.

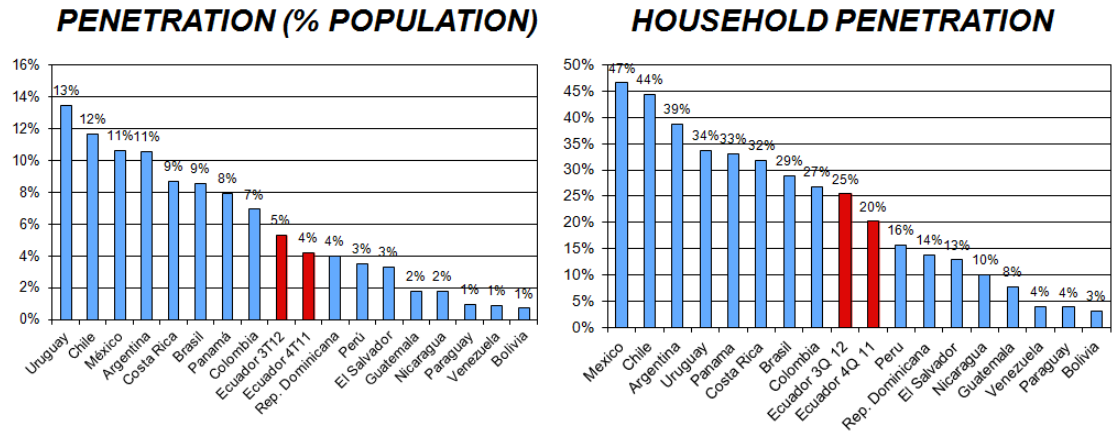
The following study presents the results of research examining the economic effects of broadband in Ecuador based on aggregate macroeconomic data and then through microdata analysis to validate initial results. The study is based on macroeconomic variables derived from information from the Ecuadorian Central Bank and the Institute of Statistics and Census of Ecuador. It is also based on microdata derived from individual information from the National Household Survey conducted by the National Institute of Statistics and Census of Ecuador (INEC) between 2009 and 2011.

This paper is organized as follows. The first section following the introduction examines the state of broadband adoption in Ecuador, highlighting the geographic duality that exists at the district and parish (administrative division) levels. The second section presents the results of the models based on macroeconomic data, which leads to the initial evidence that later guides the study of the effects of broadband based on microdata. The third section outlines the microdata used in the research, the identification strategy, and the definition of the treatment and control groups. Finally, the fourth section discusses the results of the micro-model and then presents the conclusions of the research.

2. BROADBAND IN ECUADOR

Ecuador's broadband penetration is at the mid-point relative to other Latin American countries (see Exhibit 2).

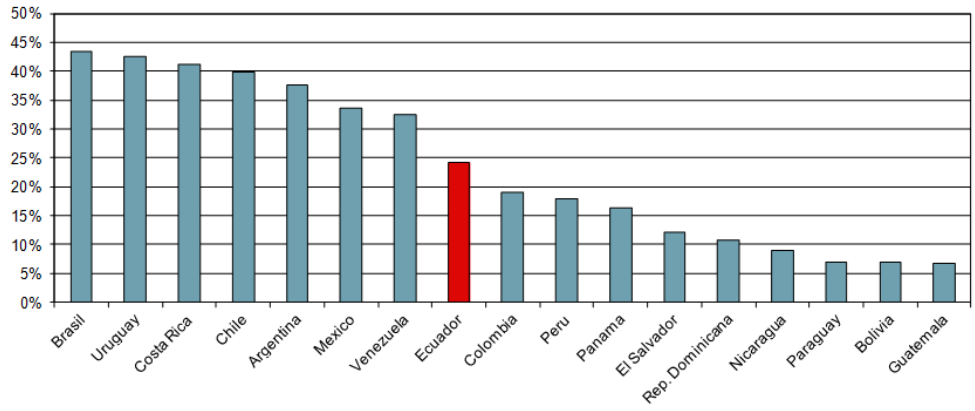
Exhibit 2. Latin America: Comparative penetration of fixed broadband (2011)



Source: UIT and SENATEL. Analysis by the authors

By the end of 2012, the percentage of individuals connected to fixed broadband in Ecuador had reached 5.45% while the percentage of households connected was 26.76%. Fixed broadband penetration in Ecuador was still far behind Uruguay, the leading country in the region with 13.47% of individuals and 33.74% of households connected at the end of 2011. Ecuador's relative position in the Latin American region improves marginally if mobile subscribers are added to the fixed broadband penetration (see Exhibit 3).

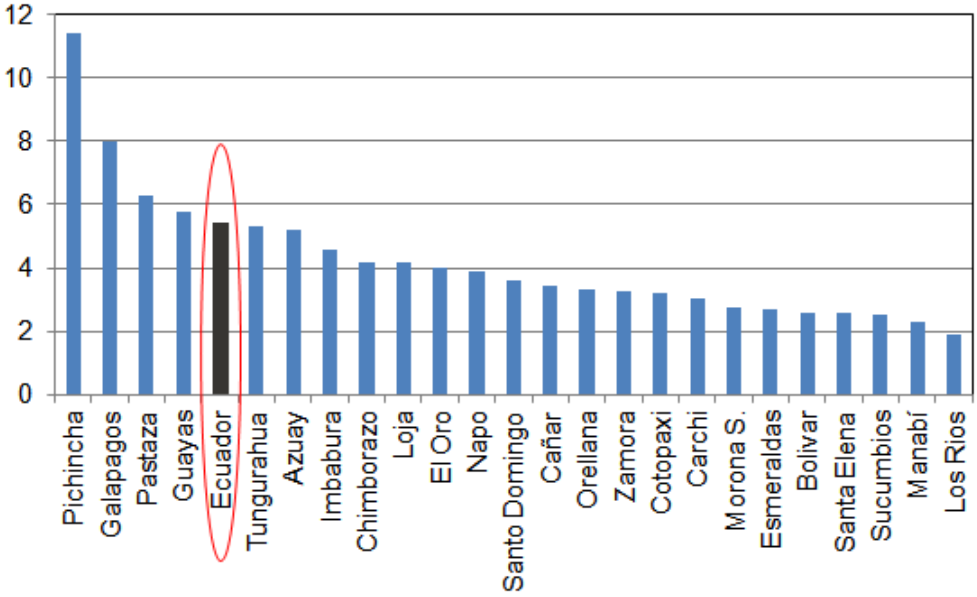
Exhibit 3. Latin America: Comparative penetration of fixed and mobile broadband (4Q2011 Fixed broadband and 3Q2012 Mobile broadband)



Source: UIT, Wireless Intelligence and SENATEL. Analysis by the authors

Beyond these national-level penetration, the country's data by province highlights a pronounced geographic duality: only four provinces have adoption rates above the national average (see Exhibit 4).

Exhibit 4. Ecuador: Fixed broadband adoption by inhabitants at the provincial level as of 4Q 2012 (%)



Source: SENATEL. Analysis by the authors.

Exhibit 4 shows that only the Pichincha (11.4%), Galápagos (7.9%), Pastaza (6.2%), and Guayas (5.7%) provinces exceeded the national average. In reality, however, a closer look reveals that the geographic duality extends within the provincial level. Four cantons (administrative subdivision of

districts) have broadband penetration levels above 6%, but only two of them have more than 10000 inhabitants: Quito and Guayaquil (see Table 1).

Table 1. Ecuador: Fixed broadband penetration by district, December 2011

Fixed broadband penetration per inhabitant	Number of districts
> than 10 %	1 (Quito in Pichincha)
From 6 % to 10 %	3 (Isabela* and San Cristóbal* in Galápagos; Guayaquil in Guayas)
From 5 % to 6 %	7
From 4 % to 5 %	6
From 3 % to 4 %	17
From 2 % to 3 %	23
From 1 % to 2 %	60
Less than 1 %	104

Source: SENATEL. Analysis by the authors
*Cantons with fewer than 10000 inhabitants.

Geographic location is the first explanatory variable for the broadband gap: 20% of the Ecuadorean population lives in parishes without fixed broadband service (see Table 2).

Table 2. Ecuador: Coverage at a parish level (December 2011)

Indicator	Urban	Rural	Total
Parishes with penetration levels above 1 % (Number)	144	2	146
Parishes with penetration levels below 1 % (Number)	68	63	131
Parishes with no connections (Number)	9	735	744
TOTAL (Number)	221	800	1021
Parishes with penetration levels above 1 % (% Population)	64.88 %	0.03 %	64.91 %
Parishes with penetration levels below 1 % (% Population)	9.17 %	5.86 %	15.03 %
Parishes with no connections (% Population)	0.24 %	19.82 %	20.06 %
TOTAL (% Population)	74.29 %	25.71 %	100 %

Source: SENATEL. Analysis by the authors.

Along these lines, further analysis should consider the potential for mobile broadband to solve, in part, the lack of coverage by fixed services. Coverage of 3G networks has continually increased in both urban and rural areas in recent years. Considering that 53% of the rural population had mobile service coverage in 2012, many of the rural parishes lacking fixed broadband services can be served by mobile broadband service. When incorporating mobile broadband to service coverage statistics, the unserved population decreases to 10.89%. Finally, of the 588 parishes without retail fixed or mobile broadband services, 247 have access to the Internet in *Infocentros* (telecenters) and 429 can connect at local schools, leaving 119 parishes (or 2.13% of the population) unconnected.

Beyond the lack of coverage, generational, educational, and – primarily – economic variables can explain the demand gap (i.e. the population that can access but does not purchase the service). Indeed, broadband adoption in situations where the head of the household is older than 55 years of age decreases from 22% to 12%. Similarly, in instances where the head of the household has just a primary education (or less), broadband penetration hovers at 10%, while this number jumps to 21% for household heads with a secondary education. Finally, broadband adoption exceeds 12% when looking at households in the sixth income decile or above (52% for the tenth decile), compared to adoption rates at or below 7% for households in the fifth decile or lower.

3. AGGREGATE ECONOMIC EFFECTS OF BROADBAND

In order to determine the economic impact of broadband in Ecuador and develop a theoretical framework, the authors first constructed two models based on aggregate macroeconomic data at the canton level. The models focused on estimating: 1) broadband's contribution to economic growth, and 2) its impact on the labor market, in terms of job creation.

3.1 Contribution to economic growth

To estimate broadband's contribution to GDP growth, the authors relied on a structural model, originally developed by Roller and Waverman (2001) for fixed telephony and subsequently adapted to examine broadband (Koutroumpis, 2009) and mobile telephony (Gruber and Koutroumpis, 2011). The model consists of four equations: a production function, which models the country's aggregate economic performance, and three distinct functions of demand, supply, and economic output. The last three functions model the broadband market, controlling for reverse causality (see Table 3):

Table 3. Ecuador: Impact model of increasing broadband penetration on GDP growth

Function	Equation
Aggregate Production Function	$\Delta GDP_{it} = \alpha_1 \Delta\, Fixed\ Capital_{it} + \alpha_2 \Delta\, Labor\ Force_{it} + \alpha_3 \Delta\, Oil\ Price_{it} + \alpha_4 \Delta\, Broadband\ Penetration_{it} + \epsilon_{it} + Year\ Fixed\ Effect_t$
Demand function	$\Delta Broadband\ Penetration_{it} = \alpha_1 \Delta\, Broadband\ Price_{it} + \alpha_2 \Delta\, Household\ Income_{it} + \epsilon_{it} + Year\ Fixed\ Effect_t$
Supply function	$\Delta Revenues\ of\ Broadband\ Companies_{it} = \alpha_1 \Delta\, Household\ Income_{it} + \alpha_2 \Delta\, Urban\ Population_{it} + \epsilon_{it} + Year\ Fixed\ Effect_t$
Output function	$\Delta Broadband\ Penetration_{it} = \alpha_1 \Delta\, Revenues\ of\ Broadband\ Companies_{it} + \epsilon_{it} + Year\ Fixed\ Effect_t$

In the aggregate production function, GDP is linked to fixed gross capital formation, skilled labor (measured as a percentage of the economically active population with at least a secondary education), and fixed

broadband infrastructure, estimated by penetration (measured as a percentage of the population with Internet connection download speeds greater than or equal to 256 Kbps). Given the importance of oil revenues for the Ecuadorian economy, the price of oil was included in this equation as an explanatory variable of GDP growth (considered as the price of a barrel of crude on the last business day of each quarter).

The demand function links broadband penetration to the price of basic service - the number of subscribers depends on access prices – as well as the price of a broadband connection with download speeds of 1Mbps and its average household income as reported in the National Accounts by the Central Bank of Ecuador.[2]

The supply function links aggregate broadband sales revenue to average household income and the country's rate of urbanization. To the extent that the deployment of fixed broadband correlates with urban concentration, the service offering should reflect this structural trend.

The output function links the annual change in fixed broadband penetration to broadband sales revenue; this change indicates annual capital investment in broadband.[3]

According to these models, fixed broadband significantly contributed to the Ecuadorian GDP growth between 2008 and 2012. For every 1% increase in penetration, the average annual contribution to GDP growth was estimated at 0.052% (see Table 4).

[2] *Since GDP per capita is not a perfect indicator of family wealth (GDP undergoes variations due to changes in oil prices), this indicator is used instead of GDP per capita.*

[3] *This premise assumes a stable and constant relationship between sales and investment, which in many cases is not realistic. The formation of fixed capital in telecommunications, a more appropriate variable, is not available.*

Table 4. Ecuador: Results of the impact model of fixed broadband on GDP growth

Function	Variables	Coefficients
Growth (ln GDP_{it})	Work force (In L_{it})	0.300
	Fixed capital stock (In K_{it})	1.106
	BB Penetration (ln BB_Pen_{it})	0.052**
	Oil price (In Oil_t)	0.093 ***
	Constant	5.189
Demand (ln BB_Pen_{it})	Fixed BB price (ln BB_Pr_{it})	-0.347*
	Average household expenditure (ln_$Cons_{it}$)	6.555***
	Constant	-1.127
Supply (ln $BB\_Revenue_{it}$)	Average household expenditure (ln_$Cons_{it}$)	1.871
	Urbanization (Urb_{it})	1.209***
	Constant	-1.127***
Output (ln BB_Pen_{it})	BB Revenue (lnBB_Rev_{it})	0.889***
	Constant	-18.143***
Year effects		YES
Observations		17 (2Q2008 – 2Q2011)
R^2	Growth	99.75%
	Demand	98.75%
	Supply	99.60%
	Output	99.89 %

*** statistically significant at the 10 level, ** statistically significant at the 5 level, * statistically significant at the 1 level.

The structural model leads to other conclusions as well. In addition to the contribution of capital, a 1% increase in skilled labor increases GDP by 0.30%. Finally, the model shows the elasticity of broadband subscription rates: a 10% drop in prices increases broadband penetration by 3.4%.

3.2 Impact of Broadband on the Labor Market

To measure broadband's contribution to job creation, the authors built two models to determine the impact on employment and unemployment. The first model estimates jobs created as a result of increased broadband penetration; the second model estimates the impact of the same variable on the reduction in the unemployment rate. Along these lines, the first model focuses on jobs that can be filled by a) individuals entering the job market (graduating students entering the workforce), b) under-employed individuals (with part-time jobs) moving into full-time positions, and c) the unemployed obtaining a paid job. The second model measures only

the proportion of the economically active population without a job (see Table 5).

Table 5. Ecuador: Model of broadband impact on job creation

Function	Equation
Variation in the employment rate (jobs created)	$\Delta Employment\ Rate_{it} = \alpha_1 \Delta\ Broadband\ Penetration_{it} + \epsilon_{it} + Year\ Fixed\ Effect_t + Region\ Fixed\ Effect_i$
Variation in the unemployment rate	$\Delta Unemployment\ Rate_{it} = \alpha_1 \Delta\ Broadband\ Penetration_{it} + \epsilon_{it} + Year\ Fixed\ Effect_t + Region\ Fixed\ Effect_i$

Both models are based on a panel of canton-level quarterly data from 4Q2008 to 4Q2011, which helps to control for fixed effects. The data are grouped into four regional categories: Quito, Guayaquil, Cuenca, and Others. In the case of the model that estimates the impact on the employment rate, the authors used the number of employed individuals and the percentage of the population with an Internet connection with download speeds of 256 Kbps or higher. In the case of the model that estimates the impact on unemployment, the same information was used, but in this case, the number of unemployed individuals was also included.

Based on these models results, broadband in Ecuador has not only helped to reduce unemployment but, above all, it has created full-time jobs (see Table 6).

Table 6. Ecuador: Model results of impact of broadband on the job market

Function	Variables	Coefficients
Variation in Unemployment Rate (Unemployment $_{it}$)	Broadband penetration (In_Penetration B.A. $_{it}$)	- 0.105 *
	Constant	0.758 ***
Variation in Employment Rate (Employment $_{it}$)	Broadband penetration (In_Penetration B.A. $_{it}$)	0.056 ***
	Constant	2.559 ***
Year Effects		Yes (2008-2011)
Effect per canton		Yes (Quito, Guayaquil, Cuenca and others)
Observations		47
R^2	Unemployment rate	92.41 %
	Employment rate	98.46 %

*** statistically significant at the 10 level, ** statistically significant at the 5 level, * statistically significant at the 1 level.

According to the model results, a 1% increase in broadband penetration in Ecuador increases the employment rate by 0.056 points and lowers the unemployment rate by 0.105%. Both coefficients have the right sign (positive for employment, negative for unemployment) and are statistically significant.

Based on these results, the increase in broadband penetration from 4.19% to 5.21% in 2012 generated more than 85000 jobs, of which previously unemployed individuals filled 6960 and either the previously economically inactive population or the underemployed workforce filled 79394. These 85000 jobs fall into three categories: direct labor used in broadband deployment (for example, construction workers and telecommunications technicians and staff), jobs in sectors that provide goods and services to the telecommunications industry deploying broadband (e.g., metallurgy, electrical products, and professional services), and jobs created as a result of new businesses and increased product output and innovation.

It should be mentioned, however, that these models do not take into account the possibility of reverse causality, where, for example, the rise in employment results in an increased demand for broadband. As such, it is necessary to shift the analysis toward a model based on microdata that successfully captures these effects.

4. BROADBAND'S CONTRIBUTION TO POVERTY REDUCTION IN ECUADOR BASED ON MICRODATA

4.1 Methodology

To estimate the impact of broadband on poverty reduction using microdata, the authors calculated the impact of broadband deployment on average income at the canton level. Ecuador is an appropriate case for this analysis because, while at the end of 2009 the country had a limited offering of residential broadband services, between 2009 and 2011, CNT, Ecuador's telecommunications fixed broadband provider, greatly expanded its coverage. As a result, the population in newly served townships could access fixed broadband service for the first time. This expansion led to a significant increase in broadband penetration at the provincial level in the country (see Table 7, which shows the difference in penetration rates between 2009 and 2011).

Table 7. Broadband penetration at a provincial level in Ecuador

Province	Broadband penetration at baseline	Broadband penetration at target	Province	Broadband penetration at baseline	Broadband penetration at target
Azuay	1.11 %	2.29 %	Los Ríos	0.21 %	1.25 %
Bolívar	0.42 %	1.81 %	Manabí	0.38 %	1.66 %
Cañar	0.28 %	2.58 %	Morona S.	0.19 %	2.18 %
Carchi	0.62 %	2.15 %	Napo	0.81 %	2.98 %
Chimborazo	0.99 %	3.04 %	Orellana	0.23 %	1.93 %
Cotopaxi	0.48 %	1.97 %	Pastaza	0.97 %	5.08 %
El Oro	0.41 %	2.94 %	Pichincha	4.97 %	9.27 %
Esmeraldas	0.37 %	1.56 %	Santa Elena	0.27 %	1.91 %
Galápagos	2.55 %	5.29 %	Santo Domingo	0.20 %	3.37 %
Guayas	2.95 %	4.81 %	Sucumbíos	0.67 %	1.72 %
Imbabura	0.71 %	2.84 %	Tungurahua	0.21 %	4.01 %
Loja	0.39 %	3.10 %	Zamora	0.27 %	2.30 %
			TOTAL	*1.05 %*	*4.19 %*

Source: SENATEL. Analysis by the authors.

Based on disaggregated data, a variable is built indicating the cantons that lacked broadband access in 2009 (due to a lack of coverage) but gained service by late 2010 / early 2011 (thanks to the aforementioned extension of the state-owned telecommunications operator's network). Through this process, two groups were created: 1) a treatment group, comprised of those individuals living in cantons where broadband was introduced during the

2010-11 period, and 2) a control group, comprised of those individuals living in cantons that already had access to residential broadband services by the fourth quarter of 2009.

Using this identification strategy, and given that the treatment group and the control group are statistically equal at the baseline of the observed variables, a regression model that estimates the impact of treatment on individual income levels is built. Controls are included for the variables that, at the individual level, can affect income (age, gender, employment status and healthcare coverage, level of formal education, and role within the family). This section presents in detail the research methodology that focuses on the surge in broadband service penetration and coverage between the baseline (December 2009) and the target achieved (December 2011).

4.1.1 Data

The National Institute of Statistics and Census (INEC) conducts quarterly National Household Surveys, gathering information on the employment status and income level of Ecuadorian households. Since 2008 the fourth quarter survey of each year incorporates the ICT module, capturing information about survey participants' computer and Internet usage trends.

This study uses data from surveys conducted between December 2009 and December 2011, which include more than 230000 individual observations of more than 58000 household surveys. As such, for each survey, an average of 75000 individual observations of 20000 urban and rural households are available.

However, as mentioned in Section 2, even in 2012, Ecuador's rural areas still suffered from limited broadband service availability (by 2011, not a single rural canton had a penetration rate above 1%). Therefore, this research only uses information provided by urban households and individuals, reducing the sample to a total of 128000 individual surveys from 33000 households.

4.1.2 Identification Strategy

Once the micro database was established, the authors identified the treatment group (i.e. those cantons affected by the introduction of broadband during the period studied) and the control group (i.e. the cantons with access to broadband before 2009). As discussed above, the process that led to increased broadband access by late 2010 / early 2011, namely the expansion of the state-owned telecommunications operator's

network, provides the framework to define these two groups. This increase in broadband deployment came as a result of policies that encouraged the operator, CNT, to expand its network in areas without coverage.

By December 2009, only ten cantons had broadband penetration rates greater than 0.25 connections for every 100 individuals. While broadband penetration in these areas increased during the study period, as shown in Table 10, the authors considered that these townships had access to service since 2009.

Based on the broadband deployment event, the database was divided into two groups: 1) a treatment group – those individuals who live in cantons where broadband was introduced during the period studied, and 2) a control group – those individuals who live in cantons where residential broadband was already available by the fourth quarter of 2009. Table 8 lists the cantons that comprise the control group.

Table 8. Broadband penetration at the canton level before and after treatment - Control Group

Canton	Province	Broadband penetration at baseline	Broadband penetration at target	Population
Tena	Napo	0.27 %	3.31 %	60880
Riobamba	Chimborazo	0.28 %	5.29 %	225741
Portoviejo	Manabí	0.29 %	3.14 %	280029
Pastaza	Pastaza	0.30 %	5.64 %	62016
Tulcán	Carchi	0.51 %	3.14 %	86498
Manta	Manabí	0.54 %	3.04 %	226477
Rumiñahui	Pichincha	0.99 %	5.60 %	85852
Cuenca	Azuay	1.50 %	2.78 %	505585
Guayaquil	Guayas	2.83 %	6.77 %	2350915
Quito	Pichincha	3.06 %	10.22 %	2239191

Source: SENATEL. Analysis by the authors.

The remainder of the cantons did not have access to residential service coverage in 2009, although a small handful of businesses in these townships could access broadband through enterprise-only service providers. However, between 2009 and 2011, CNT and its resellers launched residential services in these cantons and penetration levels surpassed 2.5 connections per 100 inhabitants by December 2011. The residents of these counties comprise the treatment group. The following table presents the cantons in this group and their evolution in terms of broadband subscribers.

Table 9. Penetration at the cantonal level - Treatment Group

Canton	Province	Broadband penetration at baseline	Broadband penetration at target	Population
Chunchi	Chimborazo	0.00 %	3.06 %	12686
Portovelo	El Oro	0.00 %	2.55 %	12200
Pimampiro	Imbabura	0.00 %	2.62 %	12970
Catamayo	Loja	0.00 %	3.48 %	30638
Macará	Loja	0.00 %	3.59 %	19018
Gualaquiza	Morona S.	0.00 %	3.46 %	17162
Sucúa	Morona S.	0.00 %	2.95 %	18318
Mera	Pastaza	0.00 %	5.67 %	11861
La Troncal	Cañar	0.02 %	2.18 %	54389
Pasaje	El Oro	0.03 %	2.98 %	72806
San Miguel	Bolívar	0.05 %	2.35 %	27244
Zamora	Zamora	0.05 %	5.56 %	25510
Loja	Loja	0.06 %	4.82 %	214855
Morona	Morona S.	0.06 %	3.77 %	41155
Azogues	Cañar	0.07 %	5.06 %	70064
Atacames	Esmeraldas	0.07 %	2.15 %	41526
Quevedo	Los Ríos	0.07 %	2.46 %	173575
Guaranda	Bolívar	0.10 %	2.04 %	91877
Caluma	Bolívar	0.10 %	2.35 %	13129
Playas	Guayas	0.10 %	4.73 %	41935
Ambato	Tungurahua	0.11 %	5.37 %	329856
Antonio Ante	Imbabura	0.12 %	2.53 %	43518
Machala	El Oro	0.16 %	4.29 %	245972
Durán	Guayas	0.16 %	2.66 %	235769
Esmeraldas	Esmeraldas	0.18 %	2.54 %	189504
Ibarra	Imbabura	0.20 %	4.33 %	181175
Lago Agrio	Sucumbíos	0.22 %	2.70 %	91744

Source: SENATEL. Analysis by the authors.

The treatment group is thus defined as the population in those townships that had broadband penetration rates below 0.25 connections per 100 inhabitants at the baseline and above 2.5 connections per 100 inhabitants at the end of the time period.

4.1.3 Variables in the econometric model

The econometric model only covers those individuals living in urban households who also belong to the control or treatment group, as based on the definition presented in the previous section. Also, it only includes those responses related to income, age, health care, and educational

attainment from respondents interviewed in the ICT module of the National Household Survey. These requirements result in a control group of 7664 individuals and a treatment group of 8785 individuals.

The following table lists and explains the variables used in the econometric analysis. Income is the dependent variable and age, gender, health plan, educational attainment, employment status, and role in the household are the control variables. Lastly, the responses regarding computer and Internet usage from the ICT module will be used to estimate the differential impact on individuals directly exposed to the treatment.

Table 10. Variables used in the research

Variable	Explanation	Mean Value
Labor income	The total income in dollars of individuals derived from labor activity	US$ 353.45
Age	Individual age (in years)	40
Men (% Pob.)	Binary variable that takes the value 1 if the individual is a male, 0 if not	58.14%
Public health (% Pob.)	Binary variable that takes the value 1 if the individual has healthcare coverage through the Ecuadorian Social Security Institute (a proxy of formal work), 0 if not	38.85%
Private health (% Pob.)	Binary variable that takes the value 1 if the individual has private healthcare coverage (A proxy of high income or employment), 0 if not	0.90%
Without coverage (% Pob.)	Binary variable that takes the value 1 if the individual does not have healthcare coverage (a proxy of informal labor), 0 if he/she does	60.25%
Primary education o inferior (% Pob.)	Binary variable that takes the value 1 if the individual has a primary-level education or less	32.93%
Secondary education (% Population)	Binary variable that takes the value 1 if the individual has a secondary-level education (complete or incomplete), 0 if not	36.47%
Tertiary education (% Population)	Binary variable that takes the value 1 if the individual has a tertiary education or higher, 0 if no	30.60%
Underemployment (% Population)	Binary variable that takes the value 1 if the individual reports to be underemployed, 0 if he / she has a full-time job	52.45%
Head of household (% Population)	Binary variable that takes the value 1 if the individual is the head of the household, 0 if not	48.46%
Use of computer	Binary variable that takes the value 1 if the individual reports having used a computer in the past 12 months, 0 if not	40.12%
Internet use	Binary variable that takes the value 1 if the individual reports having used the Internet in the past 12 months, 0 if not	32.72%

Source: SENATEL. Analysis by the authors.

4.1.4 Test of Mean Difference at Baseline

The estimated impact of broadband deployment at the canton level needs a control group in order to establish a number of observations with a

counterfactual condition. Along these lines, the cantons that already had residential broadband service in 2009 serve as the control group.

The following table, constructed by using a test of mean differences at the baseline, shows that both the control group and the treatment group are statistically similar when examining the observed variables. The only difference is observed in the underemployed variable, but since this last one is included as a control in the regression, the estimated impact remains valid.

Table 11. Test of mean difference in baseline - Complete sample

Variables	Average treatment group	Average control group	Average difference at baseline	Average difference at target
Dependent Variable				
Labor Income	344.18	363.04	-18.86	5.84
	(12.42)	(21.25)	(24.68)	(26.62)
Independent Variable				
Age	40.56	39.74	0.82	1.55
	(0.47)	(0.50)	(0.66)	(0.49) ***
Male (% population)	58.23	58.06	0.17	2.27
	(0.96)	(1.36)	(1.61)	(1.76)
IESS healthcare (% population)	35.68	42.13	-6.45	-1.15
	(2.55)	(0.31)	(3.84)	(2.64)
Private healthcare (% population)	0.65	1.15	-0.50	-0.44
	(0.08)	(0.34)	(0.34)	(0.49)
Primary education or less (% population)	34.28	31.53	2.75	4.58
	(1.74)	(1.59)	(2.29)	(2.87)
Secondary education (% population)	35.75	37.21	-1.46	0.95
	(1.61)	(0.30)	(3.08)	(5.71)
Underemployment (% population)	55.46	49.33	6.13	8.68
	(1.52)	(0.30)	(3.32) *	(3.26) **
Head of household (% population)	49.19	47.69	1.50	2.95
	(0.95)	(1.24)	(1.58)	(2.09)

In brackets, standard deviation state level clustering
* statistically different at the 10 level, ** statistically different at the 5 level, *** statistically different at the 1 level.

Similarly, Table 12 shows that the control group and the treatment group for the subsample that only includes individuals that used computers are statistically equal at the baseline in terms of the observed variables. In the case of the differences in some variables (e.g. health insurance received by the ***Ecuadorian*** Social Security Institute, underemployment level), they are corrected by introducing these variables as controls in the specified models. Also, including the appropriate control variables corrects the differences between both groups found at the target line.

Table 12. Test of mean difference in baseline - Individuals that used a computer in the last 12 months

Variables	Average treatment group	Average control group	Average difference at baseline	Average difference at target
Dependent Variables				
Labor Income	479.45	492.57	-13.12	29.01
	(17.13)	(28.59)	(32.42)	(20.11)
Independent Variables				
Edad	35.82	35.20	0.62	1.37
	(0.55)	(0.90)	(1.01)	(0.65)**
Male (% population)	55.32	55.33	0.01	-4.29
	(0.92)	(1.40)	(1.71)	(1.92)**
IESS healthcare (% population)	56.85	60.13	-3.28	0.36
	(2.90)	(3.41)	(4.22)	(0.61)
Private healthcare (% population)	1.06	2.02	-0.96	-0.36
	(0,14)	(0.50)	(0.50) *	(0.48)
Primary education or less (% Population)	6.15	5.31	0.84	0.76
	(0.63)	(0.62)	(0.90)	(0.59)
Secondary education (% population)	30.06	33.45	-3.39	-6.65
	(2.28)	(3.19)	(3.69)	(4.45)
Underemployment (% population)	43.41	38.57	4.84	5.89
	(2.26)	(1.97)	(2.94)	(4.83)
Head of household (% population)	39.21	37.46	1.75	6.65
	(1.49)	(2.62)	(2.94)	(3.32) *

In brackets, standard deviation state level clustering
* statistically different at the 10 level, ** statistically different at the 5 level, *** statistically different at the 1 level.

Finally, Table 13 includes a test of mean differences between the control group and the treatment group at the baseline for the subset of individuals who used the Internet.

Table 13. Test of mean difference at baseline - Individuals who used the Internet in the last 12 months

Variables	Treatment group average	Control group average	Average difference baseline	Average difference target
Dependent Variable				
Labor Income	504.85	510.51	-5.66	30.21
	(17.68)	(34.04)	(37.59)	(20.05)
Independent Variable				
Age	35.29	34.51	0.78	1.57
	(0.49)	(0.95)	(1.04)	(0.66) **
Male (% population)	54.79	54.62	0.17	-4.11
	(0.87)	(1.75)	(1.88)	(1.78) **
IESS healthcare (% population)	59.60	61.98	-2.38	0.57
	(3.15)	(3.57)	(4.43)	(0.53)
Private healthcare (% population)	1.19	2.06	-0.87	-0.57
	(0.19)	(0.56)	(0.57)	(0.47)
Primary education or less (% population)	3.68	3.89	-0.21	1.23
	(0.47)	(0.66)	(0.83)	(0.56) **
Secondary education (% population)	25.96	29.44	-3.48	-7.02
	(2.57)	(3.13)	(3.78)	(4.50)
Underemployment (% population)	42.40	36.94	5.46	6.71
	(2.36)	(2.07)	(3.08) *	(3.59) *
Head of household (% population)	37.91	35.40	2.51	2.16
	(1.73)	(2.97)	(3.39)	(1.91)

In brackets, standard deviation state level clustering
* statistically different at the 10 level, ** statistically different at the 5 level, *** statistically different at the 1 level.

To conclude, both the control and treatment groups are initially equal, while the difference in the income level may be due to the treatment effect (controlling for the characteristics, and changes therein, between the baseline and the target line). The following section presents the model results and findings.

5. FINDINGS

5.1 Econometric model

In this section, the average impact on individual income level of broadband introduction at the canton level is estimated. We proceed after showing that the broadband impact variable is exogenous and that both groups are statistically equal in the observed baseline variables. The model used to estimate the treatment effect on the Y variable (individual income) is as follows:

$$Y_i = \alpha + \gamma Treatment_i + \beta X_i + u_i + t_i + e_i \qquad (1)$$

Where i denotes each individual; Y is the dependent variable (individual income); γ is the variable of interest that estimates the causal impact of treatment ('Treatment' is given the value of 1 if the individual was treated; 0 if not treated). X is a vector of control variables including age, gender, educational level, health plan, type of work, and family role; u is a fixed effect defined by the individual's province; t is an annual fixed effect; and, finally, e is the error term.

Table 14 presents the results of the regression estimates for all individuals. It also includes the results for the case that only covers those individuals who used computers in the past 12 months as well as the case that only covers individuals who accessed the Internet in the past 12 months.

Table 14. Estimate of the impact of broadband on individual income in Ecuador 2009-2011

Independent variables	Total population	Computer-using population (last 12 months)	Internet-accesing population (last 12 months)
Treatment	25.76	38.36	51.86
	(12.59) **	(22.40) *	(23.71) **
Age	14.73	11.31	12.84
	(0.79) ***	(1.67) ***	(1.87) ***
Age^2	-0.13	-0.03	-0.04
	(0.01) ***	(0.02)	(0.02) *
Men	72.71	82.43	85.58
	(4.43) ***	(7.23) ***	(7.87) ***
IESS	83.27	105.38	111.95
	(5.81) ***	(10.76) ***	(12.21) ***
Private health	145.43	134.64	134.54
	(19.16) ***	(27.41) ***	(29.37) ***
Primary education	-289.98	-203.21	-150.21
	(5.65) ***	(16.92) ***	(22.34) ***
Secondary education	-207.33	-156.08	-139.82
	(4.66) ***	(7.28) ***	(8.22) ***
Underemployed	-270.08	-288.14	-288.47
	(4.40) ***	(7.42) ***	(8.16) ***
Head of household	71.87	108.19	117.80
	(4.86) ***	(8.14) ***	(8.92) ***
Observations	24 028	12 062	10 497
Fixed effect per year	YES	YES	YES
Fixed effect by province	YES	YES	YES
Mean income of the group	344.18	479.44	504.85
Impact 2009-2011 (%)	7.48%	8.00%	10.27%
Annual impact (%)	3.67%	3.92%	5.01%
R^2	40.89%	36.41%	36.36%

*** statistically significant at the 10 level, ** statistically significant at the 5 level, * statistically significant at the 1 level.

The results in Table 14 indicate that the treatment increased the average individual income by US$ 25.76, which represents a 7.48% increase in relation to the initial average income of the entire sample. Given that the introduction of broadband occurred over the course of two years - between December 2009 and December 2011 - the *annual* increase in the income level was 3.67%. This figure captures the increase in income generated directly by broadband use, the impact on the job market as a result of the labor required for network deployment and the new staff hired by companies to provide the service, as well as the spillover effect on society.

Although the positive impact of broadband introduction at the canton level was already discussed, the impact is even greater among the direct beneficiaries. As evidence, computer users witnessed an average income increase of US$ 38.36, which equates to a total 8.00% increase, or 3.92% per year.

Finally, the largest impact occurs among Internet service users, who benefit from increased speed and, in the case of those users who previously used dial-up Internet service, elimination of the incremental cost of usage. Users who can now access the service directly in their homes as a result of network deployment also benefit. For this group, the increase in the income level is substantially greater than in the previous cases. As a result of the treatment, their income increased by US$ 51.86, a 10.27% rise relative to their initial income, or a 5.01% increase per year.

It should be noted, however, that these differences in income level growth (3.67% versus 3.92% versus 5.01%) are relatively small and, at 95%, not statistically significant. A more detailed examination of the relative importance of these three factors - Internet use, computer ownership, and dial-up access - will require additional statistical analysis.

5.2 Channels

The previous section demonstrated that the introduction of broadband services at the canton level results in an increase in average income. While the causes for this increase can vary, broadband does have an impact on the labor market by way of infrastructure construction, improved labor productivity, skill “signaling” to designate highly skilled workers, and reduced transaction costs. This section reviews these channels through which broadband deployment impacts wages.

Broadband deployment at the canton level requires infrastructure construction in order to provide the service, additional workers for the operator’s new commercial offices, and technical personnel for the installation and maintenance of household broadband. The need for these additional inputs increases in cases where the service is not operated directly by the state-owned provider, CNT, in which case it is offered by a local reseller that specializes in certain local markets. The new demand for labor in a market with an unemployment rate that is already below 5% generates a shift in the demand curve for workers, which leads to an increase in equilibrium wages. Furthermore, the rise in wages through this channel may reflect a need for better compensation for those workers who, given the low unemployment rates, should receive better wages to meet or exceed their reservation wage.

A second explanation for the income increase is that, as seen in Katz (2012), broadband has a positive effect on worker productivity. Classic labor economics literature shows that wages in competitive markets equal marginal productivity. As a result, higher labor productivity should yield higher wages.

Research results also show that the effect of broadband deployment is greater for computer and Internet users. In this sense, the introduction of broadband at the canton level allowed workers with digital literacy skills to signal their computer knowledge to potential employers and then use those skills in the workplace in return for a higher wage.

Finally, the introduction of broadband can also help to reduce the time otherwise required for an effective job search, allowing underemployed workers to look for full-time work using broadband services. This increase in efficiency leads to a reduction in unemployment periods and generates an increase in the migration of underemployed workers to full-time positions, which, in turn, results in higher labor income.

5.3 Robustness testing of results

In order to assess the robustness of the model results, the same model was run, this time changing the treatment group threshold. In this case, the threshold was defined as inhabitants of cantons with broadband penetration rates below 0.15 connections per 100 inhabitants at the baseline (instead of .25 connections per 100 inhabitants in the original model) and more than 4.0 connections per 100 inhabitants at the target line (instead of 2.5 connections).

The results of the new model are presented in Table 15.

Table 15. Estimate of broadband impact on individual labor income en Ecuador 2009-2011 (with threshold change)[a]

Independent variables	Total Population	Internet-using population (last 12 months)
Treatment	66.54	106.10
	(30.62) **	(58.63) *
Age	15.58	12.42
	(1.08) ***	(2.42) ***
Age^2	-0.14	-0.03
	(0.01) ***	(0.02)
Men	74.50	81.80
	(5.88) ***	(10.22) ***
IESS	85.60	114.59

	(7.66) ***	(15.85) ***
Private health	132.74	115.42
	(23.94) ***	(35.69) ***
Primary education	-300.24	-153.48
	(7.63) ***	(29.79) ***
Secondary education	-221.71	-157.60
	(6.15) ***	(10.72) ***
Underemployed	-258.48	-284.00
	(5.91) ***	(10.82) ***
Head of household	78.85	127.41
	(6.43) ***	(11.58) ***
Observations	14 186	6509
Fixed effect per year	YES	YES
Fixed effect by province	YES	YES
Mean income of the group	361.87	517.00
Impact 2009-2011 (%)	18.39%	20.52%
Annual impact (%)	8.80%	9.78%
R^2	39.42%	35.37%

[a] This change in threshold value was considered because a marginal change maintains the treatment and control groups unchanged (see table 9).
*** statistically significant at the 10 level, ** statistically significant at the 5 level, * statistically significant at the 1 level.

The results of the analysis indicate that the model is robust to withstand other thresholds for the absence and/or presence of broadband service. In relation to the original model, the impact on the income level of Internet users in those cantons that went from not having any service to a penetration level above 4% is greater (9.78% versus 5.01%). This result is particularly important because it indicates that possible positive externalities of scale can result from Internet use. In other words, the higher the broadband adoption rates among Internet users, the greater the impact on income levels. In terms of Internet use, return to scale was already identified in the analysis of the digitization impact (Katz et al., 2013). In this last case, when examining causality, higher broadband adoption is accompanied by increased efficiency in terms of information transmission, and, as a consequence, accelerated income growth.

5.4 Impact on income controlling for gender

To evaluate in more detail the channels that impact income, the sample was broken down by gender: male and female. Table 16 presents the results of the estimated impact of broadband on male income.

Table 16. Estimated impact of broadband on individual labor income of men in Ecuador 2009-2011

Independent variables	Total population	Computer-using population (last 12 months)	Internet-using population (last 12 months)
Treatment	27.24	77.66	83.09
	(17.60)	(32.60) **	(33.91) **
Age	14.33	15.30	17.27
	(1.17) ***	(2.48) ***	(2.80) ***
Age^2	-0.13	-0.08	-0.09
	(0.01) ***	(0.03) ***	(0.03) ***
IESS	95.79	116.54	127.57
	(8.37) ***	(15.65) ***	(17.91) ***
Private health	176.32	169.72	167.55
	(27.63)***	(39.88) ***	(43.20) ***
Primary education	-313.90	-194.89	-112.97
	(7.92) ***	(22.93) ***	(30.92) ***
Secondary education	-224.36	-156.90	-135.00
	(6.69) ***	(10.49) ***	(11.80) ***
Underemployment	-265.74	-303.05	-305.47
	(6.26) ***	(11.06) ***	(12.27) ***
Head of household	104.32	140.86	143.51
	(7.36) ***	(12.13) ***	(13.25) ***
Observations	13 802	6551	5658
Fixed effect per year	YES	YES	YES
Fixed effect by province	YES	YES	YES
Mean income of the group	394.00	537.67	565.24
Impact 2009-2011 (%)	6.91%	14.44%	14.70%
Annual impact (%)	3.40%	6.98%	7.10%
R^2	37.62%	35.16%	35.56%

*** statistically significant at the 10 level, ** statistically significant at the 5 level, * statistically significant at the 1 level.

Analysis of this subsample indicates that introducing broadband at the canton level positively impacts the income of the male population. This impact is more pronounced in cases of individuals with skills that allow for the productive use of new technology, with little difference between computer use and Internet adoption. Unlike the general model in Table 14, the difference in impact between the whole population sample and the sample of individuals who use computers or access the Internet is, at 99%, statistically significant. At the same time, the impact on the female subsample is not statistically significant.

To determine how the treatment variable interacts with gender, the results of the regression are presented below.

Table 17. Estimate of the impact of broadband on individual labor income in Ecuador 2009-2011 – Treatment interaction with gender

Independent variables	Total population	Computer-using population (last 12 months)	Internet-using population (last 12 months)
Treatment	36.56	45.35	56.06
	(13.43)***	(23.50) *	(25.01) **
Men	81.54	88.21	88.87
	(5.85)***	(9.32)***	(10.05)***
Male*Treatment	-18.14	-12.47	-7.30
	(7.84)**	(12.70)	(13.85)
Age	14.72	11.31	12.84
	(0.79)***	(1.67) ***	(1.87) ***
Age^2	-0.13	-0.03	-0.04
	(0.01) ***	(0.02)	(0.02)*
IESS	83.38	105.32	111.90
	(5.80) ***	(10.76)***	(12.20) ***
Private health	146.34	135.12	13.82
	(19.16)***	(27.42) ***	(29.40) ***
Primary education	-289.87	-203.11	-150.17
	(5.65) ***	(16.92) ***	(22.34) ***
Secondary education	-207.14	-155.97	-139.76
	(4.66)***	(7.28) ***	(8.22) ***
Underemployed	-270.34	-288.33	-288.57
	(4.40)***	(7.42) ***	(8.22) ***
Head of household	72.00	108.54	118.06
	(4.86)***	(8.15) ***	(8.94) ***
Observations	24 028	12 062	10 497
Fixed effect per year	YES	YES	YES
Fixed effect by province	YES	YES	YES
Mean income of the group	344.18	479.44	504.85
Impact 2009-2011 (%)	10.62%	9.46%	11.10%
Annual impact (%)	5.18%	4.62%	5.41%
R^2	40.91%	36.41%	36.36%

*** statistically significant at the 10 level, ** statistically significant at the 5 level, * statistically significant at the 1 level.

In Table 17, the treatment effect is still significant in all three groups, and gender does not appear relevant in cases where the individual used a computer or the Internet prior to the introduction of broadband at the canton level.

6. CONCLUSIONS AND FUTURE RESEARCH

In summary, this work provides evidence of the positive impact of broadband in Ecuador based on a series of econometric models developed using macro and micro data. The following table outlines the set of results.

Table 18. Economic impact of broadband in Ecuador

Type of model	Type of impact	Evidence
Multiple structural models based on macrodata	Impact on GDP growth	The average annual contribution to GDP growth was estimated at 0.052% for every 1% increment in broadband penetration
Simple regression models based on macrodata	Impact on job market	A 1% increase in broadband penetration increases the employment rate by 0.0156 percentage points, and a drop of 0.105% in unemployment
Regression models based on microdata	Average impact on individuals' income levels	Broadband deployment in cantons that were unserved up until 2009 results in a 3.67% annual increase in income levels
	Impact on income levels of individuals that own computers	Broadband deployment in cantons that were unserved up until 2009 results in a 3.92% annual increase in income levels
	Impact on income levels of individuals that access the Internet via dial up	Broadband deployment in cantons that were unserved up until 2009 results in a 5.01% annual increase in income levels
	Impact on income levels of male individuals that access the Internet via dial up	Broadband deployment in cantons that were unserved up until 2009 results in a 7.10% annual increase in income levels

Different methodologies and models, including structural models as well as simple regression models based on macro- and microdata, confirm the positive economic effects of broadband deployment.

In particular, the microdata model shows that broadband deployment at the canton level increases average income by US$ 25.76 (a rise of 3.67% annually) on a monthly income of US$ 353.45. Furthermore, this impact on income tends to increase with technology adoption (computers, Internet, dial-up access) due to four effects included in the treatment:

- Infrastructure Effect: broadband deployment has an impact on the creation of jobs needed for network construction (direct labor and indirect labor have been quantified in studies with input/output matrices, Liebenau 2010, Katz and Suter, 2009, Katz et al., 2010). With unemployment rates below 5% (full employment), job creation generates a shift in the demand curve, which in turn increases wages.

- Productivity Effect: in competitive markets, wages equal the ***marginal product of labor***, thus more productive workers equals higher average wages.

- Skill Signaling Effect: broadband deployment allows workers with computer and Internet skills (i.e. workers who already used computers) to signal their knowledge and skills in exchange for higher pay.

- Improved access to the job market: reduced transaction costs related to finding employment can ultimately result in higher income (with less search time required, the underemployed can find full-time work)

The future research agenda should focus on exploring these effects in more depth. This evaluation must also include falsification exercises to verify broadband's impact on income in the absence of effects related to other public policies, such as investment in education or infrastructure.

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