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Energy Division

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POLICY BRIEF Nº
IDB-PB-253

June 2016

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Inter-American Development Bank

Cataloging-in-Publication data provided by the
Inter-American Development Bank
Felipe Herrera Library

Jiménez, Raúl.
Rural Electricity Access Penalty in Latin America: Income and Location / Raúl Jiménez.
p. cm. — (IDB Policy Brief ; 253)
1. Rural electrification-Latin America. 2. Electric power distribution-Latin America. 3. Rural poor-Latin America. 3. Low-income consumers-Latin America. I. Inter-American Development Bank. Energy Division. II. Title. III. Series.

IDB-PB-253

http://www.iadb.org

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Abstract

This paper examines three intrinsic underlying variables affecting the provision of rural electricity services: household income, household location and a country's relative wealth in terms of per capita income. A cross section of nationally representative household surveys from sixteen Latin American countries provides a recent snapshot of access to electricity in the region. This examination shows that despite recent progress in rural electrification, low-income countries still face significant challenges. Rural electricity coverage is as low as 55% for the poorest income group in some LAC countries, while around 90% of the total access gap is concentrated among the poorest households living in rural areas of low-income countries. Location explains most of the lack of access, however in low-income countries, income is also a key barrier to electrification. These patterns translate into a sizeable barrier to electricity access that mainly affects poor households in poor countries, emphasizing the need for effective rural electrification programs to promote inclusive economic growth and social well-being.

JEL codes: O18, O55, Q01, Q41

Key words: rural electrification, Latin American countries, economic development, poverty, residential sorting.

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The findings, interpretations and conclusions herein are strictly those of the author and should not be attributed in any manner to his affiliated institutions. The document was prepared under the lead of Ariel Yepez-Garcia, Energy Division Chief. The author is grateful for comments and suggestions of Arnaldo Vieira de Carvalho, Hector Baldivieso, Lauro Lage-Filho, David Lopez, and Javier Castillo. All remaining errors are the author's responsibility.

1. Introduction

Access to electricity represents a major component of modern life, and the goal of reaching universal access has received strong support at national and international levels. Still, the effectiveness of electrification programs has been varied, resulting in slow-paced electrification (Cook 2011; D. F. Barnes 2010; Doll and Pachauri 2010) with around 1.2 billion people still lacking this basic infrastructure as of 2013.[1] Economic factors and the dispersion of rural settlements are frequently cited as explanations for this slow progress; however, there is limited evidence available about the basic patterns characterizing electrification (Zvoleff et al. 2009; Lee et al. 2015).

Certainly two key dimensions for understanding the process of electrification are household income and geographic location. Household income greatly influences electricity access, as households with higher incomes can more easily afford connection costs. Also, income levels are strongly associated with appliance ownership, leading to high levels of electricity demand among richer households, which makes them more attractive clients for electricity providers. On the other hand, the geographic location of rural communities presents a technical challenge to the extension of traditional electricity services at a reasonable cost. The above conditions—income and location—interact in ways that may multiply the difficulties of providing electricity. Lower rural population density implies lower, more dispersed demand, higher costs of transmission and distribution, and lower market financial incentives for electrification in such areas.

Along with these factors, national income also shapes the path of electrification. Dynamic economic growth translates into greater demand for physical infrastructure, which sustains increased economic activity and induces greater demand for services from a population with rising income. An interrelated channel is that as national income grows, a country's financial capability to face the above challenges also increases. Indeed, aggressive rural electrification programs have typically relied heavily on fiscal resources (i.e Barnes & Foley, 2004; Kitchens & Fishback, 2013) under general goals of fostering social and economic progress.

This paper characterizes patterns of access to electricity, distinguishing between household location, household income, and national per capita income, a less commonly examined variable in the literature that can also be interpreted as an indicator of economic development. We apply modern descriptive tools to examine these dimensions in a set of nationally representative households surveys from 16 Latin American (LA) countries, with a focus on the following questions: What are the relative roles of location and income in the electrification process? and what is the electricity

[1] According to the International Energy Agency, World Economic Database 2015.

access gap between countries at different stages of development? We exploit a collection of micro data from LA countries to provide a comprehensive picture of these determinants of electrification.

The LA region is a suitable case study for investigating these questions, as it comprises a heterogeneous set of countries at different stages of development and with different degrees of electricity coverage. The sample also includes countries with significantly different geographical conditions, adding an important source of variability in order to meaningfully address the proposed questions. Our collection of nationally representative household surveys from the most recent year available allows us to take into account the location of each household and to provide a recent snapshot of the conditions of electrification in the LA region.

This work is mainly related to the literature on determinants of electricity access, with a particular focus on the link between income and electricity access. Findings from a number of case studies suggest that household income, household location and political support play a role in determining the effectiveness of rural electrification programs (i.e. Oda and Tsujita 2011; Khennas 2012; Lee et al. 2015; D. F. Barnes 2010; Zvoleff et al. 2009). The study of such determinants and the characterization of patterns of electricity access also contribute to prospective analysis oriented toward strategies that could improve coverage in low income countries (Panos et al. 2016). Our findings also relate to assessments of the relationship between access to electricity and multidimensional measures of poverty, particularly to the literature on equality of access to basic services as a basis for development (Barros 2009). Access to electricity is included in indexes aimed at quantifying poverty beyond income,[2] and it is a stated necessary transversal condition for meeting all millennial development goals (MDG) (Modi et al. 2005).

The main results indicate that household income and location tend to have similar weight in explaining the lack of electricity access. However, a country's overall stage of economic development seems to determine the likelihood that a given household has access. That is, given similar levels of household income and taking into account geographical characteristics, a family in a poorer country has a lower probability of having electricity.

This brief is structured as follows. Section 2 provides background on the data to be analyzed, with particular attention to its representativeness. Section 3 presents some patterns in electrification progress over the last few decades. Section 4 examines the role of household income, household location and per capita income. Section 5 lays out the final remarks.

[2] Two efforts are the Global Multidimensional Poverty Index (MPI) and the Human Opportunity Index.

2. Data

The regression analysis is based on a cross-sectional dataset of nationally representative household surveys from 12 countries for the year 2014, with the exception of Chile (2013). The countries were selected based on the availability of household surveys with relevant variables for analysis, including geographic location (urban versus rural), household income, and access to electricity. The unit of observation is the household, which is the main analytical unit used in welfare and public policy analysis, and is strongly related to the number of electricity connections in a given country. In addition, descriptive statistics are also presented for four additional countries: Colombia, Jamaica, Nicaragua, and Uruguay. While these countries provide income information, in their cases it was not possible to identify household location variables with sufficient disaggregation.

Access to electricity is defined as a household reporting that they are connected to the grid, either directly or indirectly, or that they receive electricity from an isolated solution, whether individual or communal.[3] The ratio of electricity coverage is then defined as the number of households with access to electricity divided by the total number of households. We do not address the availability and quality of electricity service, important dimensions in which differences may be found between off-grid and on-grid access, area of living (urban/rural), or income groups.

Since this examination is by income group, it is important to emphasize that we restricted the sample—used to calculate the access ratio—to those households reporting a positive income. Therefore, there are two potential sources of bias in the calculation of electricity access mean by income group: non-response in access and/or in income. Systematic non-response patterns between the two variables could lead to a biased calculation. For example, if low-income households without access to electricity tend not to declare information related to income, then dropping those observations would lead to an overestimate of electricity coverage for those income groups. Similarly, if high-income groups with access to electricity tend not to declare income, it would lead to an underestimate of the country's access ratio. If households not reporting access to electricity also tend not to declare income, that would introduce significant uncertainty as to the representativeness of the calculations.

Annex 1 reviews both sources of non-response in our sample. The share of households not reporting whether they have access to electricity is small, representing 0.1% of the total sample,

[3] The specific type of connection—on-grid versus off-grid—was only distinguished in the survey questionnaires from nine countries, with off-grid access making up a relatively small portion of access in all of those countries.

with non-response occurring only in four countries. In contrast, the share of households not providing their income is 15.7%. The correlation between the two types of non-response is small and statistically nonsignificant, suggesting no systematic loss of information. However, as income non-response is found in each country and in a significant share of the sample, the main concern is the presence of a systematic pattern between income non-response and access to electricity. Table A.2 presents a test of equal means between the entire sample and the sample reporting positive income (which is used for analysis here) indicating nonsignificant statistical differences. Therefore, no significant source of bias is identified, and no imputation measures are applied to the sample.

Per capita household income is calculated as the total monetary income of the household divided by the number of household members.[4] It is expressed in purchasing power parity at 2011 prices. Income quartiles are calculated with this measure for each country. To account for national per capita income, the countries are classified in three groups encompassing low [2,240-3,833], middle [4,000-6,080] and high [9,647-14,843] income. Low-income countries include Honduras, Jamaica, Bolivia, Guatemala, El Salvador, and Nicaragua. Middle-income countries include Paraguay, Ecuador, Colombia, Dominican Republic, and Peru. High-income countries include Costa Rica, Mexico, Brazil, Chile, and Uruguay. This classification is based on each country's gross per capita national income (Atlas method) averaged over the 2012–2014 period, as reported by the World Development Indicators. However, Colombia, Jamaica, Nicaragua and Uruguay are not considered in the calculations of section four due to their lack of sufficient location data.

The final data set contains over 380,000 households, around 94,000 of which are located in rural areas. The 16 countries in Table 1 represent over 80% of the population of the Latin American and Caribbean (LAC) region. In the 12 countries with location information (out of the 16), there are around 70,000 rural households and more than 5,900 location dummies indicating either a municipality or a village, with an average of 14 households per location.

Other information comes from the World Development Indicators (WDI).[5] Note that in the WDI, electricity coverage is defined as the percentage of the population with access to electricity, with 2012 being the most recent year available; therefore, its access rates are not perfectly comparable with our estimations that use the household as the unit of measure.

[4] In the case of Nicaragua, instead of income we used household consumption expenditure.

[5] Downloaded in June 2015.

Table 1: Summary Statistics

Countries	Survey year	Per capita GNI [1/.]	Sample of households [2/.]		Locations[3/.]	
			Urban	Rural	Urban	Rural
Bolivia (BOL)	2014	2,590	6,910	2,194	669	198
Brazil (BRA)	2014	11,997	86,965	12,450	7,679	1,443
Chile (CHL)	2013	14,843	44,941	10,424	312	274
Colombia (COL)	2014	7,627	45,695	5,055	.	.
Costa Rica (CRI)	2014	9,647	4,783	4,741	570	550
Dom. Republic (DOM)	2014	5,860	4,226	2,562	151	174
Ecuador (ECU)	2014	5,770	16,504	10,815	209	555
Guatemala (GTM)	2014	3,263	2,263	1,288	138	142
Honduras (HND)	2014	2,240	2,700	2,055	115	464
Jamaica (JAM)	2012	5,200	3,676	2,868	13	13
Mexico (MEX)	2014	9,717	13,067	4,754	2,345	280
Nicaragua (NIC)	2014	1,787	5,254	1,298	.	.
Peru (PER)	2014	6,080	17,356	10,328	3,236	1,529
Paraguay (PRY)	2014	4,007	3,064	1,708	329	170
El Salvador (SLV)	2014	3,833	10,003	6,954	174	180
Uruguay (URY)	2014	15,300	32,258	5,030	.	.
Total	-	6,860	299,665	84,524	15,940	5,972

Source: Author's elaboration based on data from National Household Surveys.
Note: 1/. Per capita Gross National Income (GNI), Atlas Method from World Development Indicators (WDI); 2/. Sample of households in each National Household Survey, unexpanded values; 3/. Number of Locations identified in each National Household Survey.

3. Background

Over the last few decades, there has been significant growth in access to electricity, but the speed of electrification has differed dramatically from country to country. Table 2 presents rates of electrification by income group and by region over the 1990–2012 period, showing that in low-income countries—mainly in Sub-Saharan Africa—the electrification process over the last few decades has been slower than in wealthier countries, with low rates of coverage persisting in both rural and urban areas. In fact, the developing world represents the bulk of lack of access as reported by the International Energy Agency. As of 2013, 1,200 million people lack electricity, of which around 97% are in Africa and Developing Asia (IEA 2015).

In this context, Latin America and the Caribbean (LAC) countries have seen notable progress over the last 25 years. At the beginning of the '90s, most urban populations in the region already had access to electricity, and most of the progress since then has occurred in rural areas where the electrification rate increased from 65% in 1990 to 87% in 2012. This translates into a regional access gap of around 22 million people without electricity, according to IEA (2015).

Table 2: Electrification Rates 1990–2012
(Ratio of population with access to electricity)

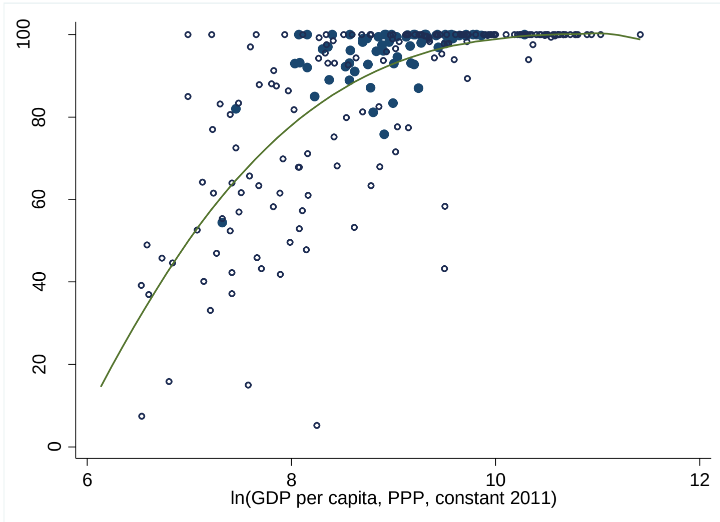
	All			Urban			Rural		
	1990	2000	2012	1990	2000	2012	1990	2000	2012
By income level									
Low income	14.8	17.0	24.9	45.3	45.4	58.7	2.6	4.4	12.2
Lower middle income	55.0	64.8	78.1	87.5	92.8	94.9	40.4	50.1	68.1
Middle income	73.5	79.6	87.5	93.7	96.0	97.6	62.1	67.5	78.3
Upper middle income	92.5	95.8	98.6	98.5	98.4	99.7	87.9	91.9	97.1
High income	99.0	99.3	99.8	99.1	99.4	99.9	98.7	99.1	99.5
By Region									
Latin America and the Caribbean	89.1	92.8	96.4	97.6	97.9	99.0	64.6	75.4	87.0
East Asia & Pacific	87.5	92.2	96.1	96.8	97.5	98.8	82.2	86.7	92.9
Europe & Central Asia	99.2	99.6	100.0	99.5	99.8	100.0	98.3	99.2	100.0
South Asia	49.5	61.3	78.0	86.1	96.2	97.5	36.2	46.7	69.4
Middle East & North Africa	86.0	90.5	96.3	95.0	96.0	99.0	74.9	82.7	90.2
Sub-Saharan Africa	22.8	26.1	35.4	61.1	60.3	71.9	7.7	9.8	15.3
World	75.7	79.3	84.7	94.3	95.3	96.5	60.8	64.2	71.8

Source: Author's elaboration based on information from WDI.

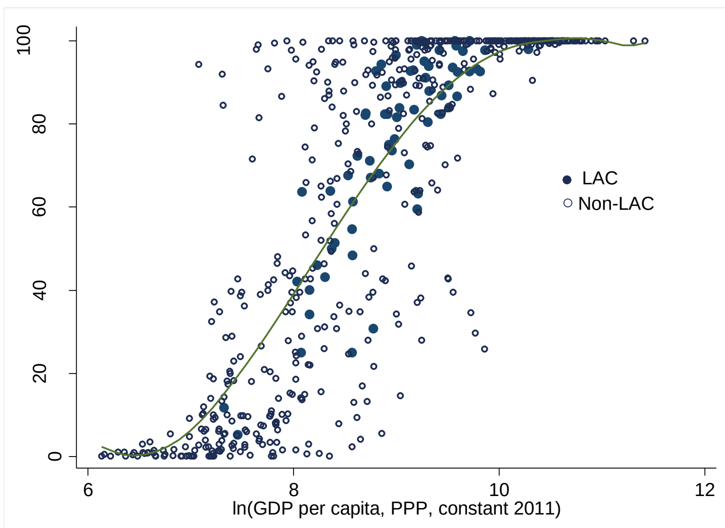
Throughout this process, growth in electrification has closely followed the path of economic growth, but with different patterns in urban versus rural areas. As shown in Figure 1, in general, the relationship between electricity access and countries' per capita income appears to be nonlinear, suggesting that reaching higher per capita income levels disproportionately increases the electricity coverage. This relationship differs visibly between urban and rural areas, as electricity access among lower income levels tends to grow at a more accelerated rate in urban than in rural areas. In particular, below 20% coverage and at lower income levels, electrification in rural areas is slower than its urban counterpart. As per capita income increases, coverage rises steeply until it reaches about 80%–90% coverage, after which electrification expansion decelerates, mainly due to the financial and technical difficulties of reaching more isolated rural households. Such difficulties are more common in rural than in urban areas, explaining to a certain extent this nonlinear pattern that is more pronounced in rural areas.

Figure 1: Relationship Between Country Electrification Rates and Per Capita Income (2012)

Panel A - Urban



Panel B - Rural



Source: Author's elaboration based on information from WDI.
Note: Trends are 3-degree local polynomial smooth lines using epanechnikov kernel function.

Lack of electricity is concentrated among lower income families in rural areas, but patterns and intensities in electricity access vary from country to country. Table 3 shows the distribution of access to electricity across income groups, revealing that in urban areas, access to electricity tends to be almost complete and mostly homogeneous across countries and income groups, although with the important exception of the poorest quartile (Q1) where some gaps persist. In contrast, half of LAC countries reviewed here still have rural electrification rates below 90%, indicating that the LAC electrification gap is mostly rural. Rural electrification rates range from 55% for the lowest income group in Nicaragua to almost universal access in Uruguay. That is, the income classification groups countries, and households within them, according to their electrification access; indicating that lack of access is concentrated in the poorest groups, and mainly in low-income countries. Moreover, it is notable that lack of access is spread along the entire income distribution in relatively low-income countries such as Bolivia, Nicaragua, Peru, Guatemala, and Honduras, indicating severe barriers to electricity expansion in those economies.

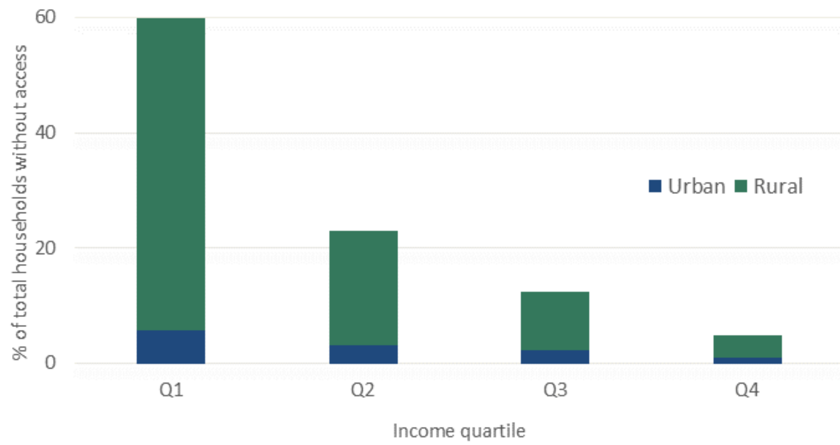
Table 3: Electricity Coverage Ratio by Area and Income Quartile
(% of households with electricity access on-grid and off-grid)

Country	Urban				Rural				All
	Q1	Q2	Q3	Q4	Q1	Q2	Q3	Q4	
Bolivia	98.1	99.0	99.6	99.8	64.4	78.6	76.1	82.0	90.0
Brazil	99.9	100	100	100	97.4	98.8	98.7	99.1	99.7
Chile	99.7	99.8	99.9	100.0	97.6	98.5	98.7	99.0	99.6
Colombia	99.5	99.8	99.9	100.0	87.8	92.5	93.9	95.4	97.8
Costa Rica	99.3	99.7	100.0	99.9	96.9	99.4	99.1	99.8	99.3
Dom. Republic	99.6	99.9	99.9	99.9	92.0	94.8	93.9	98.9	98.1
Ecuador	99.7	99.8	99.9	99.9	95.2	98.2	98.8	98.9	99.0
Guatemala	90.1	94.7	98.3	98.8	67.0	76.3	85.6	92.5	87.5
Honduras	93.8	98.7	99.3	100.0	66.6	77.0	90.5	93.8	88.7
Jamaica	82.6	91.0	92.5	95.6	91.7	96.0	98.0	99.3	93.3
Mexico	98.9	99.5	99.4	99.8	95.6	97.4	98.6	98.6	98.8
Nicaragua	93.4	98.5	99.3	99.9	54.6	73.1	78.6	87.9	85.7
Peru	96.5	99.0	99.5	99.6	71.7	80.2	85.4	89.2	93.1
Paraguay	99.4	99.9	99.9	100.0	96.4	99.3	98.6	98.4	99.0
El Salvador	95.2	97.7	98.0	99.4	89.1	91.4	90.4	95.7	95.3
Uruguay	99.7	99.8	100.0	100.0	97.8	99.2	99.3	99.3	99.7

Source: Author's calculation based on data from National Household Surveys.
Note: Access by income level is estimated for samples with positive reported income.

To better appreciate the distribution of lack of access by geographic area and household income groups in LAC, Figure 2 shows the share of total households without access by area and income quartile. Approximately 90% of total households without access to electricity in our sample live in rural areas. Around 75% of the total access gap is located in the two lowest income groups in rural areas. Lack of access in urban areas seems to be a problem in Guatemala, Honduras, Nicaragua and El Salvador, and may be related to the growth of cities via slums with inadequate infrastructure. In urban areas, this mismatch between the growth of cities and the adequacy of infrastructure planning often gives place to an increase in informal electricity connections, translating into electricity and financial losses for utilities.

Figure 2: Percentage of Households Without Electricity by Income Quartile and Area

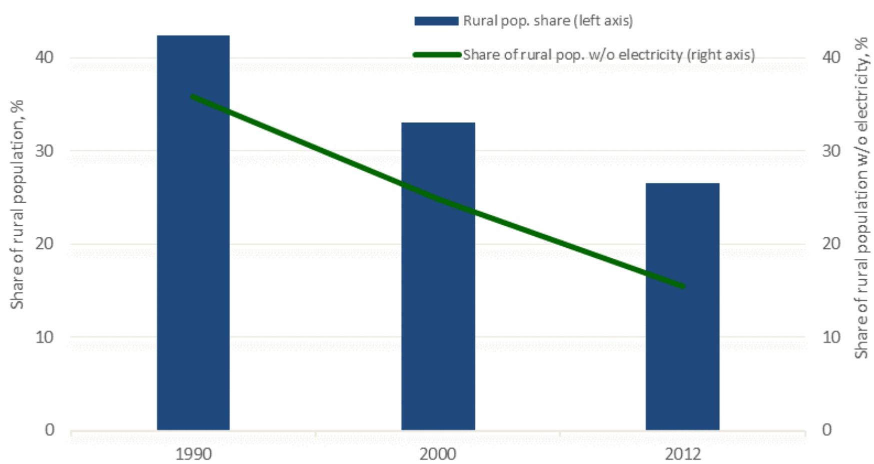


Source: Author's elaboration based on data from National Household Surveys.

Previous patterns suggest that a country's overall stage of economic development conditions access to electricity. However, disentangling the effects of household income from the effects of economic development is not a straightforward process, as household income in less developed countries tends to be lower than household income in more advanced economies for the same income group (Annex 2 presents the household income distributions). Distinguishing between the two helps to reveal the extent to which the access problem is due to a given economy's overall investment capacity, versus if there is limited investment because end-users cannot afford connections and thus cannot guarantee that demand for electricity will be profitable. In addition, having established that geographic area largely explains lack of access, finer location identifiers within rural areas in each country may help to better identify the characteristics of the access gap. Even in rural areas with limited electricity infrastructure, it is possible that households lack electricity connections due to their financial incapacity to afford such connections or the required electricity installations.

Another important point is that a related underlying factor behind the observed trends in electrification is their relation to changes in urban-rural population composition. That is, progress in terms of access to electricity may be due, in part, to migration from rural areas to urban centers within a country, or more generally from off-grid areas to on-grid areas. This may be the case in the LAC region, where the rural population share decreased between 1990 and 2012, closely following the decreasing trend in the share of rural population lacking electricity (see Figure 3). Nonetheless, while this pattern is generally sustained, there are important heterogeneities that must be taken into account. For example, in our sample, progress in rural electrification has been observed despite a stable and significant share of rural population in Ecuador, Honduras and Bolivia (Annex 3).

Figure 3: LAC Population Composition and Lack of Rural Access



Source: Author's elaboration based on WDI, 25 LAC countries.

4. Income, Location, and Per Capita Income

This section examines the association between household income, household location and countries' per capita income, focusing on rural areas where most of the lack of access is concentrated. First, we examine the influence of income, area of living (urban/rural) and location (within each area) for each country. Then, we predict the probability of access.

4.1 How Much Do Location and Income matter?

Since living in rural areas has been shown to explain most of the lack of access, an important question is the relative weight of household income, taking into account a finer indicator of geographical location. If, regardless of household location, income is the main driver of lack of access, that is an indication of severe affordability problems. That is, if regardless of available electricity supply in the area, households are unable to connect, this represents a severe sunk cost for public infrastructure, implying the no realization of the expected economic and social benefits, which are usually accounted for during the design stage of electrification projects. On the other hand, if lack of access can mainly be explained by household location, this would indicate a lack of available infrastructure. These two factors are not necessarily exclusive; as discussed by Lee et al. (2015), in some contexts, grid extension does not necessarily translate into greater electrification due to household financial constraints.

To disentangle the correlations between income, location, and electricity access, we performed an ordinary least squares regression with the following specification (1)[6].

$$A_{i,c} = \beta q_{i,c} + \alpha_c + \varepsilon_{ic} \qquad \text{(eq. 1)}$$

Access is defined at the household level (sub-index i) as a dichotomous variable, with 0 indicating no access and 1 indicating access, which may be on- or off-grid. The income is represented by an indicator variable showing whether a household belongs to the lowest quartile of the country's income distribution ($q_{i,c}$). To account for household location, we take advantage of detailed geographical location information data. This information is translated into fixed effects (α_c) indicating the specific location of each household in each country, as detailed in Section 2. This is expected to capture the provision of electricity infrastructure by sub-area. It should be noted that to a certain extent, household income level (and position in income distribution) may correlate heavily with location, particularly in rural areas, potentially leading to multicollinearity. Since, in extreme cases, a high degree of multi-collinearity could lead to obtaining the wrong sign or implausible magnitudes, it is important to select locations with sufficient variability. ε_{ic} represents the error term.

The regressions are performed with and without location dummies. The joint effect of the location dummies is approximated by the reduction in the income coefficient. The estimations are performed for each country in the sample, for the sample as a whole, and for each country income group.

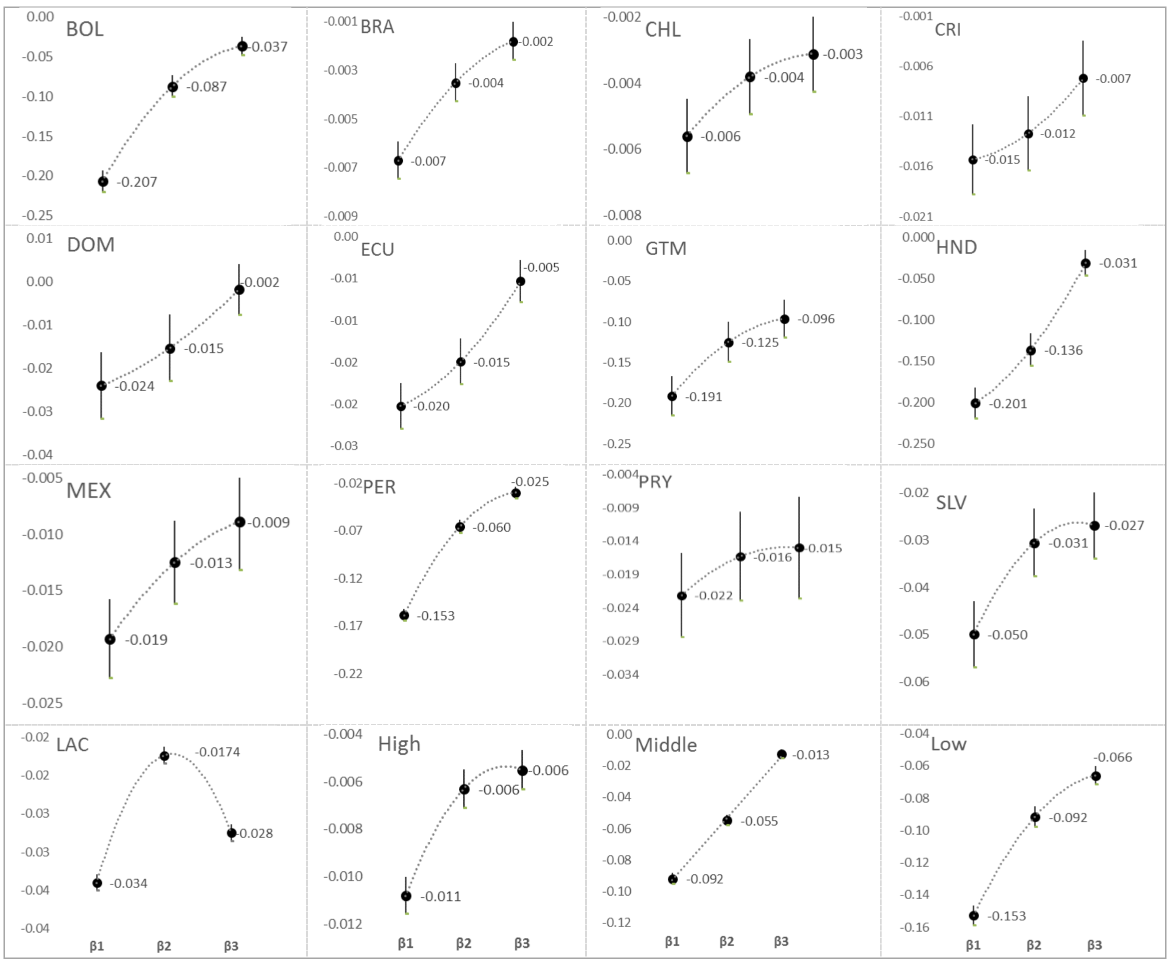
The results are summarized in Figure 4 and detailed in Annex 4. They show that as location indicators are included in the regressions, the income coefficient decreases in all countries, although with significant heterogeneities across countries. While the income coefficient is always statistically significant, it is smaller in higher income countries. The income coefficient goes from 1.1% to 0.6% in high-income countries, from 9% to 1% in middle-income countries, and from 15% to 7% in low-income countries. That is, the introduction of location absorbs around 8% of the income effect. This may be interpreted as a 7% lower probability that households in the lowest income quartile will have access to electricity. This suggests that while location is the key determinant of access, affordability issues are relevant in low-income countries. As can be seen in the LAC panel of Figure 4, the income driver remains relevant even in the pooled sample, after accounting for the full location data.

[6] We closely follow a similar exercise by Schady (2014) in the case of water and sanitation.

In particular, the effect of location is strong in countries at lower levels of economic development, which have less extensive electricity coverage. In Honduras and Guatemala, where the explanatory power of income is always statistically significant and sizeable, it is markedly reduced after location is accounted for. Location seems to matter less in countries with higher electrification rates (i.e. Costa Rica, Chile, Uruguay, Mexico). However, note that in those countries the size of the income coefficient is small. That is, in those countries the remaining lack of access is concentrated in hard-to-reach isolated rural areas, where grid expansion is unfeasible due to topological conditions and low market demand.

Figure 4: Estimated Income Coefficients of Equation 1

($\hat{\beta}$ with confidence interval at 95% for specification without (w/o) and with location dummies)



Note: β_1-without controls; β_2-controlling for urban/rural; β_3-controlling for full set of locations.

4.2 Income, Location and the Likelihood of Having Access to Electricity

To explore the relationship between a country's level of economic development and its electrification rates, this sub-section examines the difference in the probability of having access to electricity for households of similar income but in countries with different levels of per capita gross national income (GNI). We group countries according to section 2 (low, middle and high-income). In order to have sufficient variability, and given how concentrated lack of electricity access is, the analysis focuses on rural households. The access probability is modeled with a logistic approach. So, for a given household i living in location c, the probability of having access $p_{i,c,1}$ is expressed in equation (2), representing a binary logit model with fixed effects with the function of maximum likelihood as equation (3):

$$p_{i,c,1} = \frac{\exp(\beta y_{i,1} + \alpha_{c_i})}{1 + \exp(\beta y_{i,1} + \alpha_{c_i})} \qquad \text{(eq. 2)}$$

$$f_{\mathrm{A}|\alpha_c,\beta,\mathrm{y_i}} = \prod_{i=1}^{N} \frac{\exp(\beta \mathrm{y_i} + \alpha_{c_i}) A_i}{1 + \exp(\beta \mathrm{y_i} + \alpha_{c_i})} \qquad \text{(eq. 3)}$$

In this set-up, the probability of having access is specified to depend on household income ($\mathrm{y_i}$) and household location α_{c_i}. c_i emphasizes that households are grouped within locations, representing the baseline odds. The estimations are performed with and without these fixed effects. We expect that the inclusion of household location helps to predict the probability of having access, and that location is not perfectly correlated with income such that the returned probability under the two models (with and without location) will differ[7,8]. However, the estimations with fixed effects must be interpreted carefully due to the cross-sectional nature of the data.[9] In each regression, it is assumed that β is homogenous across households. The estimations are performed for rural households in each country, and for the three sets of countries grouped according to per capita gross national income. The former allows for the estimate of access probabilities accounting for potential heterogeneity between countries. The latter evaluates whether there is any intrinsic difference in such a probability that may be attributed to the country's relative level of economic development.

Table 4 presents the average predicted probabilities of having access for each income quartile using the model with and without location, and testing the statistical differences in those predictions. Table

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[7] That is, accounting for location adds information to the estimation, with the expectation that it will return more accurate predicted probabilities. In contrast, if location and income are highly correlated, the estimated probability in the model 'without location' would tend to closely resemble the model 'with location.'

[8] We test the difference in predicted $\mathrm{p_{i1}}$ through a t-test.

[9] This is because estimation with fixed effects is developed in panel data structures, while this specification proposes a group structure in a cross-sectional design. In general, under standard maximum likelihood procedures, it will not return consistent estimations for fixed T (Chamberlain 1980). Therefore, this application relies on the assumption of homogeneity among households within each location.

4 indicates that, in rural areas, location plays an important role in determining access to electricity, reducing the expected probability of having access for all income quartiles (note that the estimated likelihoods, with and without location, are statistically different). In particular, accounting for location significantly reduces the estimated probabilities of access in countries such as Honduras and Peru, where electricity access is particularly low, suggesting that independent of household income level, lack of access in rural LAC is related to lack of electricity infrastructure.

Table 4: Average Predicted Probabilities of Rural Electricity Access by Income Quartile

Country	Specif.	Income quartile 1	2	3	4
BOL	w/o	0.63	0.72	0.75	0.79
	w.	0.64	0.67	0.68	0.66
	t-stat	-0.89	2.71	2.88	4.73
BRA	w/o	0.97	0.98	0.98	0.99
	w.	0.78	0.83	0.83	0.87
	t-stat	28.45	18.28	13.98	12.40
CHL	w/o	0.97	0.98	0.98	0.98
	w.	0.94	0.95	0.95	0.96
	t-stat	27.97	22.66	21.31	17.27
CRI	w/o	0.97	0.99	0.99	1.00
	w.	0.78	0.89	0.92	0.94
	t-stat	19.96	16.21	14.67	7.11
DOM	w/o	0.90	0.93	0.95	0.96
	w.	0.78	0.82	0.84	0.86
	t-stat	12.84	8.85	7.81	6.18
ECU	w/o	0.93	0.97	0.98	0.99
	w.	0.84	0.92	0.94	0.96
	t-stat	22.87	14.65	10.83	9.44
GTM	w/o	0.68	0.78	0.82	0.87
	w.	0.62	0.70	0.77	0.88
	t-stat	3.85	5.31	3.22	-0.43
HND	w/o	0.67	0.81	0.86	0.90
	w.	0.53	0.58	0.63	0.69
	t-stat	10.19	13.29	10.32	7.97

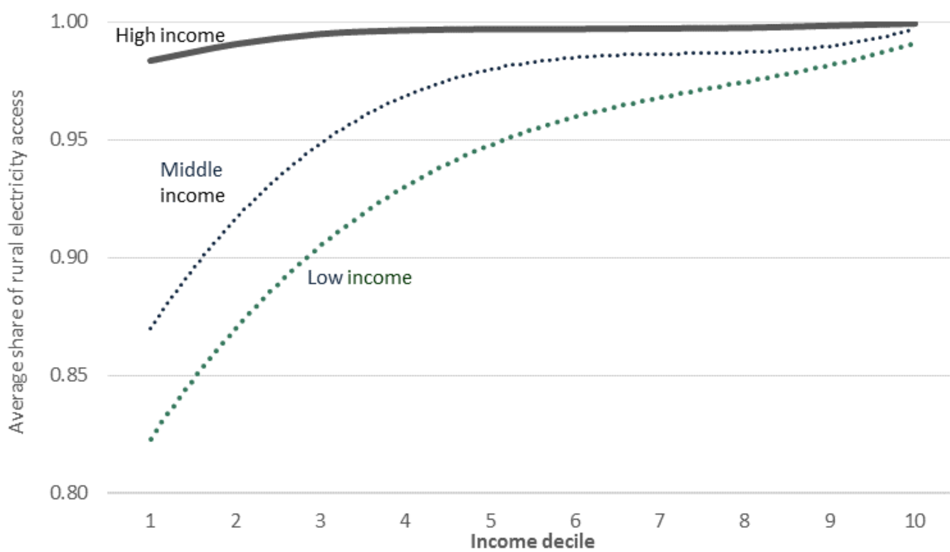
Country	Specif.	Income quartile 1	2	3	4
MEX	w/o	0.96	0.98	0.98	0.98
	w.	0.87	0.91	0.91	0.91
	t-stat	22.93	18.03	10.85	7.73
PER	w/o	0.71	0.80	0.83	0.86
	w.	0.62	0.69	0.73	0.75
	t-stat	17.94	15.12	9.59	8.64
PRY	w/o	0.97	0.98	0.98	0.99
	w.	0.87	0.90	0.92	0.92
	t-stat	25.98	17.00	15.09	14.02
SLV	w/o	0.90	0.92	0.93	0.94
	w.	0.89	0.91	0.92	0.94
	t-stat	10.05	9.75	5.40	1.01
High income	w/o	0.97	0.98	0.98	0.99
	w.	0.88	0.93	0.93	0.94
	t-stat	40.86	30.98	24.09	20.55
Middle income	w/o	0.81	0.89	0.93	0.94
	w.	0.73	0.81	0.85	0.87
	t-stat	25.36	18.66	13.96	11.55
Low income	w/o	0.81	0.87	0.89	0.91
	w.	0.80	0.84	0.86	0.88
	t-stat	2.70	8.31	5.80	5.55

Note: w (w/o) indicates predicted likelihood (not) including location. See country codes in Table 1.

These estimates closely predict the observed patterns of access to electricity in rural areas between income groups and across countries at different income levels, which indicates the relevance of household income and location as determinants of access. The differences in probability among countries of different per capita GNI can be calculated directly from the actual data. Figure 5 presents the average rural electrification rate by income decile for each country-income-group. These curves can be interpreted as the likelihood that a given household has access, and they show that a household in a richer country tends to have a better chance of getting an electricity connection than a household in the same income decile in a poorer country. That is, in this sample, a household in the poorest income decile in a low-income country has about a 15% lower chance of getting access to electricity than a household in the poorest income decile in a high-income country. The observed rural electrification gap may be interpreted as the penalty associated with a low economic development. As observed in the figure, while this penalty tends to decrease as the household income increases, there is a persistent and sizeable gap affecting low-income countries. This pattern shows the progressive character of rural electrification programs.

Figure 5: Rural Access to Electricity by Income Decile and Country Income Group

(16 LAC countries)



Source: Author's elaboration based on data from household surveys.
Note: See country classification in Section 2.

5. Final Remarks

The Latin American and Caribbean region has seen notable progress in access to electricity, particularly in rural areas where the rate of electricity coverage has grown by more than 20% over the last few decades (1990–2012). This progress has closely followed the path of economic growth and seems to be associated with growth in the urban population. Still, lack of access to electricity represents a serious problem that is more pronounced in rural areas in low-income countries where the absence of electricity services tends to extend along the entire income distribution. In our sample, as of 2014 around 90% of households without access belonged to the lowest income groups and lived in rural areas.

The introduction of finer location indicators within countries (beyond the distinction between urban and rural areas) shows the importance of residential sorting for access to electricity. Living in urban areas significantly reduces the weight of household income as a barrier for having electricity. These location fixed effects explain around 8% of the access gap in the poorest income quartile. However, after accounting for economic development of a given country, income continues to be an important driver, explaining around 7% of the access gap, suggesting significant affordability problems. That is, all else being equal, a family living in a poor country has less opportunity to get an electricity connection than a family with a similar income living in a richer country (defined in terms of GNI per capita). This represents an access penalty associated with low economic development which is borne by families regardless of their income or the area in which they live.

These cross-sectional estimates represent electricity access ratios, but they also represent the actual chances that a household can access electricity infrastructure, revealing a severe inequality of opportunities which hurts families that live in rural areas of less developed countries. This access penalty has important policy implications. Lack of electricity access constitutes a barrier to expanding economic activity in rural areas, and it is a factor influencing the migration decisions made by the rural households. Access to electricity is an important way to reduce energy poverty, and beyond the energy sector there is a strong body of empirical evidence indicating that electricity access is closely linked to improvement in human development as it increases productivity through specific gains in health, education, and safety. Further, access to electricity improves quality of life and promotes gender equality, two key issues in rural areas (i.e. Fisher-Vanden et al. 2015; Kitchens & Fishback 2013; Lipscomb et al. 2013; Grogan & Sadanand 2013; Barron & Torero 2014; Goldemberg et al. 1985).

Regardless of the benefits of electrification, finding economically sustainable ways to provide access remains a major challenge. Low and dispersed electricity consumption, low household income, and the isolation of rural populations are among the obstacles faced by policymakers. To some extent, these factors explain why the observed process of electrification is strongly associated with the path of economic growth. In this context, electrification programs represent strategies that promote endogenous economic growth and social well-being in a way that facilitates the inclusion of rural areas. As emphasized by Kitchens and Fishback (2013): "providing electricity access contributes to making rural life more attractive by increasing productivity and improving amenities in the home. [This is] expected to have a spatial impact on the population as people move to take advantage of changes in wages and the standard of living associated with the newly constructed infrastructure."

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Annex 1

This annex reviews patterns of non-response with regard to income and access to electricity. Table A.1 presents the percentage of households not responding to questions about their access to electricity and their income (over the entire sample). The last column of this table shows that the correlation between non-responses in each category is not statistically significant at 5%. This test is performed using an OLS regression.

Table A.2 shows the ratio of electricity access for each sample. Since non-response to questions about access is uncommon, we take those values as benchmarks for the analysis of our sample. The last columns present the test of proportions between (A) and (B), suggesting that there are not significant differences between the two.

Table A.1: Non Response in Access to Electricity and Income in National Household Surveys

Country	(A) Share of hh not responding access to electricity			(B) Share of hh not responding income			(C) Statistical significance of correlation between income and access non-response					
							All		Urban		Rural	
	Urban	Rural	All	Urban	Rural	All	t-stat	p-value	t-stat	p-value	t-stat	p-value
BOL	0.0	0.0	0.0	8.3	5.1	7.5	.	.	.	.	.	.
BRA	0.0	0.0	0.0	19.3	25.8	20.1	.	.	.	.	.	.
CHL	0.1	0.5	0.2	15.9	20.6	16.8	-1.64	0.10	-1.73	0.08	-0.82	0.41
COL	0.0	0.0	0.0	11.9	9.1	11.7	.	.	.	.	.	.
CRI	0.0	0.0	0.0	15.6	17.4	16.5	.	.	.	.	.	.
DOM	0.6	2.9	1.5	14.9	14.8	14.9	-1.37	0.17	-1.76	0.08	-1.00	0.32
ECU	0.0	0.0	0.0	10.9	8.7	10.0	.	.				
GTM	0.0	0.0	0.0	6.4	4.4	5.7	.	.				
HND	2.0	1.6	1.8	11.2	16.1	13.4	0.46	0.65	0.71	0.48	-0.18	0.86
JAM	0.3	0.8	0.5	0.0	0.0	0.0	.	.	.	.	.	.
MEX	0.0	0.0	0.0	8.2	9.5	8.5	.	.	.	.	.	.
NIC	0.0	0.0	0.0	5.0	1.7	4.4	.	.	.	.	.	.
PER	0.0	0.0	0.0	9.0	12.3	10.3	.	.	.	.	.	.
PRY	0.0	0.0	0.0	8.3	6.7	7.7	.	.	.	.	.	.
SLV	0.0	0.0	0.0	12.7	28.1	19.7	.	.	.	.	.	.
URY	0.0	0.0	0.0	23.6	21.2	23.2	.	.	.	.	.	.
Total	0.0	0.2	0.1	15.5	16.5	15.7	-1.01	0.31	-1.1	0.27	-1.68	0.09

Source: Author's elaboration based on data from National Household Surveys.

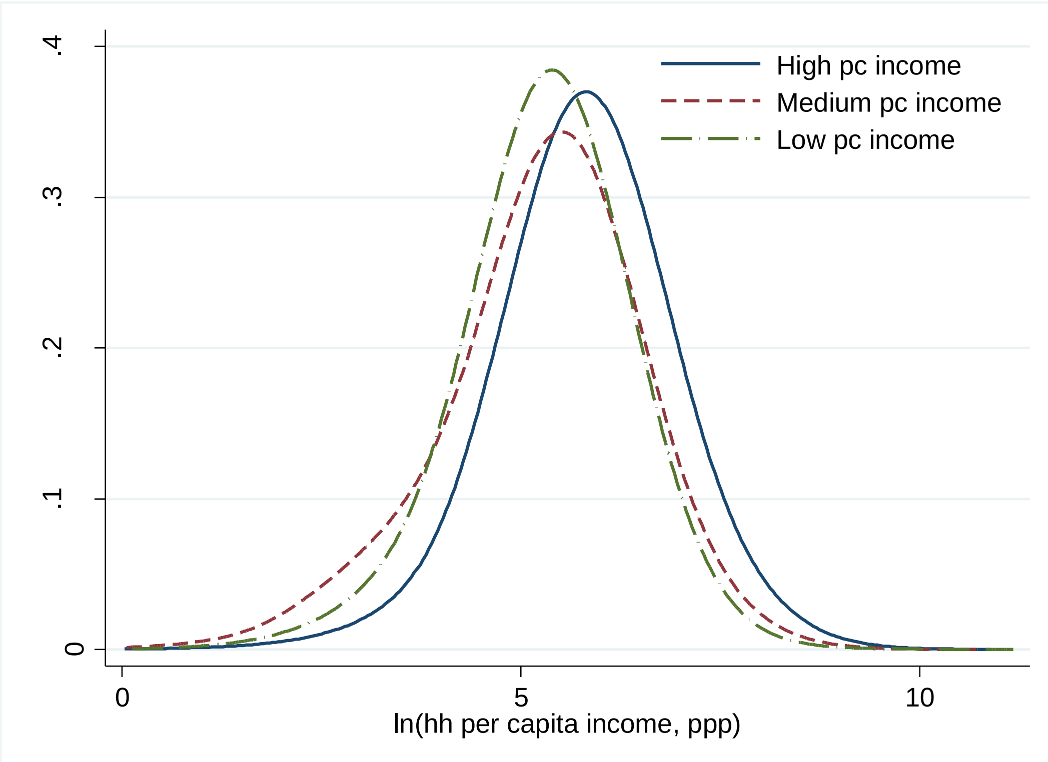
Table A.2: Ratio of Electricity Coverage by Non-Response Sample

Country	(A) All sample			(B) Sample for analysis			(C) Sample not declaring income			prtest Urban		prtest Rural		prtest All	
	Urban	Rural	All	Urban	Rural	All	Urban	Rural	All	z-stat	p-value	z-stat	p-value	z-stat	p-value
BOL	99.3	71.5	90.0	99.3	71.2	89.8	99.1	75.5	93.4	0.1	0.9	0.3	0.8	0.8	0.4
BRA	99.9	97.9	99.7	100.0	98.1	99.7	99.9	97.4	99.4	-1.4	0.2	-1.4	0.2	-2.7	0.0
CHL	99.8	98.0	99.6	99.8	98.2	99.6	99.7	97.1	99.3	-0.9	0.4	-0.9	0.4	-1.7	0.1
COL	99.8	90.5	97.8	99.8	90.4	97.7	99.8	91.7	98.3	-0.3	0.7	0.2	0.8	0.5	0.6
CRI	99.7	98.3	99.3	99.8	98.4	99.4	99.4	97.9	99.0	-0.4	0.7	-0.6	0.6	-0.7	0.5
DOM	99.9	94.4	98.1	99.8	94.2	98.0	100.0	95.5	98.4	0.4	0.7	0.4	0.7	0.5	0.6
ECU	99.8	97.1	99.0	99.8	97.2	99.0	99.8	95.1	98.5	-0.5	0.6	-0.1	0.9	0.0	1.0
GTM	96.7	76.3	87.5	96.7	75.8	87.2	96.7	88.5	93.7	0.0	1.0	0.4	0.7	0.4	0.7
HND	98.8	76.3	88.7	98.7	77.3	89.3	99.5	71.1	84.6	0.3	0.8	-1.0	0.3	-1.3	0.2
JAM	89.7	96.7	93.3	89.7	96.7	93.3	.	.	.	.	.	.	.	.	.
MEX	99.4	96.7	98.8	99.5	96.8	98.9	98.8	96.1	98.2	-0.4	0.7	0.0	1.0	-0.3	0.8
NIC	98.7	67.7	85.7	98.7	67.4	85.4	99.1	82.7	95.7	0.1	0.9	0.0	1.0	0.4	0.7
PER	98.9	75.2	93.1	99.0	76.0	93.6	97.6	69.9	88.5	-0.9	0.3	-1.2	0.2	-2.2	0.0
PRY	99.8	97.8	99.0	99.9	97.8	99.1	99.4	96.6	98.4	-0.4	0.7	-0.1	0.9	-0.2	0.8
SLV	97.8	90.8	95.3	97.9	90.6	95.6	97.5	91.2	94.0	-0.8	0.4	0.8	0.4	-1.0	0.3
URY	99.8	98.7	99.7	99.9	98.8	99.7	99.7	98.2	99.5	-1.0	0.3	-0.6	0.6	-1.0	0.3
Total	99.6	90.5	97.7	99.6	89.9	97.6	99.6	93.9	98.4	0.7	0.5	1.5	0.1	1.1	0.3

Source: Author's elaboration based on data from National Household Surveys.

Annex 2:

Figure A2: Household Income Distribution by Country Income Classification

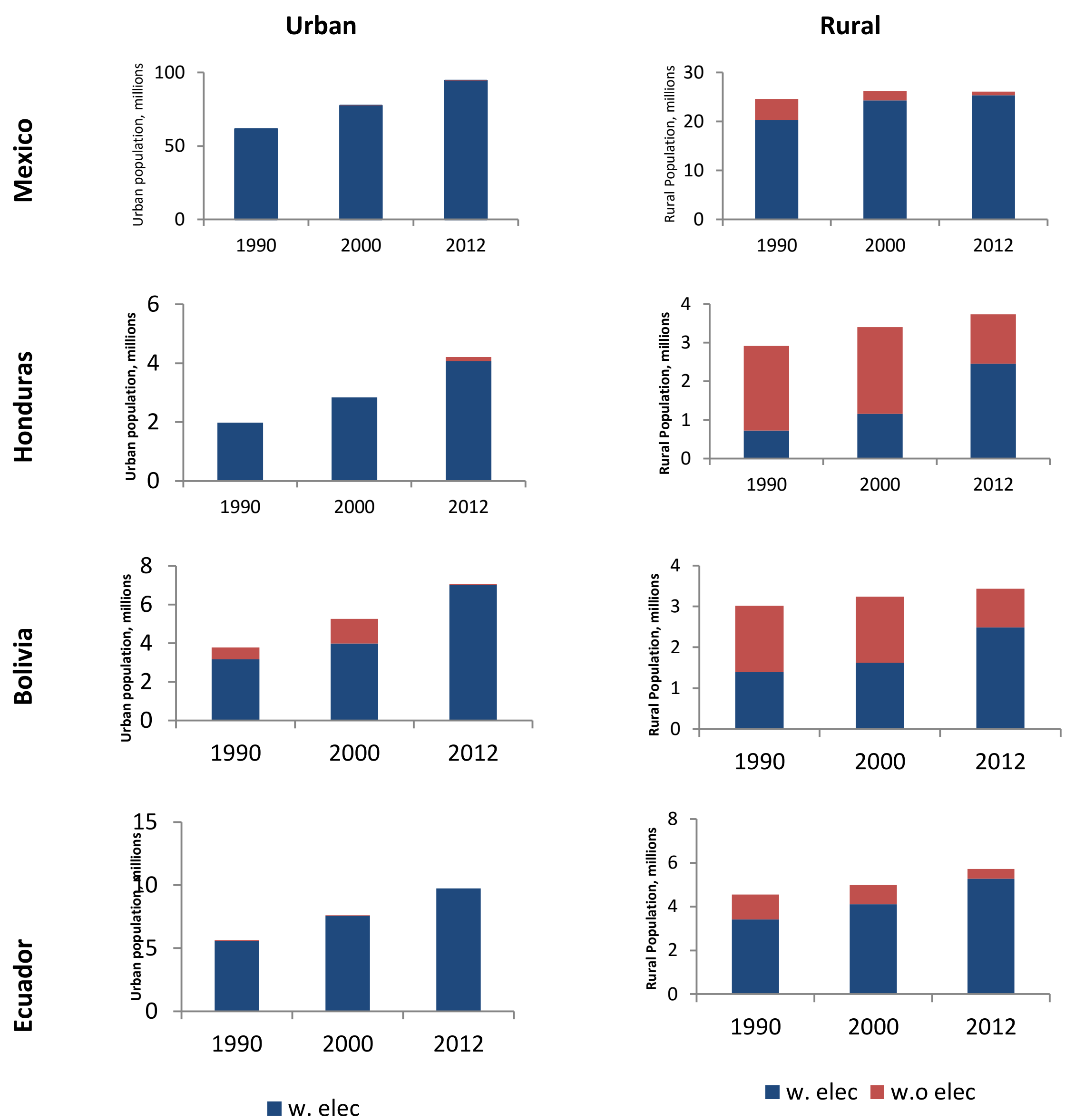


Note: Countries are divided by per capita income according section
Source: Author's elaboration based on data from household surveys.

Annex 3:

Taking into account that changes in electrification rates also depend on the relative composition of the population, below are presented the cases in which rural populations have not decreased in absolute terms and the rural population remains a significant share of the population as a whole.

Table A3: Access to Electricity in Countries with Steady or Increasing Rural Population



Source: Author's elaboration based on data from WDI.

Annex 4:

Table A.4: Electricity Access Penalty of Being in the First Quartile

(Results of Eq. 1)

Country	specif.	Coef.	SE	t-stat	Obs.	R^2 adj.	rmse
BOL	β_1	-.2067***	0.0070	-29.49	9,104	0.09	0.29
	β_2	-.087***	0.0073	-11.92	9,104	0.21	0.27
	β_3	-.0367***	0.0062	-5.97	9,104	0.54	0.21
BRA	β_1	-.0067***	0.0004	-17.36	99,415	0.00	0.05
	β_2	-.0035***	0.0004	-8.89	99,415	0.02	0.05
	β_3	-.0018***	0.0004	-4.47	99,380	0.22	0.05
CHL	β_1	-.0056***	0.0006	-9.66	55,365	0.00	0.06
	β_2	-.0038***	0.0006	-6.58	55,365	0.01	0.06
	β_3	-.0031***	0.0006	-5.16	55,365	0.04	0.06
CRI	β_1	-.0148***	0.0018	-8.09	9,524	0.01	0.08
	β_2	-.0122***	0.0019	-6.5	9,524	0.01	0.08
	β_3	-.0067***	0.0019	-3.52	9,524	0.17	0.07
DOM	β_1	-.024***	0.0039	-6.17	6,788	0.01	0.14
	β_2	-.0153***	0.0039	-3.97	6,788	0.04	0.14
	β_3	-0.002	0.0030	-0.58	6,787	0.46	0.10
ECU	β_1	-.0202***	0.0014	-14.89	27,319	0.01	0.10
	β_2	-.0149***	0.0014	-10.83	27,319	0.02	0.10
	β_3	-.0053***	0.0013	-3.96	27,319	0.20	0.09
GTM	β_1	-.191***	0.0124	-15.35	3,551	0.06	0.32
	β_2	-.1248***	0.0128	-9.75	3,551	0.12	0.31
	β_3	-.0962***	0.0119	-8.09	3,551	0.46	0.25
HND	β_1	-.2006***	0.0098	-20.43	4,755	0.08	0.30
	β_2	-.136***	0.0100	-13.61	4,755	0.15	0.29
	β_3	-.0307***	0.0079	-3.9	4,715	0.63	0.19
MEX	β_1	-.0193***	0.0018	-10.69	17,821	0.01	0.10
	β_2	-.0125***	0.0019	-6.61	17,821	0.01	0.10
	β_3	-.0089***	0.0022	-4.09	17,792	0.07	0.10
PER	β_1	-.1534***	0.0033	-46.9	27,684	0.07	0.24
	β_2	-.0604***	0.0035	-17.19	27,684	0.17	0.22
	β_3	-.0246***	0.0032	-7.76	27,671	0.53	0.17
PRY	β_1	-.0221***	0.0032	-6.86	4,772	0.01	0.10
	β_2	-.0163***	0.0034	-4.8	4,772	0.02	0.10
	β_3	-.015***	0.0039	-3.82	4,772	0.02	0.10
SLV	β_1	-.0499***	0.0036	-13.86	16,957	0.01	0.20
	β_2	-.0305***	0.0037	-8.21	16,957	0.03	0.20
	β_3	-.0268***	0.0037	-7.15	16,957	0.08	0.20
High income	β_1	-.0108***	0.0004	-26.96	182,125	0.00	0.07
	β_2	-.0063***	0.0004	-15.27	182,125	0.01	0.07
	β_3	-.0055***	0.0004	-12.72	182,070	0.16	0.07
Middle income	β_1	-.0918***	0.0018	-51.13	61,791	0.04	0.19
	β_2	-.0547***	0.0018	-29.57	61,791	0.09	0.19
	β_3	-.0126***	0.0015	-8.33	61,777	0.54	0.13
Low Income	β_1	-.1527***	0.0032	-47.44	39,139	0.05	0.28
	β_2	-.0916***	0.0033	-27.57	39,139	0.12	0.27
	β_3	-.0659***	0.0029	-22.83	39,099	0.48	0.21
All countries	β_1	-.034***	0.0006	-60.11	283,055	0.01	0.13
	β_2	-.0174***	0.0006	-30.16	283,055	0.05	0.13
	β_3	-.0275***	0.0006	-47.56	282,997	0.20	0.12

Note: β_1-without controls; β_2-controlling for urban/rural; β_3-controlling for full set of locations; All regressions are robust estimated using the population expansion factor.