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Assessment of Access to Electricity and the Health, Education and Agricultural Productivity Effects in Rural Areas of Colombia

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In Colombia there have been some attempts to measure the impact generated by the energization projects from the technical-economic point of view. However, no studies have been made that address the quantification of the impact of these projects on the quality of life of the populations. Therefore, the purpose of this study is to assess qualitatively the bidirectional relationship between access to electricity and income, education, health and job productivity, and its effect in the quality of life of rural areas of Colombia. To deal with the endogeneity of the above variables an econometric model of simultaneous equations was proposed by means of the three-stage least squares method. The data for the test were obtained from the Colombian National Agriculture Census, which were conducted by the National Administrative Department of Statistics. The results showed that access to electricity has positive impacts on quality of life of rural areas. It was observed a significant and positive effect of the electrification on income, education and agricultural productivity, but negative on health. Finally, the highly significant magnitude of the impact of the access to electricity on the quality of life of the population is an important and powerful argument for including energy policies in national development plans.

1. Introduction

The empirical evidence has shown the relation of effect and causality between electrification and the improvement of the quality of life (QL) (Bridge et al., 2015). The most recent research on the subject exposes the health risk, the detriments in education, and the productivity challenges of those societies that suffer lack of access to modern electricity services (Sovacool, 2012). Other studies have also shown the positive impact of the electricity consumption per capita on growth at macro levels (Shahbaz et al., 2013).

Furthermore, Bridge et al., (2015) studied the effects of electrification on income, education, health, and job productivity in Nepal. Their results showed that the lack of electricity in those territories, negative affects the conditions of their inhabitants' QL. This is due to the electricity services impact on productivity, health, education, and income (Gaye, 2007).

On the other hand, the lack of access to modern electricity sources strongly impacts education. Rural households in developing countries adopt kerosene lamps in order to supply their lighting demand. They do not obtain sufficient luminance for studying in a house at night, and this is one of the obstacles to achieving higher education. Therefore, it is largely expected that energy access improvement for lighting demand through electrification, which is achieved by the dissemination of electric appliances, creating a desirable educational environment for children (Kanagawa and Nakata, 2008). In terms of health, unstable service of the electrical facility makes it difficult for health centres to take care of it, due to limitations in the use of modern biomedical technology, which greatly affects the quality of the available services. Thus, the lack of permanent electricity supply breaks the cold chain of medicines, such impact can reduce the quality or even leave them unusable (Birol, 2007). The income and work productivity have a similar behaviour. The safe and reliable electricity supply impacts almost every aspect of daily life: the use of electric appliances and machines for

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building, agricultural work or traditional industry requires electricity to perform any kind of work after sunset (Bernard and Torero, 2013).

In the case of Colombia, there are no studies which involve resources and logistics for monitoring the regions after they are interconnecting with national grid or getting self-generation with own energy sources (Rosso Cerón et al., 2017). Consequently, the purpose of this study is to assess qualitatively the bidirectional relationship between access to electricity and income, education, health and job productivity, and its effect in the QL of scattered rural areas (SRA) of Colombia. To deal with the endogeneity of the above variables an econometric model of simultaneous equations was proposed by means of the three-stage least squares (3SLS) method, introduced by Zellner and Theil (1962). This is an econometric method that efficiently solves simultaneous equations systems, taking into account all possible statistical information. In addition, 3SLS lets to a correlation between unobserved disturbances across various equations to be used in the analysis (Bakhsh et al., 2017). 3SLS estimates are more consistent and asymptotically normal, and under some conditions, asymptotically more efficient than single equation estimations (Ba, et al., 2010).

2. Scattered rural areas of Colombia

The SRA of Colombia are constituted by 1,122 municipalities, (NADS, 2014). In the SRA of Colombia, there are one and a half million hectares dedicated to crops, of which an important part is located in territories of ethnic groups. Half of the Agricultural Production Units (APU) of the country have at least one plot of land dedicated to self-consumption. In terms of population, the SRA of the country have decreased in recent years and the poverty gap between urban and SRA persists, with a decrease of 30 % compared to 2005, and concentrated in the territories of ethnic groups (NADS, 2014).

An analysis applied to the SRA of Colombia, carried out by National Agriculture Census (NAC) in 2014, showed that most of the characteristic features of the population are determining factors of the QL of the people, in their homes and productive units. In Figure 1, dark green represents scattered rural areas.

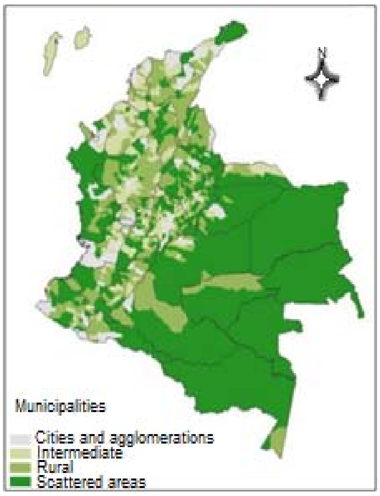

Figure 1: Classification of rurality in 2014 (National Planning Department, 2014)

3. Modelling approach

According to (Birol, 2007), the qualitative explanation of the impact generated by access to electricity implies the improvement of health, education, and job productivity. In Figure 2 is observed that there are both way relations, which indicate the causality in both directions.

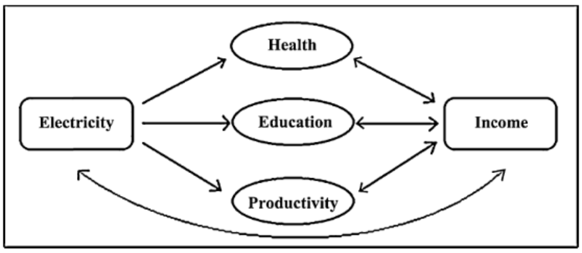

Figure 2: Conceptual model of the interrelations between electricity and income (Bridge et al, 2015)

It is comprehensible that an increase in education will lead to an increase in income. It is also true that a greater amount of income allows a family (householders) to seek better conditions of education. Due to these bidirectional causalities, the estimation of the relations will require an econometric model that takes into account the endogeneity, for example, a simultaneous equation model of 3SLS.

3.1 Functional relationships

In order to obtain a reliable knowledge of how the electrification impacts the people's wealth, it must be understood why some households have electricity and while others do not. Two simple and intuitive indicators explain this situation: (a) only those households that can pay to be connected to the local electric grid will have electricity and (b) only those families that live in an area where the electrification is available will have access to it. Eq(1) shows households' access to electrification, whose function is the wealth of households and if they live in an area with electric coverage.

$$Electrtification = \mathfrak{f}(wealth, C) \tag{1}$$

It is important to clarify that the areas where exist the variation in the access to electricity are rural (with and without electrification), where most of the households are involved in the agricultural sector. Nevertheless, the analysis of this study is only focused on rural households that reside in electrified areas. Then, for this study, Eq(1) is transformed into Eq(2).

$$Electrification = \mathfrak{f}(wealth) \tag{2}$$

The next step was to define which factors influence the wealth of households. Wealth indicators vary widely by country. In this study, primary predictors of wealth were used, such as income, education, land ownership, and health services. Eq(3) shows the wealth of households in terms of education, freehold land, and household health services.

$$Wealth = \mathfrak{f}(income, education, land\ ownership, health\ services) \tag{3}$$

After replacing the wealth determinants from Eq(3) in Eq(2), it is obtained:

$$Electrification = \mathfrak{f}(income, education, agricultural\ job, health\ service) \tag{4}$$

As is shown in Figure 2, the hypothesis is the electrification influences household welfare through the intermediate mechanisms of health, education, and productivity. Therefore, the effects of access to electricity are represented as follows:

$$Health = \mathfrak{f}(electrification, \vec{X}) \tag{5}$$

$$Agricultural\ productivity = \mathfrak{f}(electrification, \vec{X}) \tag{6}$$

$$Education = \mathfrak{f}(electrification, \vec{X}) \tag{7}$$

Where $\bar{X}$ is a vector of household characteristics and other commonly understood indicators of health, productivity and education. Finally, the interpretation of Eq(5) - (7) allows to study the indirect effects of the electrification on income. This is described mathematically as:

$$Income = \mathfrak{f}(health, agricultural\ productivity, education) \tag{8}$$

The limitations in the data will probably result in limitations in the information obtained from the estimation. For this reason, the direct impact of the electrification on income was also studied in order to take into account the missing information and offer a better interpretation of the Eq(5) - (7). Therefore, Eq(8) is estimated as:

$$Income = \mathfrak{f}(electrification, health, agricultural\ productivity, education) \tag{9}$$

3.2 Data

A sample size of 1,122 municipalities was taken from the cross-section of the NAC (2014). The level of analysis for this study differed according to the available information: households, individuals, and Agricultural and Non-Agricultural Productive Units (APU and NAPU). Therefore, this analysis considered the entire population concentrated in the SRA of Colombia. In addition, to ensure consistency and comparability with other statistical research conducted at national and international levels, an important effort was made to use similar terms and definitions approved by international organizations.

3.3 Variables and descriptive statistics

In order to carry out a representative analysis, some considerations related to the key variables were defined: a) with the exception of the Municipal Added Value (MAV) whose calculation was made for the entire municipality, the rest of the variables used in the model refers to the SRA of Colombia, in other words, a geographical area different from the municipal centres and the villages; b) with respect to the econometric model, the variable MAV was normalized and expressed in natural logarithm. Due to Colombia's national balances do not estimate the Gross Domestic Product at the municipal level, the MAV assessed by the National Planning Department (NPD, 2014) was used. The MAV is a proxy variable that is used to express the monetary value of the production of goods and services of the final energy consumption of the municipalities of Colombia. The descriptive statistics are shown in Table 1.

The Electricity Coverage Index (ECI) (relationship between homes with electricity and total housing in each municipality) of the SRA of Colombia is around 85 %. In other words, the average electrification is relatively high; however, an approximate standard deviation of 0.21 is observed, indicating an important inequality gap between municipalities that have electricity and those that do not.

A similar behaviour has the average percentage of students' absenteeism in children from 5 to 16 y in SRA in the municipalities of Colombia; this equals approximately 20 %; however, it is troubling that in some populations this index reaches values above 60 %. In addition, the average percentage of harvested areas in the SRA of the municipalities of Colombia is 17.25 %.

Finally, it is observed that the average percentage of people without affiliation to the health system in the SRA of Colombia is 3.64 %. Consequently, it is considered that the relationship of the variables illiteracy, landholding, sanitary services, and livestock holding support the analysis of this research.

Table 1: Variables and descriptive statistics

Variable	Obs.	Media	Std. Dev	Min	Max
Electricity coverage index (%)	1,122	85.15	21.30	0	100
Students absenteeism (5 - 16 y) (%)	1,122	19.95	6.56	0	60.24
Harvested area (%, in ha)	1,122	17.25	16.93	0	95.50
People without health affiliation (%)	1,122	3.64	3.06	0	29.63
Municipal Added Value (thousands of millions)	1,122	618.32	5,478.16	0.85	170,956
Illiterate rate (%)	1,122	12.71	6.67	1.09	51.56
Own productive units (%)	1,122	54.26	17.92	0	93.26
Houses with sewer service (%)	1,122	5.56	7.69	0	93.25
Housing with aqueduct service (%)	1,122	39.30	28.96	0	100
People affiliated with the subsidized health system (%)	1,122	78.64	15.84	9.56	98.7
Agricultural productive units with the presence of livestock (%)	1,122	31.49	20.46	0	92.17

3.4 Econometric approach

Figure 2 details the conceptual framework for the estimation required at this stage. From Eq(4 - 8) the results were determined together. To solve the problem, a simultaneous equations model was obtained from 3SLS:

$$Income = \beta_0 + \beta_1 electricity + \beta_2 education + \beta_3 agricultural\ productivity + \beta_4 health + \vec{Z}_1\vec{X}_1 + \varepsilon_1 \quad (10)$$

$$Health = \delta_0 + \delta_1 electricity + \vec{Z}_2\vec{X}_2 + \varepsilon_2 \quad (11)$$

$$Agricultural\ productivity = \emptyset_0 + \emptyset_1 electricity + \vec{Z}_3\vec{X}_3 + \varepsilon_3 \quad (12)$$

$$Education = \mu_0 + \mu_1 electricity + \vec{Z}_4\vec{X}_4 + \varepsilon_4 \quad (13)$$

$$Electricity = \rho_0 + \rho_1 income + \vec{Z}_5\vec{X}_5 + \varepsilon_5 \quad (14)$$

Where $\vec{Z}$ and $\vec{X}$ are vectors of coefficients and regressors, respectively. They represent the others parameters and variables (for each equation) related to QL, see Table 1.

Eq(10) could be estimated using an ordinary least squares (OLS) approach, if there were not endogenous potential for income and electricity. In this type of model's endogeneity is based on intuition, as indicated Khandker et al. (2013). Due to this endogenous potential, this system of equations was estimated through a 3SLS. Table 2 shows the results of the regression of Eq(10 - 14), where the determinants of five different variables of interest are also shown.

4. Results and analysis

The results in Table 2 show a positive impact of access to electricity in the MAV. This effect is observed directly through the intermediate effects of the levels of education, health and agricultural productivity. In the proposed functional relationships, it was supposed that the supply of electricity is positively related to the best levels of education, health, productivity, and income of the households located in the SRA of Colombia.

Table 2: 3SLS Simultaneous estimation of the effect of the electrification on households in the SRA

Models	(1) Municipal Added Value (log)	(2) People without health affiliation	(3) Harvested area	(4) Students absenteeism (5-16 y)	(5) Electricity coverage index
Electricity coverage index	0.019 (0.10)*	-0.094 (0.003)***	0.582 (0.00)***	-0.094 (0.00)***	
Students absenteeism (5-16 y)	-0.329 (0.00)***				
Harvested area	0.012 (0.082)*				
People without health affiliation	0.455 (0.00)***				
Municipal Added Value (log)					3.716(0.001)***
Illiterate people		0.158 (0.00)***	-0.060 (0.472)	0.167 (0.00)***	-0.532 (0.0)***
Own productive units	0.007 (0.144)	-0.005(0.320)	0.072 (0.008)***	0.021 (0.048)	0.033 (0.372)
Houses with sewer service		0.017 (0.066)*			
Housing with aqueduct service		0.009 (0.286)			
People affiliated with the subsidized health system		-0.070 (0.00)***			
Agricultural productive units with the presence of livestock			-0.236 (0.00)***		
_cons	7.59 (0.00)	15.025 (0.00)	-28.057 (0.00)	24.728 (0.00)	72.948 (0.00)
No. of Obs.	1122	1122	1122	1122	1122
P-value	0.000	0.000	0.000	0.000	0.000

** P < 0.10 ** P < 0.05 *** P > 0.01* *P value* parenthesis

According to the model (5) an increase in the percentage in the MAV, Céteris Páribus (CP), leads to increasing in 3.7 % the ECI in the SRA. With regard to the previous result, it can be concluded that the obtained effect is positive. In the same way, it is observed that the magnitude of the impact of electrification is as expected and very significant. This is mainly explained by the income growth of people in SRA because they can buy the fuel for the operation of diesel power plants.

From model (4), the direct impact of electrification on the variables associated with the QL can be established. The ECI has a positive and significant effect on the student's attendance of children from 5 to 16 y. This means that with an increase of 10 % in the ECI, *CP*, the percentage of student's absenteeism among children between 5 and 16 y decreases by approximately 0.9 %. This result provides a quantitative interpretation of the qualitative based discussion about the benefits of electrification on the education.

In the model (3), the qualitative evidence of the importance of the electrification over agricultural productivity is again observed. A clear example of this comes with the electric water pumps, which use irrigation supporting fertilization techniques. Similarly, the application of electric equipment improves the efficiency of APU. From Table 2, it can be concluded that when the ECI increases by 1 %, *CP*, the percentage of cultivated areas would increase by approximately 0.58 %. This result is reasonable if it is considered that an electrified farm takes full advantage of irrigation systems, fertilization, and pesticide techniques. Furthermore, an increase of 10 % in the presence of livestock, *CP*, lead to a reduction of 2.36 % in the total area harvested.

The model (2) shows remarkable results. Due to the limitations in the data, people without health affiliation were used as determinants of health. Once again, it is found a significant effect of the activation in the affiliation to the health services. The above could be explained from the following perspective: "the provision of health services is affected in the populations that have less electricity coverage". The results indicate that if the ECI increases by 10 %, *CP*, the percentage of people without health system affiliation decreases by approximately 0.9 %. It is also important to highlight the effect of illiteracy on people without health affiliation. The model indicates that an increase of 10 % of people in illiteracy conditions in the SRA of a municipality, *CP*, causes an increase of 1.6 %; the proportion of people without health affiliation. An important result is also obtained regarding the people affiliated to the subsidized health regime; an increase in this variable by 10 %, *CP*, it is expected that the number of people without affiliation to the health system decreases around 0.7 %.

The model (1) gathers all the information of the models (2) - (5) to estimate the total impact of electrification on the QL. The most remarkable result is that the three development indicators (education, productivity, and health) are significant at a level of 90 %, with the expected behaviours. An increase in the ECI by 10 %, *CP*, makes the MAV growth by 1.9 %. In addition, when the percentage of school absenteeism in children between 5 and 16 y old increases by 10 %, *CP*, the MAV decreases by 3.2 %. Regarding agricultural productivity, when the cropped area increases by 10 %, *CP,* it is expected that the MAV increases by 0.1 %. Finally, an intuitive result has been found, because there is an increase of people without health services by 1 %, *CP*, it is expected that the MAV increases by 0.45 %. Although it is assumed that health has a positive effect on income, the effect is negative. This can be explained by the nature of the variable used to measure income (MAV), explained previously.

5. Conclusions

This research studies the bidirectional behaviour and the effect of the access to electricity on income, education, agricultural productivity, and health of SRA of Colombia, through a 3SLS model. The magnitude of the impact of the electrification is as expected and very significant. In addition, the analysis demonstrates a significant positive effect (90 %) of education, income, and agricultural productivity, but a negative impact of the health. This could be explained from the following perspective: "the provision of health services is affected in the populations that have less electricity coverage". On the other hand, the contribution of the study is significant in order to provide information that may be relevant for the design of policies to improve the conditions of energy poverty in the country. Finally, for future research is needed more practical analysis, for example, acquisition of more field data and the inclusion of other socio-economic impacts of access to energy.

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