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Methodology to Evaluate the Residential Electrical Stock Appliances According to Socioeconomic Status

Jhon J. Pérez*, Efraín Bernal, Juan S. Giraldo

[1]Department of Electrical Engineering, La Salle University, Colombia, [2]Department of Automation, La Salle University, Colombia, [3]School of Electrical and Computer Engineering, University of Campinas, Brazil. *Email: jjperez@unisalle.edu.co

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ABSTRACT

This paper attempts an understanding of the use of stock electrical appliances in the city of Bogot´a D.C. We developed a methodology based on Colombia's National Quality of Life 2016, the methodology uses a questionnaire survey focused on information related to: Type of residential building, appliances stock, socioeconomic status and income, among others. The proposed study explains the relationship between appliance stock and socioeconomic status, income, and type of household by using an econometric energy model. The results obtained have a potential application in energy planning strategies and policies, especially for lowest social status.

Keywords: Electrical Stock Appliances, Socioeconomic status, Econometric Energy Model
JEL Classifications: C50, D12, Q40

1. INTRODUCTION

In 1971 the total primary energy supply (TPES) in the world was of 5523 MToe, while in 2014 it increased by almost 2.5 times to 13,700 MToe (EIA, 2016), however, the total final consumption by sector did not dramatically change from 1971 to 2014. The consumption can be divided into: Industry (37%), transport sector (28%), residential sector (23%), commerce and public services (8%), agriculture (2%), and others (2%)[1]. Colombia, on the other hand, achieved a TPES of 129.44 MToe by 2016, exporting 87.72 Mtoe, and a total consumption of 29.7 MToe.

Colombia was Latin America's fourth largest economy measured by gross domestic product (GDP) at purchasing power parity in 2010 of 349.22 billion USD, with an approximate population of 47.8 million according to the National Administrative Department of Statistics (DANE), represented by a primary energy of approximately 123.23 MToe and net imports of 88.27 MToe, corresponding to a TPES of 34.01 MToe, and estimated CO2 emissions of 72.50 Mt. The total consumption of electricity in 2015 corresponded to 53.13 TW[2], while end use energy can be divided into: Residential (42%); industry (27%); commercial (21%) and others (10%) (Birol et al., 2015).

The structure of the Colombian energy market is based on Laws 142 and 143 of 1994 (Valencia 2004), regulating public services and electricity, respectively. The Unit for Mining and Energy Planning (UPME) is the responsible for the study of future energy requirements and supply situations, while the regulatory commission for gas and energy (CREG) is in charge of regulating the market[3]. The Colombian ministry of mines and energy has developed two main strategies for enhancing energy efficiency and conservation namely: Program of rational and efficient use of energy and unconventional sources - PROURE and the plan of indicative Action of energy efficiency 2017-2022.

1 Key World Energy Trends.ftp://ftp.energia.bme.hu/pub

2 Energy Indicators 2017.http://www1.upme.gov.co/Paginas/Indicadores-de-Energia.aspx

3 Boletìn Estadístico de Minas y Energìa. http://www.upme.gov.co

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Among the most important objectives of these initiates are: (i) To define the targets for energy efficiency users and for end-use equipment; (ii) to build the economic-technical regulation, and conditions to promote efficient energy goods and services, and finally (iii) to harmonize the goals of this Indicative Action Plan with the commitments acquired for the country at COP21 (Law 1715, 2014).

Bogotá D.C. is not only Colombia's geographic capital, but also its most important cultural, economic and industrial city. Located in the center of the country, its population exceeds 8 million people and the nominal GDP contributes to about 25% of the country. Currently Bogotá is the seventh largest city by GDP in Latin America (close to 160 billion USD) (Smith, 2017; Henderson et al., 2000). In 2015 its total consumption of electricity was 9306 GWh corresponding to 17.5% of the whole country from which the residential sector was responsible for 3806 GWh, representing 17.1% of the total residential consumption of the country. The consumption of electricity for each status of Bogotá is divided as follow: Status 1 26.7%; status 2 34%; status 3 22.4%; status 4 8.7%, status 5 4.2%, and finally status 6 with 3.9%[3].

This paper is divided into three main parts: First, the materials and methods are presented, which corresponds to the theoretical framework, data description and the proposed methodology. Second, the results show the descriptive analysis of use of electrical appliances in Bogotá D.C. and the econometric results. Finally we present the concluding remarks about the study.

1.1. Aim of the Study

This article aims to find the relationship between socioeconomic status and household appliances stock in Bogotá D.C. Colombia is divided in six main socioeconomic status from status (1) i.e. lower status, to status (6) representing the highest status. The study has the following three goals to achieve: (i) To present a methodology for assessing the use of electrical appliances according to socioeconomic status; (ii) to characterize the use of stock of electrical appliances in Bogotá D.C. and (iii) to establish econometric relationships between income, type of dwelling and appliances stock.

2. LITERATURE REVIEW

There are several studies focused on classifying electrical appliances in buildings for energy performance purposes. Droutsa et al. (2017) conducted a study to classify the use in non-residential buildings using several energy conservation measures. Galante et al. (2012) developed a methodology for the classification of the energy performance in residential urban buildings. Sharma and Marwaha (2015) applied a case study that included documentation retrieval, choice of sample buildings, data processing, survey planning and geographic information system implementation for classifying buildings. Panão et al. (2018) developed an energy stock model based on a Monte Carlo approach, this model allows to predict the energy consumption hourly.

A study that analyzes electrical consumption patterns using a 1-min resolution in 23 households in Ottawa, Canada is described by Johnson and Beausoleil-Morrison (2017). These works as based on Bottom-Up approach (Andersen et al., 2017). There are other approaches, like the analysis of energy patterns: Sukarno et al. (2015) determined the energy consumption pattern in residential, commercial, industrial and transportation sectors of Padang, Indonesia. Matsumoto (2016) studied the relationship between income and expenditure in appliances in the households based on the Japanese National Survey of Family. Danlami et al. (2014) analyzed the determinant patterns of household energy selection in developing countries using a conceptual framework. Finally, recent studies have been focused on consumer's habits to determine necessary policy regulations and long-term planning regarding the penetration of new generation technologies by modelling the behavior of users related to socioeconomic, cultural and demographic aspects, as in (Cabeza et al., 2017; Baldini et al., 2018; Filippini et al., 2018).

3. METHODS AND DATA

3.1. Theoretical Framework

This section introduces the theoretical framework to determine the relationships between Stock Appliances (SA) and the socioeconomic status using statistical evaluation. The SA demand depends on consumer's preferences, and it is subject to budget constraints. The consumer theory defines some properties of the consumer by means of the utility function (U) (Pindyck and Rubinfeld, 2005): (i) Continuity; (ii) deferentially; (iii) monotonicity; and (iv) concavity.

The consumers maximize the utility function to acquire goods; from this work's interest, the SA are constrained by the income of the households (Varian, 1987).

$$Max\ U(x1, x2, SA, \ldots, xn)$$
$$Subject\ to\ p(p1, p2, \ldots, pn) \leq m \quad (1)$$

$$x1 \geq 0$$
$$xn \geq 0$$

Where:

U: Utility function
xi: Goods ($1,2,\ldots, n$)
SA: Stock appliances
m: Income; budget constraint
p: Vector of prices

p is a price Prices are related in vector $p = (p_1, p_2, p_n)$ for each good and SA. The solution of the Equation 1 consist in finding the optimal price for each good. Applying the first order conditions and solving the optimization problem, we can get the optimal demand (SA), as follow:

$$SA^* = SA(p_{SA}, p_2, \ldots, p_n, \ldots, m) \quad (2)$$

The coefficients estimators are obtained applying a linear regression model using ordinary least square regression (OLS) for continuous and ordinal variables, we assumed that the OLS linear model is homoscedastic and presents uncorrelated errors (Gauss-Markov assumptions) (Verbeek 2008):

$$\hat{\beta}_i = (X'X)X'Y \quad (3)$$

Where:

β: Estimator
X: Be an N k matrix of the observations on K variables for N units
Y: An n-vector of observations on the dependent variable

Socioeconomic characteristics such as the type of household and the socioeconomic status are used as variables in a restricted linear regression with dependent categorical variables. This approach is known as reduced number of qualitative variables, we can use a variable of contrast of discrimination (CD) (Lavergne 1998). For instance $CD_0 = 0$ is the reference group for cases of CD. $CD_1 = 1$, if $CD_1 = 0$ if not,…, $CD_4 = 1$ if $CD_4 = 0$ and so on. The independent variable is the difference from another fixed factors (FF), the model can be described as follow:

$$FF = a_0+\delta_1 CD_1+\delta_2 CD_2+\delta_3 CD_3+\delta_4 CD_4+e_t \quad (4)$$

Where:

δ_j: Is the difference in FF between a factor j and j1.
CD_i: Discriminant variables

3.2. Data

The national quality of life (NQL) of Colombia includes survey questionnaires in urban, municipal townships, and rural areas. The NQL is divided into nine regions, namely Caribbean, Santander, Antioquia, Pacific, Central, Orinoquia, Amazon, San Andres Islands and the capital district Bogotá.

The NQL 2016 was designed and executed following the methodology known as the living standards measurement study (Grosh and Glewwe, 1995) which was promoted by the World Bank and conducted by the DANE[4]. In this survey the accuracy is expressed in terms of the standard error, and the relative standard error (RSE) or coefficient variation. The desirable accuracy level for the RSE was established at a maximum of 5%. The NQL 2016 sample contains approximately 23,000 interview questionnaires divided into: Urban 14,226; townships 3121 and rural 5546 households respectively.

The DANE collected several surveys[5] related to measure the living standards and characterize the population in urban, municipal townships, and rural areas of Colombia covering a national representative sample. In the database it was applied a preprocessing process of data, transforming raw data into an understandable format, since these databases usually have missing values or inconsistencies. Data preprocessing prepares raw data for further processing, including data cleaning, dimensionality reduction and handling of imbalanced data sets. In this work we used particularly the data related to Bogotá D.C. which were divided into ordinal and nominal data as follow:

1. Kind of household: Has been divided two groups housing and apartment (ordinal).
2. Socioeconomic status: Divided into six types: Low-low; low; middle-low; middle; middle- high and high (ordinal).
3. Income (nominal).

3.3. Flowchart of the Methodology

The methodology has been divided into 4 stages according to Figure 1: (i) Questionnaire survey; (ii) classifications of residential dwellings; (iii) classification of electrical appliances stock by type of use and (iv) econometric model for the analysis of electrical SA by socioeconomic status.

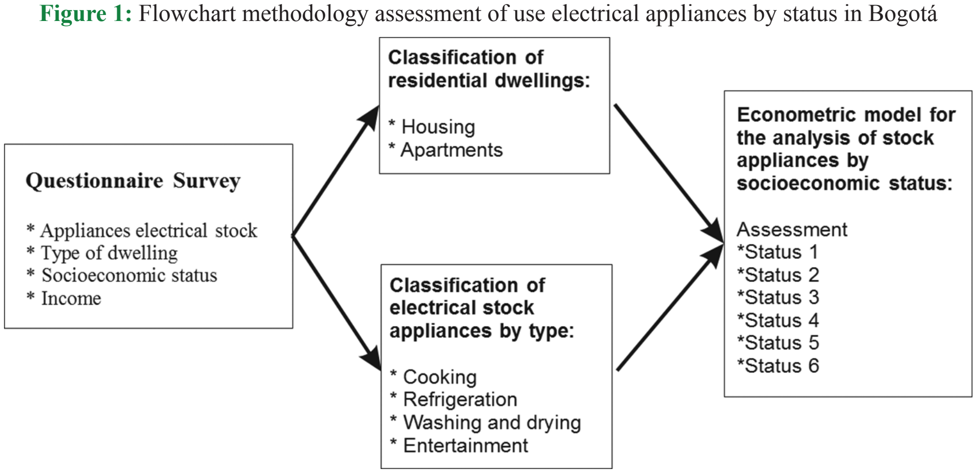
For this study the database is carried out using questionnaires based on personal interviews in households. Table 1 presents the distribution of the sample households in Bogot´a D.C. by socioeconomic status. The QLS section for living conditions and possession of assets contains 29 questions about household appliances used at home. The SAs can be characterized in five main gropus: Cooking, refrigeration, washing and drying and entertainment. This division was made in accordance to REMOCEDE project[6] developed for the European Union - 27 Countries (EU27) (Almeida et al., 2011).

4 Departamento Nacional de Estadística. http://www.dane.gov.co

5 DANE CLSS 2016. http://formularios.dane.gov.co

6 REMOCEDE EU. http://remodece.isr.uc.pt

Figure 1: Flowchart methodology assessment of use electrical appliances by status in Bogotá



3.4. Descriptive Analysis

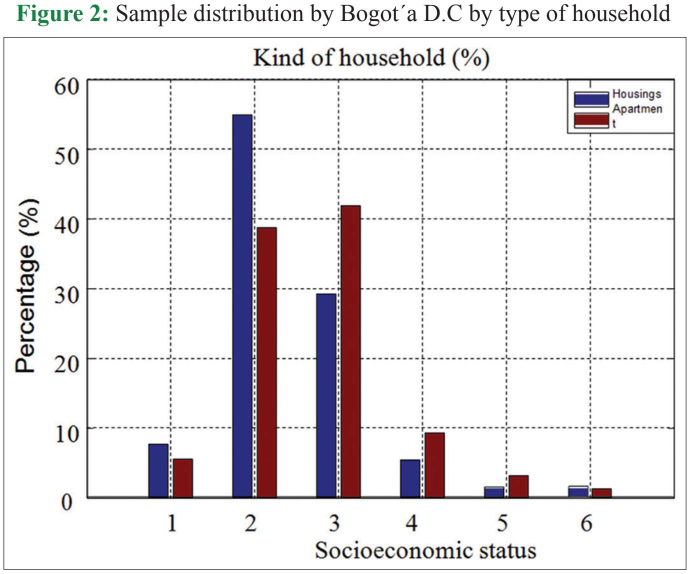
Households are the centers of demographic, social and economic processes in life. For this reason, factors like the type of household, the socioeconomic status, and the use of electrical appliances plays an essential role for understanding the patterns of development and growth of society. In this paper we describe the type of household according to socioeconomic status for Bogotá D.C. The NQL 2016 sample for corresponds to 1,848 households that are distributed according to Figure 2 as follow: In status (1) 7.6% lives in housings and 5.5% lives in apartments; status (2) 54.8% lives in housings and 38.8% in apartments. In contrast, in others socioeconomic status these distributions change, in status (3) 29.2% lives in housings and 41.9% in apartments; in status (3) 5.4% lives in housings and 41.9% lives in apartments; in status (4) 5.39% lives in housings and 9.34% in apartments; in status (5) 1.49% lives in housings and 3.2% in apartments, at last in status (6) the households prefer housings with 1.5% in comparison with apartments 1.3%.

SA are related in Figure 3, which shows the percentage of appliance by use in housings and apartments for each socioeconomic status, respectively. In housings, according to Figure 3a, cooking appliances have a growing share by status as can be seen in status (1) with 40%; in status (2) with 53%; and in status (3) with 64%. For status (4), (5) and (6) the values are between 90% and 95% whose variation can be considered as constant.

Table 1: Sample frequency by socioeconomic status and type of household - empirical results

Status	Type of household	Count (%)
1	Housing	41 (35.6)
	Apartment	67 (58.2)
2	Housing	295 (35.7)
	Apartment	473 (57.3)
3	Housing	157 (22.6)
	Apartment	511 (73.6)
4	Housing	29 (20.3)
	Apartment	114 (79.7)
5	Housing	8 (17)
	Apartment	39 (83)
6	Housing	8 (33)
	Apartment	16 (67)

Figure 2: Sample distribution by Bogot´a D.C by type of household



In housings, refrigeration is the most used appliance with a range between 92% and 95% in the lowest status, and 100% for the rest. Washing and drying also have a monotonic growth in status (1), (2), and (3) with 50%, 65%, and 74%, respectively. For the remaining status the share is almost constant above 93%. Regarding entertainment, the use is lower than the others household's appliances, in the status (1) and (3) it is between 32% and 51%, whereas for status (4) and (5) is almost the same with approximately 63%, and for status (6) it shows a reduction with 61%.

On the other hand, the use of appliances is slightly different in comparison with housings. Figure 3b shows that cooking appliances is less used in status (2), however, it is widely used in higher status (5) and (6) above 94%. A very interesting aspect is the shift that occurs between status (3) by 62% and (4) by 86%. Again, refrigeration is the most used appliance. Regarding washing and drying, a constant growing can be evidenced as happened with housings for status (5) and (6) the use corresponds above 94%. Entertainment appliances use in status (1) and (3) is 45% and 40%, respectively. From status (4), (5) and (6) there is a constant growing between 48% and 74%, which is greater, than the housings are lower than the others households appliances.

Figure 4 shows the monthly income distribution in Bogotá D.C. divided into the six socioeconomic statuses. The box plot contains five important data: Minimum value, first quartile, median, third quartile, and maximum value. Between the first and third quartile we have the median value. In status 1 the median corresponds to 500 USD; in status 2 the median is 600 USD; status 3 correspond to almost 900 USD; status 4 is approximately 1.600 USD; status 5 correspond to 2.300 USD and by last in status 6 is almost to 3.400 USD.

The first quartile is the median of the data points to the left of the median and the third quartile is the median of the data points to the right of the median. For status 1 the quartiles correspond between 300 and 700 USD; status 2 between 400 and 950 USD; status 3 between 600 and 1.600 USD; status 4 between 900 USD and 2.800 USD; status 5 between 1.100 USD and 4.000 USD and finally status 6 between 1.300 USD and 5.400 USD. Related to maximums the results shown in status 1 a maximum value of 1.300 USD; status 2 a maximum 1.800 USD; status 3 a maximum of 3.000 USD; status 4 maximum of 5.500 USD; status 5 a maximum of 7.600 USD by status 6 a maximum of 10.900 USD.

3.5. Statistical Inference

Several energy models have been used in econometric estimates trying to explain the relationships in energy demand (Pindyck and Rubinfeld, 1988; Letschert, 2009). We applied an appliances stock model (Bendezù and Gallardo, 2006; Dubin and McFadden, 1984) that includes: Appliances stock (SA_i), socioeconomic status (S_i), type of household (H_i) and income (Y_i), where i, corresponds to socioeconomic status.

The model contains: Dependent variable which is the continuous variable called *appliances stock* and independent variables such as, categorical variable (*status socioeconomic*; binary

Figure 3: (a and b)s Type of appliances use in households in Bogot´a D.C

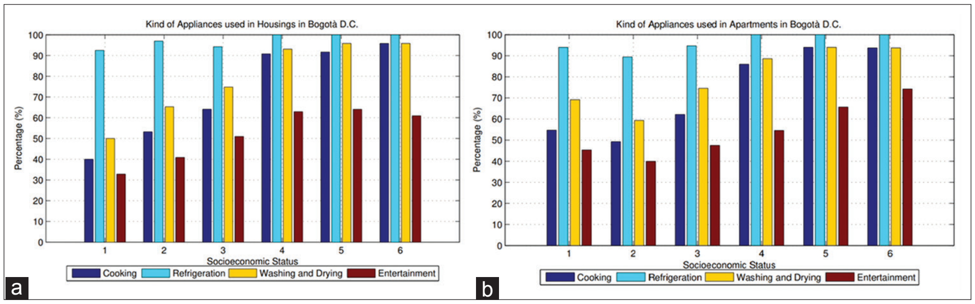
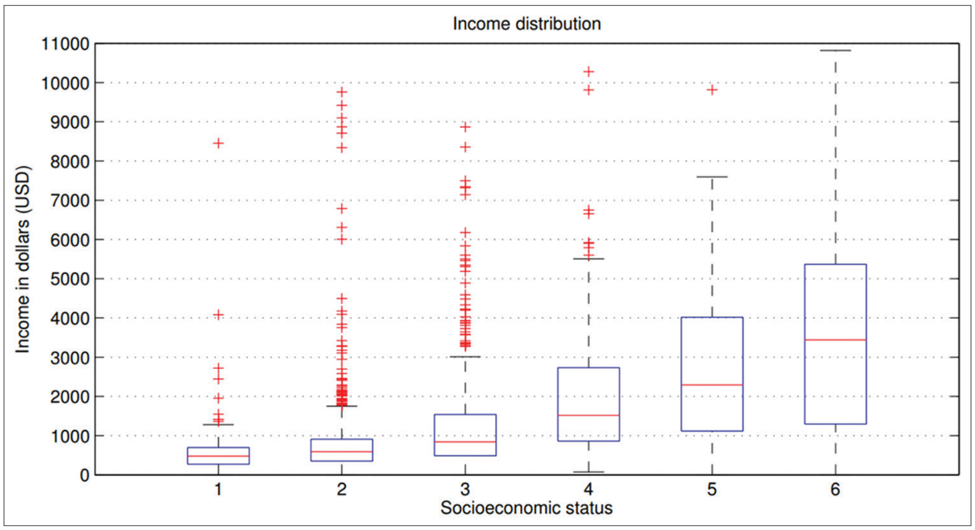


Figure 4: Distribution of income in the sample by socioeconomic status



variable (*type of household*); and continuous variable (*income; square income2*). In this study, we adopted an energy model to assess the relationships between electrical appliances stock and socioeconomic status. The first model shows the relationship between SA and income, according to equation (7). The second model accounts for the type of household, according to equation (8) and the third model analyzes type of socioeconomic status. The $Status_j$ can be interpreted as the difference of the coefficients between $Status\,(j+1)$ and $Status_j$ for the same type of housing and income. The proposed analysis is a log-linear energy model stock for Bogot´a D.C. (McCullagh 1980).

6*Washing:* Washing machine, electric water heater. *Refrigerator*: Fridge and refrigerator. *Cooking*: Electric stove electric oven and microwave oven. *Drying*: Iron, air conditioner, fan and dryer. *Entertainment*: LCD TV, Led TV, TV, video player, digital music player and stereo.

$$SApp = a0+\beta_1 Income+\beta_2 Income2 \quad (5)$$

$$SApp = a0+Housing+Income+Income2 \quad (6)$$

$$SA_{pp} = a_0+\delta_1 Status_2+\delta_2 Status_3+\delta_3 Status_4+\delta_4 Status_5+\delta_5 Status_6 +Housing+Income+Income^2 \quad (7)$$

The Tables 2-4 provide the results related to the application of the models described into equations 7, 8 and 9. For the first model

Table 2: OLS regression model 1

Coefficients	Estimate	Standard error	t value	Pr(>—t—)
Multiple R²: 0.2284, Adjusted R²: 0.2248				
F‑statistic: 63.94 on 8 and 1728 DF, P: <2.2e‑16				
(Intercept)	−0.333	1.671	−0.200	0.841
Income	0.810	0.230	3.521	0.0004***
Income2	−0.017	0.007	−2.173	0.029*

Significant at 0 ***0.001 **0.01 *0.05. OLS: Ordinary least square regression

Table 3: OLS regression model 2

Coefficients	Estimate	Standard error	t value	Pr(>—t—)
Multiple R²: 0.2284, Adjusted R²: 0.2248				
F‑statistic: 63.94 on 8 and 1728 DF, P: <2.2e‑16				
(Intercept)	−0.333	1.671	−0.200	0.841
Housing	−0.004	0.031	−0.131	0.896
Income	0.810	0.230	3.520	0.0004***
Income2	−0.017	0.007	−2.172	0.029*

Significant at 0 ***0.001 **0.01 *0.05. OLS: Ordinary least square regression

(Equation 7) the estimated coefficient for the income is 0.81, that is statistically significant at $P < 0.001$. This elasticity has positive sign, meaning that an increase of 1% in income represents an increment in appliances stock of 0.81%. The expected sign of the coefficient of square income is negative and statistically significant at $P < 0.005$ this result indicates a monotonic increase in the relationship with appliances stock. The negative sign evidences inequality between income and appliances stock as seen in the

Table 4: OLS regression model 3

Coefficients	Estimate	Standard error	t value	Pr(>—t—)
Multiple R^2: 0.2284, Adjusted R^2: 0.2248				
F-statistic: 63.94 on 8 and 1728 DF, P: <2.2e-16				
(Intercept)	−2.018	1.670	−1.208	0.227
Status 2	0.144	0.062	2.313	0.020*
Status 3	0.349	0.064	5.448	5.84e-08***
Status 4	0.513	0.080	6.422	1.73e-10***
Status 5	0.522	0.111	4.710	2.68e-06***
Status 6	0.414	0.149	2.774	0.005**
Housing	0.047	0.031	1.483	0.138
Income	1.062	0.231	4.592	4.70e-06***
Income2	−0.027	0.008	−3.467	0.0005***

Significant at 0 ***0.001 **0.01 *0.05. OLS: Ordinary least square regression

Figure 4. Kuznets curve or inverted U hypothesis related to inequality explains the poverty as a lack of income; which can be interpreted in this paper as a reduction in the number of appliances in the poorest households.

The second model includes a dummy variable with qualitative information about the type of household where 1 means housing and 0 means apartment. The sign of coefficient is negative and inelastic. The income and square income have the same results that for the first model.

The third model is based on ordinal variables. These variables are known as categorical variables and are subdivided into socioeconomic status as is shown in the equation 9 using dummy variables. Applying a continuous dependent variable in an OLS regression, the F-statistic is less than $P < 0.0001$ being statistically significant. The reference group is the Status 1. In the Status 3, 4, 5, income and square income are significant at $P < 0.0001$. In the Status 6 is significant at <0.001; in Status 2 is significant at $P < 0.05$ and for housing is not significant. All coefficient variables have the expected signs. These results showed that the model is statistically significant in general. The reference group is the Status 1, according to 100 [$exp(\delta_{(i+11)}$ 1] the results can be calculated as 15.4% for status 2, 41.7% for status 3, 67.1% for status 4, 68.5% for status 5, and finally 51.2% for status 6. These results indicate the relationship in percentage for SA compared to status 1. This result agrees with the data in Figure 3.

4. CONCLUDING REMARKS

This paper described a methodology for evaluating the residential electrical SA taking into account the socioeconomic status existing in Colombia. The penetration of SA was determined and characterized for the capital district of Bogotá. Finally, an econometric energy model was used to determine the elasticities between the SA, income, type of household, and socioeconomic status.

The main conclusion of the paper is that empirical evidence shows the relationship between appliances stock and income. The income also was measured based on socioeconomic status in Colombia as categorical variable. These results identified the increase of stock appliance as the socioeconomic status grows. We found the following values of SA: The average of Status (1) is 2.12 kW; of Status (2) is 2.66 kW; Status (3) is 2.84 kW; Status is 3.84 kW; Status (5) is 4.12 kW; and Status (6) is 4.23 kW. We found the stabilization value of SA in 4.0 kW. These SA close to Status (4), (5) and (6).

The electric power in Colombia is based on large hydro-power close to 64% and thermal generation 33% and the participation of small renewable sources. The regulatory CREG defines the tariff structure in socioeconomic status in Colombia. Residential consumers have the tariff structure regulated by CREG. Status (1), (2), and (3) have subsidized tariffs; 50%; 40%; and 15% respectively. The Status (4) has no subsidy and the Status (5) and (6) have an additional contribution of 20% respectively. Despite the subsidies in the lowest status, we consider these subsidies necessary taking into account that these households are on growth path related to the demand of energy unsatisfied.

These results are one step toward the understanding of the existing inequality in the lowest social status related to the acquisition of electrical appliances necessary for human development: In Status (1), (2), and (3). Decision makers need to understand the penetration and energy consumption of SA in lowest Status to design public politics that allow the acquisition of "white goods" such as: Refrigerators, washing machines, TV and entertainment devices. This purpose will increase the quality of life of these families.

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