Self-Financed Income-Based Cross-Subsidy Allocation in the Electricity Sector in Colombia: A Socioeconomic and Public Health Equity Perspective

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ABSTRACT

Restructuring of the electric sector in Colombia in 1994, included provisions to guarantee supply of electricity to less affluent groups at a price below the cost of supply. According to this, electricity service is provided at a subsidized price to almost 90% of residential customers during the study period. The system under-collects requiring budget subsidies from the government. Also, there is near one million homes in the first income decile for which monthly electricity bill represents approximately 90% of the household income. The current allocation method for subsidies does not take the household income in consideration then it is not possible to identify families that need additional financial support. Thus, this research proposes an allocation method to assign subsidies based on household income. The proposed method provides full subsidy to families in the first income decile and requires no budget subsidies from the government. However, it is important to mention that this research presents a macro-level study, then before implementing the allocation method proposed herestakeholders need to conduct more detailed level studies including evaluation of the trade-offs between the social, political and economic costs of implementing a new system against the performance of the current system.

***Key Words**: electricity tariffs, cross-subsidy, Colombia, income-based allocation, deregulated electricity sector.*

I. INTRODUCTION

The energy crisis of 1992 motivated the restructuring of the electricity sector in Colombia. During this year hydrological generation capacity was reduced due to an extremely dry season, requiring a long period of load rationing to avoid rolling blackouts. The political consequences of the energy crisis, transformed politicians and energy planners into risk avoiders favoring an electric system with over capacity (Barrera Rey & García Morales, 2010; Larsen et al., 2004). Restructuring of public industries could take the form of deregulation, re-regulation or liberalization (Heald, 1996; Voll, Pabon-Agudelo, & Rosenzweig, 2003). In public network industries, this restructuring generally seeks to provide lower prices, promote competition, increase efficiency and attract new investments (Baumol, 2001; Palmer, 1992). These are also some of the primary reasons for the restructuring of the electric sector in Colombia in 1994 (Larsen, Dyner, Bedoya V, & Franco, 2004).In Latin American countries deregulation has been considered a means to generate the financial resources to add capacity to guarantee the provision of public services. Because these are considered common goods, the government generally assumes regulatory oversight and maintains shared ownership of certain assets, as in the case of Colombia.

Restructuring of the electricity sector in Colombia in 1994 included provisions to allocate subsidies based on equity and social responsibility principles.In Colombia the electricity services are provided at a subsidized price to approximately 90% of all the residential consumers during the period analyzed in this research (Departamento Administrativo Nacional de Estadisticas, 2006).However, there is near one million homes in Colombia for which monthly electricity bill could represent approximately 90% of the household income (Cedeno, 2016).In addition, the cross-subsidy system under-collects requiring budget subsidies from the government. Therefore, the objective of this research is to propose a self-financed allocation mechanism that gives full subsidy to these customers.

Subsidies occur when products or services are priced below their marginal costs. Subsidies also occur when the government provides a payment to either producers or consumers directly or indirectly to lower the price of the product or to lower production costs(Lin and Jiang, 2011). Tariffs to promote universal access often price basic services low relative to costs, whereas other services are priced high relative to costs to compensate(Palmer, 1992). This pricing creates cross-subsidies. Subsidized customers are encouraged to consume more, whereas subsidizing customers reduce their consumption below the so-called "efficient level of consumption"(Chattopadhyay, 2007; Lin and Jiang, 2011; Liu and Li, 2011; Voll et al., 2003). The electricity sector in Colombia is financed by contributions from more affluent residential customers, industrial and commercial sectors. Tariffs for these customers are higher than the cost of supply; whereas tariffs for subsidized customers are below the cost of supply, this pricing creates cross-subsidies. The goverment provides budget subsidies to finance any defficit.

Financing social goals is considered more expensive using cross-subsidies than budget subsidies(Heald, 1997). Budget subsidies do not impose penalties on customers who are charged higher prices causing equity issues (Faulhaber, 1975; Voll et al., 2003). Social welfare losses are also likely to be less than in the case of using cross-subsidies (Chattopadhyay, 2004). Budgetsubsidies and direct subsidies preserve economic signals and are more efficient than cross-subsidies(Voll et al., 2003). Taxes to more affluent classes consuming price inelastic goods or services that can be priced using average cost pricing(Chattopadhyay, 2004) can provide the funds to finance budgetsubsidies and direct subsidies.Despite these limitations Colombia could take advantage of the fact that its citizens are used to live in a country that has a cross-subsidy system for electricity prices. Then, perhaps improving the system would face less opposition than adding new taxes. A combination of cross-subsidies and budget subsidies could be implemented in electricity markets in which the government owns and regulates the public network(Heald, 1997; Pineau, 2008). However, when operation and ownership are separated from regulation, as for instance in the MISO (Midwest Independent System Operator) and PJM (Pennsylvania, New Jersey and Maryland interconnection) markets in the US, with no political power to access budget subsidies, regulators only have access to cross-subsidies to achieve their social or political goals (Heald, 1997).

Subsidies are characteristics of network monopolies developed under public ownership(Heald, 1997). Subsidies can be used to promote network development; however, once the network is mature, they can be discontinued(Heald, 1997; Sawkins and Reid, 2007). Then, in countries with mature network industries research on energy subsidies provides more importance to determining the size of the subsidy and the impact of removing subsidies(Lin & Jiang, 2011; Sawkins & Reid, 2007). Then this research differs from previous studies by presenting an analysis from an emerging country with an electricity sector which is not mature.The electric power sector in Colombia is relevant to researches and public policy makers (Larsen et al., 2004) because this system has experienced positive results after restructuring in 1994 such as: increasing electric coverage to almost 97% in 2012, the lack of blackouts even during extreme dry seasons and the ability to promote competition and attract private investments. This research extends the work presented in (Cedeno, 2016; Cedeno, 2018) by presenting an alternative allocation method based on household income which does not required budget subsidies from the government and provides full subsidies to customers in the first income decile.

The justification to propose an income-based allocation mechanism(Rosero, 2004; Cedeno, 2016) is due to the lack of correlation(Rosero, 2004; Uribe-Mallarino, 2008) in the current allocation system with the household income based on data for 1997 and 2003 (Rosero, 2004).Therefore, the current tariff scheme based on the residential classification of homes is not charging users according to their ability to pay as reflected by their income(Rosero, 2004; Cedeno, 2016). Electricity tariffs in Colombia are determined following the same residential classification employed in the provision of residential public water service according to CREG resolution 012-93 (Comisión de Regulación de Energía y Gas (CREG), 1993). Based on this classification, six residential groups are determined from 1 to 6 in increasing order of financial wealth. Groups 1 to 3 receive subsidies. Group 4 is considered neither a contributor nor a subsidized sector. Groups 5 and 6 make contributions towards subsidies. Results from the residential classification of homes allow the identification of neighborhoods that are classified as belonging to the same tariff category for the provision of public services. Assuming that household income is similar for people leaving nearby(Pineau, 2008), the neighborhoods created using the residential classification of homes would be a good indicator of household income. However, this is not the case in Colombia due to the lack of correlation between the current allocation system and the household income.

Despite cross-subsidies often being questioned on grounds of promoting over consumption and missing the target population(Lin & Jiang, 2011; Pineau, 2008; Sun & Lin, 2013), they can be used by the government to promote equity, universal access and national development(Chattopadhyay, 2007; Faulhaber, 1975). Electricity subsidies in China(Sun & Lin, 2013)and in British Columbia,Canada(Pineau, 2008)have been reported missing the target population providing benefits to higher income consumers. Cross-subsidies may be needed because ofpolitical and equity considerations, as in the electricity sector in Colombia described in this research. In China, to provide a competitive edge, electricity tariffs are lower than the cost of supply(Lin & Jiang, 2011)and cheaper than in developed countries(Liu & Li, 2011). In Brazil large industrial customers also benefit from lower tariffs to increase their competitiveness(Voll et al., 2003). In Colombia, more affluent residential groups contributed a maximum of

60% of their electricity bill at the beginning of the restructuring process in 1994(Comisión de Regulación de Energía y Gas (GREG), 1996). Currently, these residential consumers and industrial and commercial sectors contribute approximately 20% of their electricity bill.

Subsidies have been used in the telecommunications industry in France and Canada (Heald, 1997; Palmer, 1992); postal services in the US (Heald, 1997); the water industry in Scotland (Sawkins and Reid, 2007); fossil fuels in China, India, Indonesia, Egypt, Thailand, Venezuela, Saudi Arabia, Iran, Iraq and Mexico (Lin and Jiang, 2011; Liu and Li, 2011; Plante, 2014); natural gas in Ukraine (Plante, 2014) and China (Wang and Lin, 2014); and in the electricity sector in China, Colombia, Brazil, Bolivia, Honduras, Panama, Nicaragua, El Salvador, Mauritania, Jordan, Senegal, Lebanon and Canada (Lin and Jiang, 2011; Pineau, 2008; Plante, 2014; Sun and Lin, 2013).

II. SUBSIDY ALLOCATION AND TARIFF STRUCTURE IN COLOMBIA.

Laws 142 and 143 of 1994 (Congreso República de Colombia, 1994a, 1994b; Larsen et al., 2004) provide the legal framework for the deregulation of the sector.Law 143 (Congreso República de Colombia, 1994b) is directed specifically towards the electricity sector in all its activities of generation, transmission, distribution and commercialization. This law gives authority to the Gas and Energy Regulatory Commission (CREG) to define the methodology to determine electric tariffs (Comisión de Regulación de Energía y Gas (CREG), 1994b, 1995, 1996, 1997a, 1997b) as well as tariffs to remunerate the access and usage of transmission networks (Comisión de Regulación de Energía y Gas (CREG), 1994a, 2000).

CREG resolution 012-93(Comisión de Regulación de Energía y Gas (CREG), 1993)mandates that electricity distribution companies in Colombia should apply residential tariffs according to the same residential classification employed in the provision of residential public water service.This system is based on a residential classification of homes to identify the target populationin neighborhoods for the purpose of tariff assignment(Uribe-Mallarino, 2008). Based on the residential classification of homes,there are six residential groups from 1 to 6 in increasing order of financial wealth. Groups 1 to 3 are considered less affluent groups and are the beneficiaries of the subsidies. Group 4 is considered neither a contributor nor a subsidized sector; it should pay solely for the cost of the service. Groups 5 and 6 are considered more affluent. These groups contribute to the subsidies in addition to the contributions made by the industrial and commercial sectors.Residentialelectricity tariffs are defined in resolutions CREG 80-95 (Comisión de Regulación de Energía y Gas (CREG), 1995), CREG 09-96 (Comisión de Regulación de Energía y Gas (CREG), 1996) and CREG 78-97(Comisión de Regulación de Energía y Gas (CREG), 1997a), whereas non-residential electricity tariffs are defined in CREG 79-97(Comisión de Regulación de Energía y Gas (CREG), 1997b).

Based on the rules for the sector asimplified general expression to compute tariffsis provided below (Cedeno, 2016; Cedeno, 2018):

$$T(t)_{ijk} = (1+\rho_{ik}(t))\ C_{jk}(t) \tag{1}$$

Where:

$T(t)_{ijk}$: tariff for customer from group*i* at voltage level *j* provided by company *k* at time *t*.

$\rho_{ik}(t)$: subsidy or contribution factor for customer from group*i* at time *t*provided by company *k*.

$C_{jk}(t)$: cost of supply at voltage level *j* provided by company *k*at time *t*.

Initial contribution factors for customers in groups 5 and 6 were, on average, 60 and 68%, respectively (Comisión de Regulación de Energía y Gas (GREG), 1996). CREG 78-97(Comisión de Regulación de Energía y Gas (CREG), 1997a) defines equivalent $C_{jk}(t)$ for the thirty companies serving the sector during the beginning of the restructuring process.Subsequent residential contribution factors per company defined in CREG 80-95(Comisión de Regulación de Energía y Gas (CREG), 1995)range from 20 to 35% for customers from group 5 and from 20 to 48% for group 6. Non-residential contribution factors were as high as 30% in 1998(Comisión de Regulación de Energía y Gas (CREG), 1997b). All contribution factors were established to be lower or equal to the limiting factor of 20% after 2000(Comisión de Regulación de Energía y Gas (CREG), 1997b). Initial maximum subsidy factors (Comisión de Regulación de Energía y Gas (CREG), 1997a) are negative 50, 40 and 15% for groups 1, 2 and 3 respectively. Residential customers from group 4 are only required to cover their cost of supply. Then $\rho_{4k}(t)=0 \;\; \forall k$. Subsidized prices are provided to a maximum of the subsistence level of consumption; additional consumption is priced higher at the cost of supply(Comisión de Regulación de Energía y Gas (CREG), 1995). The subsistence level was set at 200 Kwh per month(Comisión de Regulación de Energía y Gas (CREG), 1995, 1997a).

III. CHARACTERISTICS OF THE ELECTRICITY DEMAND AND PRICES IN COLOMBIA (CEDENO, 2016; CEDENO,2018)

The research presented here reports on all the available aggregate data per company serving the electricity sector in Colombia for all residential consumers during years 2005, 2006 and 2007 (Sistema Unico de Información (SUI), 2014). These data are used to compute the averages reported in this section. Limiting the study period at the moment of conducting this research to these three years is due to access to census data for year 2005 with forecast for years 2006 and 2007 (Departamento Administrativo Nacional de Estadisticas, 2006). The allocation method presented here can be applied to any other period provided access to census data is granted. The author is currently looking into this issue as part of future research.

Values in table 1 indicate that the majority of residential customers belong to the subsidized groups. Group 1 represents 24% of residential customers according to figure 1; whereas groups 2 and 3 represent 40% and 25% respectively. Then, approximately 90% of residential customers received subsidies from the system during the three-year study period.

Table 1. Subscribers per group per year.

Year	2005	2006	2007
G1	1.688.190	2.036.695	2.319.139
G2	3.158.880	3.269.392	3.543.892
G3	1.978.779	1.953.378	2.144.513
Total Subsidized Subscribers	6.825.849	7.259.465	8.007.544
G4	497.920	500.839	593.237
G5	235.417	244.844	273.781
G6	135.190	142.652	175.451
Total Residential	7.694.376	8.147.800	9.050.013

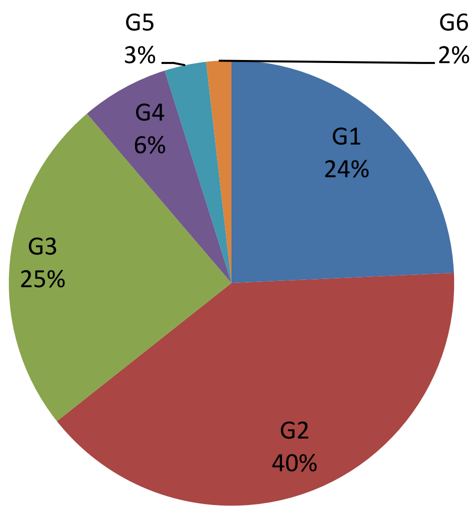

Figure 1. Average distribution of residential customers.

Average electricity prices presented in table 2 for subsidized groups exhibit the correct behavior according to the design of the system, since electricity prices increase moving from group1 up to group 4.Electricity prices for contributing residential sectors during two years are greater for group 5 than for group 6. The opposite behavior is expected according to equity principles because group 6 is the most affluent group.A similar behavior is observed in electricity prices for the capital city of Bogota in 2006 (Secretaría Distrital de Planeación, 2007; Codensa, 2013). This may be due to the way additional consumption is priced for these consumers.

Table 2Average electricity price $/Kwh (Constant US$ for 2007)

Year	G1	G2	G3	G4	G5	G6
2005	0.12	0.14	0.18	0.19	0.22	0.21
2006	0.11	0.13	0.16	0.17	0.20	0.19
2007	0.10	0.12	0.14	0.16	0.17	0.17
Average	0.11	0.13	0.16	0.17	0.20	0.19

Table 3. Average electricity consumption per subscriber (Kwh per month)

Year	G1	G2	G3	G4	G5	G6
2005	168.11	141.92	174.16	219.74	286.48	437.24
2006	148.11	138.34	171.81	217.15	273.56	417.93
2007	124.83	134.58	167.36	206.48	255.91	360.79
Average	147.02	138.28	171.11	214.45	271.98	405.32

Average electricity consumption (table 3) for all subsidized sectors is below the subsistence level of 200 Kwh per month (Comisión de Regulación de Energía y Gas (CREG), 1995, 1997a). However, during two years average consumption for group 1 is higher than that of group 2. This may indicate overconsumption due to low electricity prices (Cedeno, 2018). Average electricity consumption in residential sectors increases as one moves up in the social groups.Average consumption for residential customers in group 6 is more than twice the consumption for group 1. In India, another emerging country, cross-subsidies to domestic sector and rural areas have been increasing as demand keeps increasing(Chattopadhyay, 2004).

Table 4. Average electricity bill per subscriber per monthin USD.

Year	G1	G2	G3	G4	G5	G6
2005	22.42	19.35	23.09	28.50	35.57	53.57
2006	19.54	18.27	21.86	26.99	32.48	49.12
2007	15.67	16.54	19.75	23.91	28.16	39.48
Average	19.21	18.05	21.57	26.47	32.07	47.39

Table 4 presents average electricity bill per subscriber per month in constant USD for 2007. There is no much difference in the average bill between groups 1 and 2 despite the subsidy level each group receive is different. This is because of the high consumption of group 1 as compared to that of group 2 (Table 3). Average percentage subsidy for group 1 is almost 42%, whereas for group 2 is only 30%, table 5. These values are still within the limits established in (Comisión de Regulación de Energía y Gas (CREG), 1997a) for maximum subsidy factor per group presented in the previous section. Subsidy for group 3 is less than 9%. Average electricity bill per subscriber in group 5 is less than that for subscribers in group 6 despite the contribution factor being higher for group 5 (Table 6). This is because the consumption in group 6 is approximately 50% higher than the consumption in group 5 (Table 3).

Table 5. Percentage subsidy per group.

Year	G1	G2	G3
2006	39.54	29.53	9.32
2007	43.11	27.95	8.55
2008	42.78	31.58	8.78
Average	41.81	29.69	8.88

Table 6. Percentage contribution per group.

Year	G4	G5	G6
2005	0.03	18.14	17.68
2006	-0.02	18.13	17.50
2007	0.00	18.46	17.63

Table 7. Percentage Average Budget Subsidy.

Year	% Budget Subsidy
2005	15.14
2006	15.71
2007	13.00

Table 7 presents percentage average Budget Subsidy for the years studied in this research. The systems under-collects requiring around 15% of budget subsidy from the government. This budget subsidy is required despite the contributions from industrial and commercial customers. Next section presents two alternatives for subsidy allocation based on household income data(Departamen to Administrativo Nacional de Estadisticas, 2006).

IV. ALTERNATIVE INCOME-BASED ALLOCATION METHOD FOR CROSS-SUBSIDIES

The justification to propose an alternative allocation method for cross-subsidies in Colombia is that the current allocation method does not correlate with the household income (Rosero, 2004; Uribe-Mallarino, 2008). This causes some unfair and inefficient allocation of electricity subsidies. The alternatives presented in this section consider the cross-subsidy system to be financed only by contributions from more affluent residential customers.

The decision making problem of determining the size of the subsidized and contributing sectors, subsidy and contribution factors, involves the cross-product of these decision variables. This is characterized as a non-linear programming problem. This is also a self-referential problem since it involves determining the electricity demand and the price, where electricity demand depends on the price which is a function of the subsidy or contribution factor (Cedeno, 2019; Cedeno, 2016). Solution of this problem in real-life systems is simplified by input from various stakeholders in the problem. This problem, can also be characterized as a bilinear problem (Cedeno, 2019; Cedeno and Arora, 2013). In a bilinear problem, once one variable is specified the problem becomes a linear programming problem in the other variable (Cedeno and Arora, 2013). Then, the allocation method presented here considers users grouped in deciles according to data from(Departamento Administrativo Nacional de Estadisticas, 2006). Therefore, the relevant decisions are the size of the subsidized and contributing sectors; as well as, the subsidy or contribution factor for each group. Regarding the size of the subsidized sector, it is decided to limit it to decile 7. Decile 7 would correspond to group 4 in the current system. This number of users up to decile 7 corresponds roughly to the size of the subsidized sector reported in table 1. Then, the problem of assigning subsidy and contribution factors becomes a linear programming problem (Cedeno, 2019). This problem can also be simplified in real life by input from the stakeholders involved in setting energy policies.

Table 8 presents an alternative allocation method considering distribution of homes per household income in deciles. The first three columns are obtained from (Departamento Administrativo Nacional de Estadisticas, 2006). It is important to highlight the difference between the total number of subscribers reported in table 1 and the total number of households reported in table 8. It is beyond the scope of the present research to determine the reasons for that difference. However, one could speculate that due to the characteristics of the country there are several residential homes under the same electricity subscription as family size increases and younger families build their homes by expanding their parents' house.Table 8provides maximum and average household income. Column 4 presents the proposed average bill for each group. Decile 1 corresponds to group 1. Deciles 2, 3 and 4 corresponds to group 2. Deciles 5 and 6 corresponds to group 3. Decile 7 corresponds to group 4. Decile 8 corresponds to group 5. Deciles 9 and 10 corresponds to group 6. Then, each decile is assigned the corresponding average bill for each group presented in table 4. Column 6 presents the effective subsidy (S) or Contribution (C). Subsidy factors are given in brackets to represent negative values. Effective subsidy factors for customers in group 1 are lower than the value reported in Table 5, this is due to the differential price at which additional consumption is charged.Column 7 presents the percentage of the proposed average bill over the average income (Cedeno, 2016). The most significant aspect from this column is that this percentage decreases as income increases, representing a very heavy burden on customers from the first income decile. For these customers, electricity bill represents almost 90% of their average income (Cedeno, 2016). Column 8 gives the payments received from each group; whereas, column 9 gives the total electricity cost for each group computed as the product of the number of users in each decile times the cost of supply given by the average price for group 4 or decile 7. Comparison of total payments and total costs, indicates that this alternative would generate a surplus that could be assigned to a reserve fund (Cedeno, 2019).

Table 8. Alternative subsidy allocation based on household income.

Decile	Total Homes	Max. Income (USD)	Average Income (USD)	Proposed Avg. Bill	Effective S or C	% (Avg Bill/Avg Income)	Payments	Cost
Decile 1	1114223	64.15	21.59	19.21	(0.27)	88.98	$21,404,223.83	$29,493,482.81
Decile 2	1114352	124.1	95.24	18.05	(0.32)	18.95	$20,114,053.60	$29,496,897.44
Decile 3	1114815	182.84	154.75	18.05	(0.32)	11.66	$20,122,410.75	$29,509,153.05
Decile 4	1114365	231.42	206.69	18.05	(0.32)	8.73	$20,114,288.25	$29,497,241.55
Decile 5	1113203	291.82	261.52	21.57	(0.19)	8.25	$24,011,788.71	$29,466,483.41
Decile 6	1114972	384.92	337.96	21.57	(0.19)	6.38	$24,049,946.04	$29,513,308.84
Decile 7	1115437	509.15	442.93	26.47	0.00	5.98	$29,525,617.39	$29,525,617.39
Decile 8	1114106	697.67	595.6	32.07	0.21	5.38	$35,729,379.42	$29,490,385.82
Decile 9	1114820	1076.45	856.27	47.39	0.79	5.53	$52,831,319.80	$29,509,285.40
Decile 10	1114555	22428.45	1982.39	47.39	0.79	2.39	$52,818,761.45	$29,502,270.85
Total	11144850						$300,721,789.24	$295,004,126.56

Table 9. Alternative subsidy allocation based on household income providing full subsidy to customers in the first income decile

Decile	Total Homes	Max. Income (USD)	Average Income (USD)	ProposedAvg. Bill	Effective S or C	% (Avg Bill/Avg Income)	Payments	Cost
Decile 1	1114223	64.15	21.59	0	(1.00)	0.00	$0.00	$29,493,482.81
Decile 2	1114352	124.1	95.24	18.05	(0.32)	18.95	$20,114,053.60	$29,496,897.44
Decile 3	1114815	182.84	154.75	18.05	(0.32)	11.66	$20,122,410.75	$29,509,153.05
Decile 4	1114365	231.42	206.69	18.05	(0.32)	8.73	$20,114,288.25	$29,497,241.55
Decile 5	1113203	291.82	261.52	21.57	(0.19)	8.25	$24,011,788.71	$29,466,483.41
Decile 6	1114972	384.92	337.96	21.57	(0.19)	6.38	$24,049,946.04	$29,513,308.84
Decile 7	1115437	509.15	442.93	26.47	0.00	5.98	$29,525,617.39	$29,525,617.39
Decile 8	1114106	697.67	595.6	32.07	0.21	5.38	$35,729,379.42	$29,490,385.82
Decile 9	1114820	1076.45	856.27	51.66	0.95	6.03	$57,591,601.20	$29,509,285.40

Decile 10	1114555	22428.45	1982.39	57.34	1.17	2.89	$63,908,583.70	$29,502,270.85
Total	11144850						$295,167,669.06	$295,004,126.56

Table 9presents an alternative that provides full subsidy to customers in the first decile. The electricity bill for customers in this decile represents around 90% of their average income, table 8. This would result in a high percentage of unpaid accounts and electricity theft, creating additional costs difficult to quantify but requiring more budget subsidies from the government. Then even when the alternative proposed in Table 9 generates a surplus it is difficult to know the impact of unpaid accounts and electricity theft on any required budget subsidy. The alternative presented in Table 9 generates a small surplus requiring no budget subsidyfrom the government. The balance between payments and costs presented in this alternative is obtained by following the algorithm presented in (Cedeno, 2019). The effective contribution for groups in deciles 9 and 10 has increased considerable from corresponding values presented in Table 8. However, the effective increase considering average bill for decile 9 is only 9% and for decile 10 is 21%. The recommendation made in this paper is to sell these increases in the average bill by the percentage increase in the average bill and not by the increases in the contribution factors, since increases in the contribution factors may seem excessive.

In the analysis presented in this section it is assumed electricity demand for high income customers is almost price insensitive. This is similar to the strategy implemented in the tariff redesign for the electric sector in China in which higher income consumers with low price elasticity of demand pay a higher price(Sun & Lin, 2013).In India, using an increase in electricity prices for industrial customers to provide for residential and agricultural sectors as a financial mechanism was determined to be unsustainable because price increases caused reductions in industrial demand; subsequently the system failed to collect sufficient money to pay for subsidies (Chattopadhyay, 2007).This is the primary reason for not including industrial and commercial sectors in the analysis presented here.However, reductions in electricity demand from high income consumers in Colombia is not very likely to decrease because for them it may not be attractive or convenient to install their own electricity generators.

V. CONCLUSIONS

Although there are provisions to promote equity in the context of social responsibility in the restructuring of the electric sector in Colombia, there are still around one million users for which electricity bill represents almost 90 % of their income (Cedeno, 2016). Then, for these customers the subsidy system is not providing enough to help them. However,the current allocation method provides subsidies to almost 90% of residential customers during the study period from 2005 until 2007. The system under-collects requiring average budget subsidy of approximately 15%.The allocation of subsidies in Colombia is based on a residential classification of homes which does not include the household income as a variable (Rosero, 2004). This residential classification of homes does not correlate with the household income based on data for 1997 and 2003 (Rosero, 2004). This is the justification to propose an alternative allocation method as the one proposed here.

The analysis presented in this research is a macro level analysis that uses average values for each consumer group obtained from aggregate data for all the companies serving all clients in each region in Colombia(Departamento Administrativo Nacional de Estadisticas, 2006). However, there are important differences in electricity consumption in Colombia due to seasonal changes depending on geographical location. A more detailed analysis considering regional data is needed before implementing the proposed allocation method. The data required for conducting such study is easily available to policy makers in Colombia. However, this might not be the case for academic research. In this paper two alternatives have been presented to allocate electricity subsidies based on household income. The success of these alternatives is due in part to the sizable increased in the number of residential contributors. Then, it would be strictly necessary to determine the real number of electricity subscribers in each group to develop an allocation method based on the one presented here.In countries with mature network industries subsidies are disliked on grounds of promoting over consumption, causingtechnological biased, increasing pollution and the risk of missing the target population(Lin & Jiang, 2011; Pineau, 2008; Sun & Lin, 2013). In spite of that, in emerging countries, as Colombia, subsidies can be used by the government to achieve social goals. Then any changes in the allocation method for electricity subsidies need to take this into consideration. It is important to emphasized that this is a macro-level study, then before implementation stakeholders need to conduct more detailed level studies including evaluation of the trade-offs between the social, political and economic costs of implementing a new system against the performance of the current system.

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