Electricity Cross-Subsidies in Colombia: An alternative targeting proposal.

Juan Felipe Vélez Tamayo

Asesor: Jorge Andrés Tamayo Castaño.

Trabajo de Grado para optar por el Título como Magister en Economía Aplicada.

UNIVERSIDAD EAFIT

MEDELLÍN

2019

El autor del trabajo agradece la ayuda de su asesor y maestro el Doctor Jorge Andrés Tamayo, por su paciencia, consejos y atención durante todo el desarrollo de esta investigación. Adicionales agradecimientos a los Doctores Luis Guillermo Vélez y Jorge Barrientos, el Economista Daniel Velásquez y el ingeniero Luis Miguel García por el interés prestado durante toda la escritura de este documento. Cualquier error en el presente documento es únicamente del autor.

Index

Tables

Figures

Abstract

Los sistemas de subsidios cruzados son mecanismos universales usados para transferir vía precio un ingreso de un sector de la población a otro, para así darle acceso a algún bien o servicio que de otra forma no tendría. En Colombia el actual esquema tarifario de Servicios públicos de energía eléctrica funciona de tal manera que a través del uso de un sistema de estratificación transfiere parte del costo del kWh de los hogares de estratos más bajos a los de estrato más alto. Debido a que el sistema de estratificación opera en función al valor estimado del inmueble del hogar, sin ningún mecanismo de evaluación de ingreso real, ha resultado ser poco apropiado como instrumento de focalización. Este trabajo plantea un sistema alternativo de focalización haciendo uso principal del puntaje usado en el Sistema de Selección de Beneficiarios Para Programas Sociales (SISBEN III), entre otras alternativas, adicionalmente se estima una serie de elasticidades de corto plazo, instrumentando la tarifa del usuario final a los ciclos hidrológicos del país, para evaluar el impacto de dichas políticas en el consumo del hogar medio en las 5 principales ciudades del país.

Cross-subsidy systems are universal mechanisms used to transfer income from one sector of the population to another through the price of a given good or service they otherwise wouldn't had access to it. In Colombia, the current tariff structure for public utilities operates through the use of a stratification system which transfers part of the cost of the kWh from households from the lowest to the highest stratum. Since the stratification system operates based on the estimated value of the home, without any direct real income valuation scheme, it has turned out to be unsuitable as a targeting instrument. This paper proposes an alternative targeting system making primary use of the score used in the Beneficiaries Selection System for Social Programs (SISBEN), among other alternatives; additionally we estimate a series of short-term consumer's price elasticities, instrumenting final users tariff to country's hydrological cycles, to evaluate the impact on consumption of those policy shocks for the average household in the 5 main cities of the country.

1 Introduction

On the night of November 17 of 2016 a new bill was presented to Colombian Congress[1]. The Bill 186 of 2017. The bill pleaded the congress to restructure the current transference system of Colombia. According to it the system was broke, expensive and not working. The main source of public transference in the country is through direct subsidies to consumption, their impact is close to little as it's put by the bill[2]:

Colombia in 2015 the GINI coefficient only decreased by 0.01 thanks to monetary subsidies, this effect in other countries is much higher. In the case of United Kingdom during the same year, the impact was 0.24, which makes one of the most inequitable countries on the planet one of the most equitable.

The bill did not pass the first debate; with a peace process that was ought to be submitted to popular vote the next year, and the forthcoming of congressional and presidential elections in 2018 the priorities of Colombia's elected officers were others. Still, one of the main chapters in the bill was able to transcend the project and its being studied by the current office in power[3], this chapter was considering the present Cross-subsidy system functioning in Colombia's Electric Sector.

Cross subsidies consist of a tariff system in which tariffs are assigned above the cost to a portion of the market and below to another portion of the market, which for social policy reasons is sought to favor. The magnitude of cross subsidies is determined by the socioeconomic stratum of households and the level of households consumption (Medina & Morales, 2008).

This paper sought to analyze the current cross subsidy structure functioning in Colombia´s Electric Sector and the short and long term impacts on electricity demand and firms budgets in case of a change in the percentage of the tariff's subsidy and the exclusion of some of its current recipients.

[1] Sorce: http://leyes.senado.gov.co/proyectos/index.php/proyectos-ley/periodo-legislativo-2014-2018/2016-2017/article/186-por-medio-de-la-cual-se-regula-la-politica-de-gasto-publico-en-subsidios-se-expiden-normas-organicas-presupuestales-y-de-procedimiento-para-su-aprobacion-y-se-dictan-otras-disposiciones.

[2] Pag: 48- Proyecto de ley 186 (2017).

[3] As it was reported by one of the main newspapers in the country, El Espectador: https://www.elespectador.com/economia/subsidios-de-luz-estratos-1-2-y-3-se-van-mantener-articulo-812829.

We measure this impact by estimating the short and long-term price elasticity of the demand through exogenous changes in the price of kWh during 2006-2016, using a vertical integrated model instrumenting final consumer's tariff to the changes in water inflows though country's utilities hydropower plants and their averaged monthly kWh contribution to the system. Then we implement the estimated elasticities into subsidies of the tariff for users in the 5 main cities of the country and see how this potential change in consumption will affect the budgets of the retailers in these cities. We consider several policy changes likes the use of latest Beneficiaries Selection System for Social Programs (SISBEN) scoring measurement, SISBEN III, to assess the impact of it as a targeting mechanism, we evaluate the suppression of stratum 3 as a subject of subsidies, raising contributions through fees for over-consumption, or inducing a free-riding penalization fees for lower stratum users under a high income distribution, the shortening of subsidiable consumption for low stratum users, we finally run a Full-Scale model that integrates policies into a single tariff to assess the overall change in consumption of an exogenous shock in the price of final user's tariff and predict potential changes on utilities subsidies-contributions balances.

The structure of this paper consist on a literature review about cross-subsidies system all over the world, then we proceed to review previews exercises of estimation of the demand's price-elasticity for electricity according to international experience and Colombia; therefore we make an introduction to relevant information of the regulatory system and market structure of country's electric sector; then we cover how consumers tariff is built, the functioning of cross-subsidy system and how is affecting energy retailers. After it we explain the functioning of our model for assessing potential changes in consumption of main cities; therefore we continue to explain our approach to estimate electricity sector elasticities which function as our Empirical Approach; finally we publish the results and our conclusion derived from it.

2 Literature Review

Through the world there are several cross-subsidies systems operating within energy markets, the governments use them to promote electricity consumption among the poorest population or key sectors so they can have competitive prices in the market. Whilst the social justification of Cross- subsidies existence might be relevant for distributive purposes they tend to affect system's efficiency and distort price signaling (Laffront & N'Gbo, 2000; Pachauri & Spreng, 2011; Bruegge, 2018), while might tempt some utilities and sectors to engage in corrupt or rent seeking practices (Willems, Ehlers, & Fraga, 2008).

Some subsidies can lead to inefficient forms of generation to last over time, like the case of global kerosene subsidies which have cost around $60.3 billions in expenditures, number that can be elevated to $77.2 billions if externalities derived from its use are accounted, while undertaking the implementation of cleaner technologies in the middle east, North Africa, Pakistan and India (Mills, 2017).

Household subsidies, even if they aim to ease spending on energy for poor families, tend to be distorted in many cases and lots of non-poor families can end being the real beneficiaries of such policies due to the high cost of supplying the service to poorest areas, especially rural ones (Harish & Tongia, 2017). Also higher subsidized energy can lead to higher cost of provisions due to fraud or non-payment, or prices below losses coverage, which have created financial constraints to utilities and governments all over Latin America (Di Bella, et al., 2015).

In Colombia's case the quality of the service provision for firms can be affected, for lower income households, by the high cost of supplying subsidized energy (Li, Wang, & Yi, 2018). Due to the high costs imposed to the retailers many economist have suggested the need of replacing the current focalization methods (Medina & Morales, 2007; Melendez, 2008; Gaviria, 2016).

If such policy is implemented is to be expected a change in the amount of electricity demanded by the households that experience a rise in their bill. This change in demand can be estimated by a short-run price elasticity function. Economic theory suggests that demand for electricity is less sensitive to price changes than other commodities, still this has to be contrasted with energy subsidized demand.

Electricity prices dramatically differ from other commodities prices, or equity prices, the main differences according to Knittel & Roberts (2001) consist in a persistent behavior in the prices and squared prices, pronounced intraday and seasonal cycles, and price censoring from above[4]. This characteristics make electricity prices be governed by several factors, among them are day-to-day consumption, seasonal variations in temperature, quality of appliances used in households, and changes in regulation.

Electricity is a non-storable good, this implies that inventories cannot be used to arbitrage over the price, main difference from other sources of energy like fuel or coal. Since all the energy produced is being consumed at the same time[5] electricity demand tends to be more inelastic than other energy sources like oil or gasoline which can be regarded as elastic in the short run (Arzaghi & Squalli, 2015).

Literature has yet to come to a consensus among income and price elasticities for electricity, the demand of it depends of the geographical location, local weather and temperature, seasonality and quality of electric appliances, among other determinant factors, while the relation with income gets more loose as other variables are taken in account (Reiss & White, 2001; Filippini & Pachauri, 2002; Faisal & Eatzaz, 2011). Also elasticities tend to vary whether the price is increasing or going down (Haas & Schipper, 1998).

The methodology of how price elasticities are measured is important to the results, since Electricity prices behave like an equity there's been a share number of works using autoregressive models to estimate elasticities (Pielow, Sioshansi & Roberts, 2012; Burke & Abayasekara, 2017; Barrientos, 2018).

Okajima & Okajima (2013) use first difference generalized method of moment estimator to avoid panel dynamic bias, one of their main results was that electricity consumption in Japan (from 1990 to 2007) was affected by inequality and sever weather changes. Campbell (2018)

[4] Electricity prices share several characteristics with equity prices, including a high kurtosis and persistence in the square of prices.
[5] Hydroelectric resources, being water the main one, can be stored in a reservoir and then release it to produce energy when it is needed. However in Colombia thermo-power plants are the ones in charge of producing electricity in case of scarcity.

bounds testing approach to cointegration to obtain long-run price elasticity of demand for the period 1970–2014 His findings suggest that households are more responsive to the long-run elasticities. In Germany a quadratic expenditure system to estimate price and expenditure elasticities of energy consumption revealed that consumption response is weaker for lower income households (Schulte & Heindl, 2017). Estimating a household energy consumption from a production function has been recently suggested as method to deal with incomplete data; based on households number of composite energy goods, an utility function is stablished and minimum consumption of energy derived from it (Labandeira, Labega, & López-Otero, 2012).

Deryugina, MacKay, & Reif (2017), used the exogenous changes in tariffs, due to change of service providers for communities in the state of Illinois, to estimate the short and long run price elasticity of the market through a difference-in difference matching approach[6]. Using monthly consumption and price data from the largest firm in Illinois, which area covered around 70% of household, they found out that consumers began adjusting their consumption in the months leading up to the price change, reflecting that long run elasticity has major impact on consumption than short run elasticity.

There's been several attempts to measure demand's price elasticity in Colombia, Medina & Morales (2007), with data of the Quality of life survey[7], used block pricing methodology to estimate the linear functions for electricity demand, then they get the price and income elasticities and estimate the effects arising of rising subsidized prices for basic consumption. Their findings suggests that price demand elasticity is close to 0. Acuña, González & Forero (2013) analyzed the elasticities of demand and income from electricity for domestic and industrial use, for Colombia (2000-2011) by estimating demand equations by OLS. Recently Barrientos et al. (2018) made an estimation of price elasticity demand for the manufacturing sector through the use of a structural autorregressive model (SVAR), concluding that industrial electricity demand in forward contract is almost inelastic to price changes. Still

[6] In 1997 the Illinois market presented a structural change with the allowance of competitive supply in market, this meant the entry of several generating companies, since the two firms operating in the market were encouraged to sell their generation assets. This policy made possible to communities to choose their supplier on behalf of their residents.

[7] Which is made every year by the National department of statistics.

there's to be seen a model of household's price elasticity in electricity market accounting for exogenous factors like country's hydrology and changes in regulation.

3 The System

The Colombian electric sector is a liberalized market with participation of private and public investors (Trespalacios, Pantoja, & Fernández, 2017). The current market's supply chain consist in four types of activities Generation, transmission, distribution and commercialization. As they are stablished by the Energy and Gas Regulation Commission (CREG) [8].

- Generation: This activity consist in the energy production of the sector. In Colombia under normal hydrological periods around 80% of the electricity is generated through hydropower plants. Under prolonged periods of high temperatures, phenomenon known as "El Niño", the thermoelectric plants take up the role and generate above 50% of the countries' electricity (Trespalacios, Pantoja & Fernández, 2017, p.48).
- Distribution: It's the part of the chain which supplies energy from the substation to the final users. In Colombia the energy distribution is organized through local monopolies which are assigned in the different regions and its fees determined by the CREG every five years.
- Transmission: Consist in the transport of energy at more than 220 kV through the National interconnected system network (CREG, 1995).The main transporter is Interconoexión Eléctrica S.A. (ISA), the former state run company is the owner of 75% the grid.
- Commercialization: The agents that carry out this activity sell the electricity to final users in Colombia. The final users are composed by two kind of markets; the regulated market mainly consisting of household and users with a monthly consumption bellow 55 MWh/month. The Unregulated Market are the ones who have a Consumption above 55MWh/month or 0.1 MWh of power; this users must install a meter with telemetry capacity, they are free to choose the retailer, and represent

[8] The CREG, by its acronym in Spanish, is the government agency in charge of providing the regulatory framework in which firms can operate in Colombia's electricity market. Its specific functions will be explain further in this paper.

around 30% of total demand in the country with around 4000 registered users (Franco, Cadavid, & Dyner, 2017).

The regulatory scheme in which Colombian electricity market operates is a product of two laws: the Law 142 (1994a) of public services, which stablished the current functioning system of public services; and The Law 143 (1994b) of electricity, which stablished the legal framework in which the companies can operate and also gave the possibility of entrance to private firms in the market. The new energy law looked forward to heal the finances of the energy sector[9] and providing it with a strong market structure for preventing energy rationalization like the one occurred in 1992.

The Electricity Law reaffirmed the possibility of organizing the electric sector more efficiently, for which regulation aspects such as the operation of the national interconnected system, tariffs for access to networks and the conservation of the environment against the development of electrical infrastructure (Méndez, 2014).

Under this new framework a new regulatory institution was erected, the Energy and Gas Regulation Commission (CREG in Spanish), its duties mainly consisted in providing the normative under which the agents in the power sector could work, regulate the tariffs among the agents and final consumer. The article 23 of The Law 143 (1994b) stablished its duties as they are listed below:

1. A unified legal and regulatory regime for all companies regardless of the nature of their property.

2. A tariff regime governed by principles of economic efficiency, financial sufficiency and social solidarity.

[9] During the 70´s and 80´s the financial burden of Colombia's electricity sector represented around 20% of National Budget (Méndez, 2014). Aggravated by the devaluation of Colombia's peso the debt of energy sector rose to US$3.8 billions representing 30% of National Debt. The renewal of Colombia's energy market came in the 90's when the sector underwent drastic reformations after having large financial deficits during the beginning of the decade. Consequence of the 80's debt crisis Colombia had a huge decrease in the growth of its electric energy demand, leaving projected income by the companies in the sector insufficient to cover its deficit. Until the mid 90's the power sector was run by state companies; in this context there wasn't a clear differentiation within State's role as public policy maker, social regulator and entrepreneur; which according to Ayala & Millán (2002) generated a framework of perverse incentives for managers who's decisions were more motivated by politics rather than efficiency.

3. A single system of cross-subsidies and budget subsidies applicable to users of all companies regardless of the nature of their property. Industrial, commercial and high-income residential users pay a contribution of 20% on the value of their consumption; Residential users receive a subsidy financed with this contribution. The deficit is covered with resources from the national budget. As of 2012, the contribution to industrial consumers of electricity and natural gas was eliminated.

4. Vertical disintegration of the activities of the electric chain and business specialization or, failing that, accounting separation.

5. Separation of regulated activities, transmission and distribution, and competing activities, generation and commercialization.

6. Suppression of legal monopolies, freedom of entry and free access to transmission and distribution networks.

7. Separation in specialized entities of the state functions of regulation, surveillance and control and sectoral policy.

8. Freedom of contracting for consumers that reach consumption thresholds defined by the regulator.

9. Indicative planning of the generation and freedom of investment in generation assets. Imperative planning in transmission.

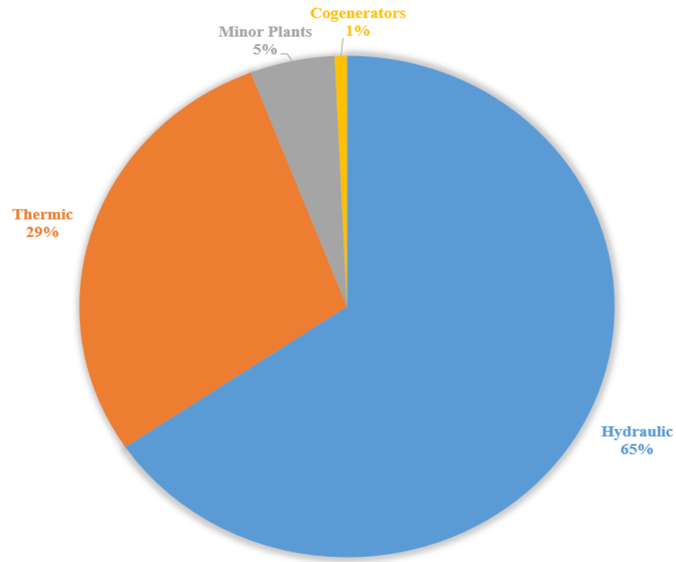
10. Creation of a short and long-term wholesale electricity market with the participation of generators, marketers and large consumers of electricity.

3.1 Market Structure

According to XM (2018) [10] currently there are 192 registered agents in the markets which 56 are dedicated to Generation, 12 to transmission, 31 to distribution, and 93 to electricity retail. The total system's generation capacity for 2014 was around 16.500 MW of power being hydraulic generation the main contributor with 65% of the share, next to thermic generation with 29%.

[10] XM is a filial of ISA. They specialize in electricity information systems, finance and energy transport. They are responsible of the management of the national interconnected system's grid.

Figure 1: Distribution of Generation Capacity in the Electric Sector, 2014.



Source: XM.

50% of market's capacity of generation is hold by 3 firms Medellín Public Company (EPM), ISAGEN, and EMGESA, these companies hold a dominant position on the market (Botero, García, & Vélez, 2013); back in 2000 these three firms had a bigger share of the market, which above 58% of generation capacity. It is worth mentioning that more than 85% of generation capacity of these three firms is hydraulic.

The main income of generation companies come from the wholesale of electricity through Forward contracts to retailers and other generators, or in the spot market. The wholesale market works through "pay what generated" policy, which mean these are mainly financial contracts and there is no compromise of a fixed quantity of energy to be delivered. Usually when the energy delivered is insufficient for the retailer this has to be purchased in the spot market (Acolgen, 2018).

The spot market consist on a daily auction of energy, a single offer with a price for every hour of day is made (CREG, 2001); in this way every generator declares the real hourly energy availability for the next day and a price is offered, additionally the spot price has a direct influence in the prices of contracts in the forward market affecting then the Unitary cost paid by the final users (Vélez, 2015).

The behavior of the spot price of energy directly concerns the generating agents that participate in the short-term market. At that price, the energy sold or purchased by each of them is liquidated, when their effective generation differs from that of long-term contracts.

3.2 Construction of the Tariff

CREG's Resolution 119 of 2007 stablished the current formula for Colombia's electric sector fee of provision for regulated users[11], which is the result of the unit cost of service supply without including subsidies nor contributions (CREG, 2007) , these are later included into the final bill through a cross-subsidies system. The current formula is defined as:

$$\boldsymbol{CU = CUv * Montlhy\ Consumption + CUf}$$

Were:

$\boldsymbol{CUv}$**:** Is defined as the sum of variable costs of commercialization.

$\boldsymbol{CUf}$**:** Represents the fixed component of the Unit cost of the service supply ($/Fee).

The CUv is calculated through next equation:

$$\boldsymbol{CUv_{n,m} = G_m + T_m + D_{n,m} + Cv_m + PR_{n,m} + R}$$

Where n means the voltage level of user's connection in the month m. The variables included in the formula are:

$\boldsymbol{G_m}$**:** Corresponds to the purchase cost of energy ($/kWh).

$\boldsymbol{T_m}$ **:** Is the cost for use of the National Transmission System in ($/kWh).

$\boldsymbol{D_{n,m}}$ **:** Constitutes the costs of distribution correspondent to the voltage level.

$\boldsymbol{Cv_m}$: Represents the commercialization margin, which includes the variable costs of this activity.

$\boldsymbol{PR_{n,m}}$ **:** Is composed by purchase cost, transport and energy losses reduction ($/kWh).

[11] For further detail in final consumer's formula check Annex 1.

$\boldsymbol{R}$: Cost of Restrictions and Services associated with generation in $ / kWh assigned to Retailer.

The current resolution modified the previous tariff that was defined by Resolution 031 of 1997, its main change is that allowed Retailers to include the costs of service provision to regulated users in the tariff. Another change was introduced during 2008 which stablished the methodology for the establishment of charges for the use of regional transmission systems and local distribution (CREG, 2008). The next major change comes from the new formula for stablishing the cost of the transmission component defined by the Resolution 011 of 2009.

3.3 Stratification

In Colombia the selection of homes subsidiaries of public transferences in their electric bills goes through a stratification system which estimates the value of the property and classifies them in a category from 1 to 6, being 1 the stratum assigned to properties with lower value and 6 to the highest.

The recipients of the subsidies are homes classified between 1 and 3 in the stratum system. The stratum 4 pays the whole bill, and Stratum 5 and 6 pay an additional contribution of 20% of their bill. The law 142 of 1994 stablished in its chapter of tariffs of public service companies the current rules for stratification in the system which includes:

- The Majors are responsible of stratification in their municipalities which will be adopted.
- Creates the figure of permanent committees of stratification, which will be composed by social leaders representing the users.
- Stablish that Superintendence of Public services can issue certificates to the municipalities of proper stratification.
- The governors have to supply the omissions of majors in stratification.
- The users can request a revision of his stratum.

One of the main problems with the current system of transferences is that the value of property is not an accurate income proxy (Meléndez, 2008). As it's indicated in the following table around 17% of households in Colombia that are under stratum 1 classification are in the 2 highest quintiles of the distribution of income in the country, and the number rise up to 41.5% of the households under stratum 2 category.

Table 1: Distribution of Electric subsidies in Colombia by users (in millions).

Stratum		Quintile 1	Quintile 2	Quintile 3	Quintile 4	Quintile 5	Total
1	**Users**	5.5	4.3	3	1.8	0.8	**15.4**
	%	35.7%	27.9%	19.5%	11.7%	5.2%	**100%**
2	**Users**	2.6	3.8	4.5	4.5	3.2	**18.6**
	%	14.0%	20.4%	24.2%	24.2%	17.2%	**100%**
3	**Users**	0.5	0.9	1.6	2.7	3.3	**9**
	%	5.6%	10.0%	17.8%	30.0%	36.7%	**100%**
4	**Users**	0.1	0.1	0.1	0.4	1.4	**2.1**
	%	4.8%	4.8%	4.8%	19.0%	66.7%	**100%**
5	**Users**	0.00	0.00	0.00	0.04	0.5	**0.5**
	%	0	1%	0.8%	6.8%	91.4%	**100%**
6	**Users**	0.00	0.00	0.00	0.02	0.3	**0.3**
	%	0.0%	1.0%	0.8%	6.8%	91.4%	**100%**
Total	**Users**	**8.70**	**9.10**	**9.20**	**9.46**	**9.50**	**45.96**
	%	**18.9%**	**19.8%**	**20.0%**	**20.6%**	**20.7%**	**100.0%**

Source: DNP[12].

Due to the stratification policy, companies in the sector are facing a rising deficits in their balances, which has made some companies enter in crisis due to their low share of contributors. As it is shown in the next graph the subsidies have risen in the last years while the contributions have fallen since 2011 due to the due to the elimination of industrial users contribution.

[12] El Departamento de Planeación Nacional (DNP), is the National Planning Bureau of Government in Colombia.

Table 2: Subsidies and Contribution in Power Sector 2002-2015. In millions of $COP.

Year	Subsidy	Contribution	Deficit	GDP	Deficit/GDP
2002	617	473	-144	245,323	0.06%
2003	747	533	-214	272,345	0.08%
2004	940	691	-249	307,762	0.08%
2005	977	670	-307	340,156	0.09%
2006	975	696	-279	379,877	0.07%
2007	1,092	853	-239	431,072	0.06%
2008	1,420	1,234	-186	480,087	0.04%
2009	1,755	1,146	-609	504,647	0.12%
2010	1,945	1,232	-713	544,924	0.13%
2011	2,063	1,265	-798	619,894	0.13%
2012	2,157	966	-1191	664,240	0.18%
2013	2,299	998	-1301	710,497	0.18%
2014	2,210	900	-1310	757,065	0.17%
2015	2,647	830	-1817	799,312	0.23%

Source: Author's estimation with information from Gaviria (2016).

The ineffectiveness of stratum system as a focalization mechanism is widely documented in literature since more than a decade (Meléndez, et al., 2004; Komives et al., 2005; Medina & Morales, 2007, 2008; Amador, 2011; Franco et al., 2017), the whole problem is aggravated since tariffs for stratum 1 and 2 can't rise above inflation by law in Colombia, leaving the firms to take all the financial burden such restriction may leave; still due to the political backlash that undertaking such policy would face there hasn't be any ambitious attempt to restructure the current system.

The only policy that tried to revert this situation is the implementation of subsistent consumption which stablished a maxium consumption that can be subsidized, 130 kWh for households in areas with an elevation major than 1000 meters above the sea level and 173 kWh of households bellow 1000 meters above sea level[13].

Amador (2011) suggested that the subsidy should also take in account the household's payment capacity and not only the stratum. Meléndez (2008) mention the use of Sisben's score as proxy of payment capacity. The Sisbén is the Identification System of Potential Beneficiaries of Social Programs that, through a score, classifies the population according to

[13] As it's specified by UPME's Resolution 0355 of 2004.

their socioeconomic conditions. The score is automatically calculated within the Sisben application from the information reported by the household in the survey and is a value between zero (0) and one hundred (100).

The benefits of using the score as a proxy are that they can't be modified at will or criterion of the pollster or administrator of the Sisben in the municipality, nor at the request of a local authority, an entity or interested person.

The line into which a household can be selectable for transference from Colombia's social security system varies from a score of 36 to 49, this line varies according to the place where the household is located, the type of subsidy the household is seeking, and other special conditions reported by the head of the household[14].

An exercise made to measure the impact of the use of Sisben score as second criterion for focalization of subsidies to water consumption in main cities in Colombia, found a potential reduction of 14% of the users for stratum 1, 25% for stratum 2.

4 Model using Sisben Score at Centile Level

4.1 Previews Models

Over one decade ago Marcela Melendez (2008) proposed the application of SISBEN score as a complementary focalization method, her study mainly focus on public service provision in the city of Bogotá, where she tries different focalization methods among them focalization through Sisben score, diminishing subsistence consumption and geographic focalization methods. Her findings show not only that stratum is indeed a bad proxy to income, also that methodologies like SISBEN score which try to assess the means of living of a household are a more efficient approximation for the distribution of subsidies. While Melendez study has proven useful for determining the necessity of complementary focalization mechanism is limited to the city of Bogotá, only considers income quintiles and no similar studies were conducted for 7 years since it.

[14] For more information on the criterions of selection of SISBEN look for: Dirección de desarrollo Social - Gupo de Calidad de Vida. (2008). Diseño del Índice en su tercera versión- SISBEN III. Bogotá D.C.: DNP.

Recently a consulting group, Economía Urbana (2015), made an attempt to test the impact of several focalization methods which included SISBEN application, stratum 3 elimination and increasing subsistence consumption, this attempt used a Regional data from 24 cities to see how the implementation of such policies would affect utilities balance. Their conclusions were similar to Melendez's, while increasing subsistence consumption, and eliminating stratum 3 were of little impact, SISBEN scoring proofed very effective. The limitations of this study were two; first it was done at aggregate regional level, second it didn't include a potential change in KWh prices could impact household's electricity consumption.

4.2 Our Model

In this paper we aimed to identify the potential reduction of users and firms contribution-subsidy deficits under the application of Sisben as focalization mechanism. Additionally, it allows evaluating measures to reduce subsistence consumption and increase the rate for high consumption in accordance with the policies of rational consumption of energy. Our model has the following features:

1. The population, more specifically households, are represented in centiles. This means that there are one hundred groups of households organized according to household's per capita income. This information was extracted from the microdata of the Great Integrated Household Survey GEIH for the years 2015 and 2016.
2. Each centile has a Sisben score associated with it. This allocation was made based on the information of the microdata available in the Banco de la República and an allocation curve was extrapolated to each centile.
3. Participation by strata was obtained from each centile. There are households in several strata in each centile, and the calculations of subsidies and contributions are made according to the strata to which they belong according to the GEIH.
4. Consumption of energy and gas for each centile was estimated through the information provided for the payment of public services per household granted by the Quality of Life Survey (LCA) for the year 2015. (Dirección de desarrollo Social -Gupo de Calidad de Vida., 2008).

5. The model was applied to five cities, Medellín, Bogotá, Barranquilla, Cartagena and Cali. These cities had adequate information availability and are representative of regions, altitudes and income levels that needed to be analyzed.

The formula applied for the estimation, is the balance between subsidies and contributions for the major retailers in the cities discussed, which is:

$$\boldsymbol{B_t = \sum_{Pe=1}^{100} C_{P_5,P_6} - \sum_{Pe=1}^{100} S_{P_1,P_2,P_3} + I_t + M_t}$$

$\boldsymbol{B_t}$: Firm's Balance Subsidies contributions on year t.

$\boldsymbol{P}$: Stands for income percentile, Sisben score will be assigned according to the centile of income the household is currently at.

$\boldsymbol{e}$: Stands for household's stratum.

$\boldsymbol{C_{P_e}}$**:** represents total households contribution, by the percentile and stratum. The household contribution is estimated as:

$$\boldsymbol{C_{P_e} = N_{P_e} * \left(Co_{P_e} * P_{kWh}\right) * 0.2}$$

- $\boldsymbol{Co_{P_e}}$**:** The consumption of the household at percentile P, under stratum e. The consumption is measured in kWh.
- $\boldsymbol{P_{kWh}}$: Is the price of kWh.
- $\boldsymbol{N_{P_e}}$**:** The number of household in the Percentile P at stratum e.

$\boldsymbol{S_{P_e}}$: Represents total households subsidies, by the percentile and stratum. The household subsidies are calculated by the following formula:

$$\boldsymbol{S_{P_e} = N_{P_e} * \left(Co_{P_e} * P_{kWh}\right) * T_e}$$

- $\boldsymbol{T_e}$: Stand for the percentage of tariff which is subsidize according to stratum $\boldsymbol{e}$**.**

$\boldsymbol{I_t}$**:** Are the industrial contributions in the year t. Industrial contributions are taking as an exogenous variable in our model.

$\boldsymbol{M_t}$**:** Are the Commercial contributions in the year t. Commercial contributions are also exogenous.

To find changes in consumption after a change in price we have to find the real price of kWh that consumer faces, denoted as $\boldsymbol{P_{R_{kWh}}}$, this is the cost of KWh consumer has to pay after discounting all subsidies or adding all contributions, as it is represented in the following denotation.

$$\boldsymbol{P_{R_{kWh}}} = \begin{cases} \boldsymbol{P_{kWh} - P_{kWh} * \%S}, & \boldsymbol{Co_{P_e} \leq R} \\ \boldsymbol{P_{kWh} + P_{kWh} * \%C}, & \boldsymbol{Co_{P_e} \geq L} \\ \boldsymbol{P_{kWh} + P_{kWh} * \%C}, & \boldsymbol{e \geq 5} \end{cases}$$

The restriction seen above are: A maximum subsidized consumption which can be define as a restriction to subsidies equation, this restriction normally is around a higher consumption of 130 kWh for Andean region, and 170 for coastal regions, the restriction is denotes as R. We can also charge the user with a penalization for over consumption, such limit will be defined as L, in our model this over consumption will be considered as such when it surpasses 200 kWh. The last restriction is a fee for households which are over stratum 5, they will pay a fee of 20% over their final tariff.

For estimating the new price when changes in regulation are introduced we have to add new restrictions which include a condition for Subsidies for high Sisben score households, our model has the flexibility to consider a three-stages gradual cut of the subsidy as Sisben score rises, so the new subsidy will not only depend on the stratum, but also on the Sisben score; so the new subsidy $S_{Sc,e}$ will be conditioned by the stratum e and the Sisben score Sc. We will also introduce a penalization T for lower stratums with high Sisben score, which means households of stratum 1,2, 3 with a Sisben score higher than M, the restriction is denoted as:

$$\boldsymbol{P_{kWh} + P_{kWh} * T}, \qquad \boldsymbol{Sc \geq M}$$

Now that new restriction of our model are introduced we can estimate the new kWh price P_N that lower stratums consumers[15] will face after the introduction of the new restrictions, the formula for the new price is the following:

$$\boldsymbol{P_N = P_{kWh} - P_{kWh} * \left[(D * S_{Sc,e}) - (U * C) - T\right]}$$

Where $\boldsymbol{D}$ is the percentage difference between Actual consumption and subsistence consumption denoted as:

$$\boldsymbol{D} = \begin{cases} \boldsymbol{1}, & \boldsymbol{Co_{P_e} \leq R} \\ \boldsymbol{\dfrac{Co_{P_e} - R}{Co_{P_e}}}, & \boldsymbol{Co_{P_e} > R} \end{cases}$$

[15] Meaning the households in stratum 3 and bellow.

U is the percentage difference between consumption and the restriction L for over consumption and will be denoted as:

$$\boldsymbol{U = \begin{cases} 0, & Co_{P_e} \leq L \\ \dfrac{Co_{P_e} - L}{Co_{P_e}}, & Co_{P_e} > L \end{cases}}$$

We proceed then to determine the difference between the real price faced by the consumer and the new one we just estimate.

$$\boldsymbol{\partial P_e = \frac{P_N - P_{R_{kWh}}}{P_N}}$$

Then we estimate the change in consumption using price elasticities $\boldsymbol{E}$ to see changes in price as the following function indicates.

$$\boldsymbol{\partial Co_{P_e} = \partial P_e * E}$$

Function that will lead us to the new consumption, defined as as Cn_{P_e}, which is calculated through the following equation:

$$\boldsymbol{Cn_{P_e} = Co_{P_e} + \partial Co_{P_e} * Co_{P_e}}$$

5 Data

In this chapter we will discuss the data studied for the construction of the model above and the development of our empirical strategy. In first section we develop the process of data treatment for our Cross-subsidies model, in the second one we make an induction of the hydrologic series we use for the development of our empirical strategy.

5.1 Consumption, Tariffs and income distribution

For our targeting model we estimate consumption based on the information provided by the Life Quality Survey (LQS) of 2015, surveyed users provide information on their current stratum level and the amount paid in their last electricity bill[16]; using that month averaged KWh tariff, provided by the utilities financial reports on SUI's website, we estimate the consumption during the month of the bill reported on the LQS. Since data of LQS is at state

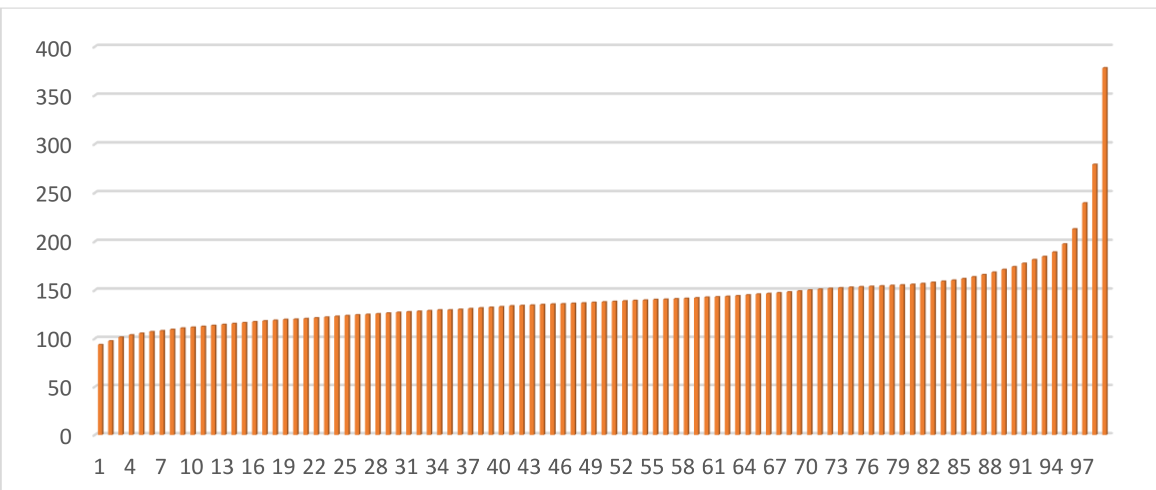
[16] There is no more information about electricity consumption in further surveys.

level we use data from the Great Integrated Households survey for estimating income centiles of households in the 5 cities subjects of our study .The Sisben score distribution was provided by Colombia’s Central Bank macroeconomic study’s branch in centiles for the purpose of this study.

According to Angulo, Gaviria & Moralres (2014) the adjusted poverty line in Colombia is around COP $275.000 per capita or COP$1’182.000 per household[17]. Since the distribution of income considerably differs from city to city the Sisben score also differs from City to city. The poverty line defined by the Sisben scores is below 30 in Bogotá, below 40 for Medellín and Cali, and 60 for Cartagena and Barranquilla.

There is a positive correlation between energy consumption an income, as income rise, energy consumption rise as well in all cities. In Graph 2 can be seen how as a household is in a higher income distribution the consumption also rises.

Figure 2: Medellín, Consumption of Energy (kWh) per Income Centile.



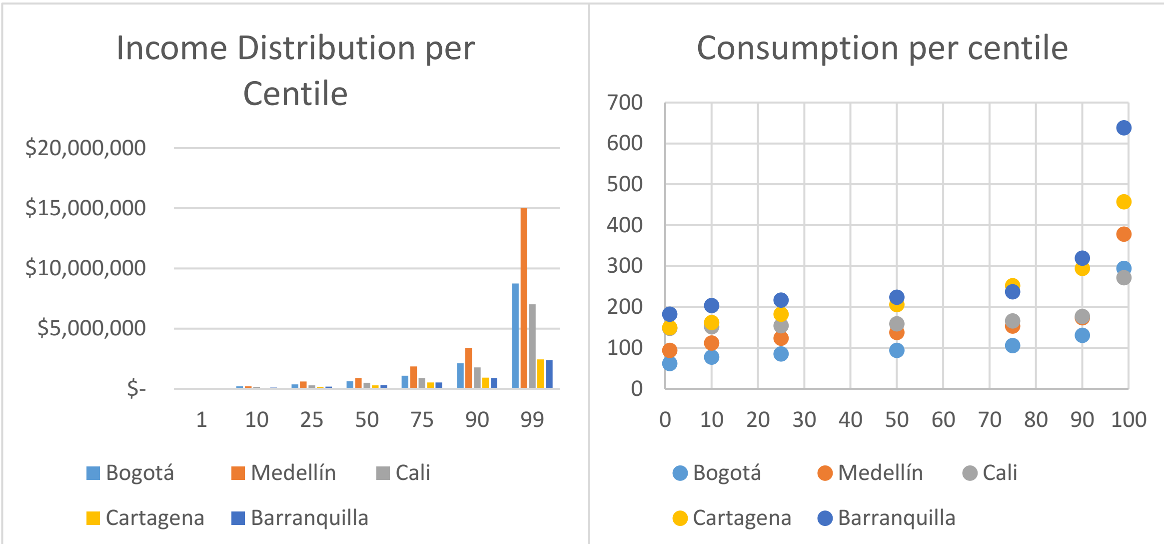
Source: Life Quality Survey of DANE, 2015.

The main difference between consumption arises across cities, median consumption in Medellín is 137.9 kWh, for Bogotá 93.8 in Bogotá, 158.6 kWh for Cali, 205.6 for Cartagena, and 223.5 for Barranquilla. Though median consumption for Cali, Cartagena and Barranquilla is higher than for Medellín and Bogotá the median income is higher on our data

[17] Assuming a household of four persons.

set for the last two cities, making consumption more susceptible to weather or cities temperature than income.

Figure 3 & Figure 4: Centile Income Distribution & Consumption of Energy (kWh) per Income Centile.



Source: Life Quality Survey of DANE, 2015.

The kWh tariffs vary from 483.7 in Cali to 409.5 in Medellin, there are not mayor difference in price between Bogota and Caribbean cities (Barranquilla and Cartagena).

In all 5 cities Utilities reported a deficit in their balance of subsidies vs contribution being the bigger gap in Bogotá, which also is the biggest city; still the problem arises in real financial constraints for caribeean cities, Cartagena and Barranquilla, both of them being supplied by Electricaribe, which is main consumer is composed on an 80% by households of stratum 1 and 2. We use June 2016 values as benchmark for our estimation, in table 3 the comparison between author's estimation and the amount of subsidizes given to the stratum 1 & 3 reported by the utilities can be seen.

Table 3: Cross-Subsidies value in $COP, 2016.

	Medellín	Bogotá	Cali	Barranquilla	Cartagena
Estimated Subsidies	$ 17,171,053,699	$ 28,185,624,372	$ 14,372,437,526	$ 13,341,469,730	$ 6,174,904,676
Real	$ 15,922,322,259	$ 21,914,035,741	$ 12,669,165,968	$ 12,562,000,643	$ 6,701,790,202

Source: Author's estimations and SUI.

Since consumptions were taken from the LQS of 2015 and due to the level of aggregation some differences may arise are expected, being the bigger difference in Bogotá where it arises above 7 Billions $COP. Using less aggregated data would be preferable for further studies on the subject.

For our Panel data modelling consumption, subsidies, tariffs, and number of users were taken from the data available in the Servicio Único de Información de Servicios públicos, which is the statistical branch of the Superintendence of Public Services in the country. We also use information of XM to measure country's hydrology, forward contracts agreement, and historical spot prices.

For modelling stratum 1 and 2 one problem arises, since the tariffs for those stratums as it was commented in this paper before, can't rise above inflation, so the impact for those during dry season is not as observable as it is for higher stratums.

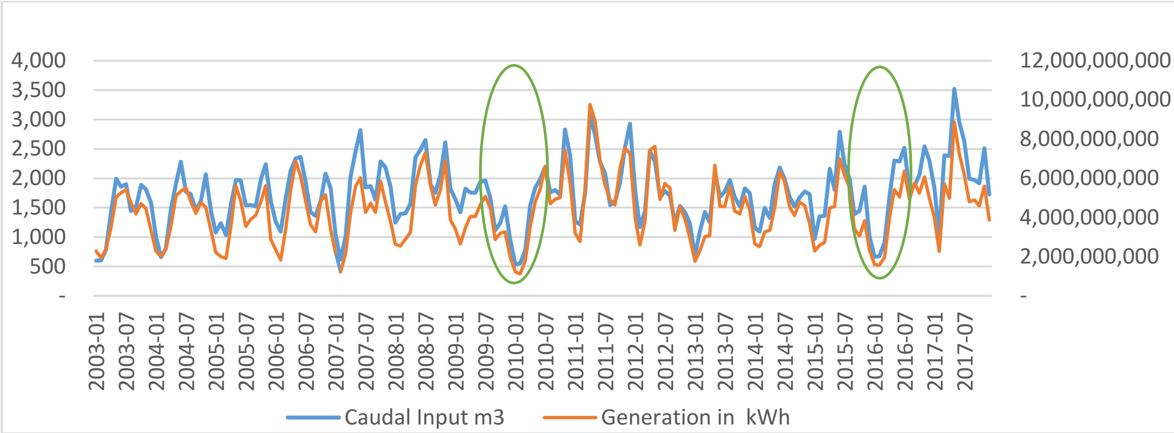
5.2 Hidrology

Our Hidrology data is obtained fromm XM for the period 2006-2016, it includes information on daily water inflows for hydropower generator, which will be averaged to cross them with SUI's averaged tariff monthly data.

Our model vertically integrates agents across generation and retailing components the agent, and instruments final users tariff on the amount of water inflows for hydropower generators, to see how hydrology would impact agents who are solely on retailing activity we also use country's monthly water inflows on main damns, and Utilities monthly volume of generation.

In recent years there's been two Niño phenomena's who have affected country's generation activity, heat waves are common during the first months of the year in Colombia until mid-April, during 2016 niño's one of the main dams in the country located in Guatape had technical failures which made the price of energy even rose higher, and putting the country at risk of energy rationing.

Figure 5: Country's Water Inflows and Generation in kWh.

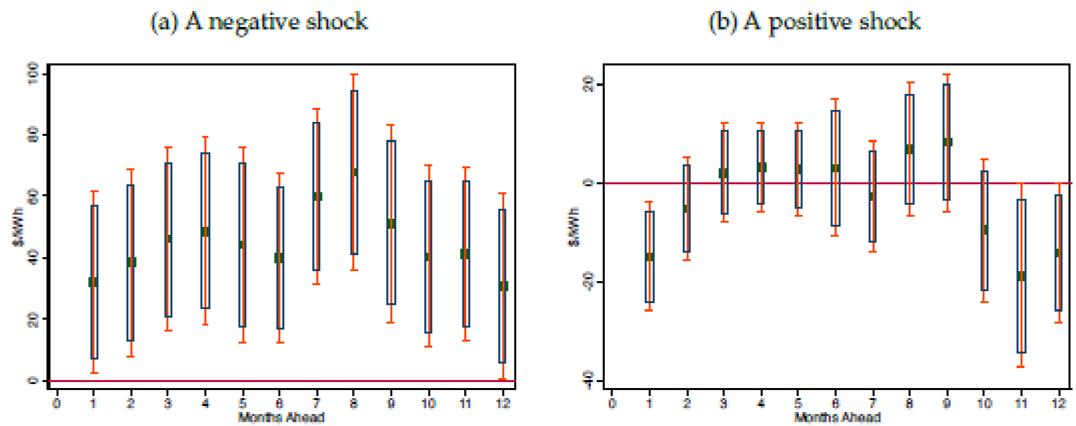


Source: XM.

While there is a clear correlation between water input and generation capacity these don't mean the generation will translate into the consumer's prices immediately, intuition suggest since tariff is regulated retailer face a load of constraints that don't allow them to increase tariff to consumers. Still literature suggest Generation component composes above 33% of the total amount of tariff, so a shcko on the hydrology intuitively does have a reasonable impact on the price of kWh final user faces.

According to Fioretti & Tamayo (2019) generators seem to anticipate shocks and water supply but react asymmetrically being the price more sensible to negative shocks than to positive where many times the effects are hardly significant at any point on future twelve months, Figure 6 shows show the positive and negative shock coefficients for the 12 months ahead of each period, respectively, with 5%(red line) and 10% (bar) confidence intervals.

Figure 6: The effect of a future shock to the water supply on the current quantity bids



Source: Fioretti & Tamayo (2019)

6 Empirical Strategy

For estimating our elasticities we'll perform an instrumental-variables regression. We intend to instrument the kWh price using generators and country's water inflows, as well as total contributions to the system system in KWh at utilities level and country level, so we can control for vertical integrated retailers.

Our model vertically integrates agents across generation and retailing components, and instruments final users tariff on the amount of water inflows for hydropower generators, to see how hydrology would impact agents who are solely on retailing activity we also use country's monthly water inflows on main damns, and Utilities monthly volume of generation. We cluster at municipality level assigning a fixed effect ω. We model the average monthly consumption kWh as a function of:

$$C_{m,i} = \propto + \beta_0 C_{m-1,i} + \beta_1 T_{m,i,r} + \omega + \varepsilon_{m,i}$$

Where $C_{m,i}$ is average consumption in the month m from location i, the tariff is represented as $T_{m,i,r}$ for the retailer r; for the instrumentation of the tariff we will take in account the following equation:

$$T_{m,i,r} = \propto + \beta_1 w_{m,r} + \beta_2 w_{m-1,r} + \cdots + \beta_t w_{m-t,r} + \tau_1 K_{m,r} + \cdots + \tau_1 K_{m-t,r} + \varepsilon_{m,r}$$

As is stated before the tariff is determined by the water influx $w_{m,r}$ lagged t times, while $K_{m,r}$ represent the agent contribution in the system in kWh, thus considering their past contributions. A larger current stock of water reduces a firm's intertemporal constraint and allows its hydro power plants to produce more in the current period. Such a large supply of water naturally implies lower prices in rainy periods, or that they will be lessen in the following months.

7 Results

Most economic literature suggest that demand tended to be inelastic to changes exogenous changes in price. Our results seems to suggest otherwise and households especially high income ones can react we a great diminution of their consumption to major price increases. These results are reflected in drastical reductions on consumption due to price changes in the final user's tariff product of new targeting policies applied to the assignment of kWh subsidies to lower stratum household, while affecting utilities ability to raise collection for the solidarity fund, due to the major reductions on consumption of higher income households.

7.1 Elasticities

For our elasticities model we found out that with an standard OLS regression our elasticity round -0.046, while when we instrument tariff with the country's water inflows lagged 1 and 6 times we reach a value of -0.498 and -0.296, respectively.

Table 4: Elasticity Results by Method

	OLS	**IV-Reg (1 Lag)**	**IV-Reg (6 Lags)**
log(Tariff)	-0.046	-0.498	-0.296
	(0.004)	(0.277)	(0.097)
Number of Observations	9501	9500	9451
Mean Dep. Variable	5.383	5.383	5.383

Note: We cluster at the municipality level. We instrumented the tariff with the inflow of water of the country. Standard error in parenthesis.

Our results suggests that utilities don't immediately transfer the cost of a water inflow restriction to consumers, due to many various reason in which the regulated tariff for final consumers, long-term contracts, and the increase of thermos-electric generation when there is a major constraint in precipitation, play an important role, the determination of the impact of this factors on the final consumer tariff lagged increase can be an interesting subject for further studies.

Applying the elasticities to our model we find small changes in consumption, still significant enough to assess a change in the overall consumption per city and calculate the amount of electricity savings per policy measure.

As we stated before in the beginning of this paper we will consider the following policies suggestion, which have been suggested by the literature and in public debate as possible reforms to counter the rising deficits that retailers are facing. First we assess the impact of cutting the whole subsidies since a relative small Sisben score, then we'll continue to assess the effects of suppressing the stratum 3 as a subsidiable Stratum, followed by the measurement of undercutting subsistence consumption, therefore we will look for the effects of raising a limit to consumption and give a penalization for consumers that surpass the restriction, finally we will analyze the possibility of households of lower stratum with high Sisben score with an extra fee.

The results also counter the wide-spread intuition among literature about demand of electricity being generally inelastic, and being considerable affected by shocks on country's water stock overall.

After assessing all the impacts of separated policies we will suggest a model which include most of the policies and asses its impact in the balance of utilities and electricity savings with the three elasticities considered above.

7.2 Initial Situation

The first step in the simulation process is the evaluation of the model in its capacity to emulate the base state of subsidies and contributions. The results are presented in the attached table. Most cities observe a consistent behavior. Bogotá moves away from this behavior and there is a very high dispersion in the ratio of strata and centiles. The bias observed is the increase in the allocation of subsidies, and should be taken into account in the specific considerations of scores within the limits of subsidies for this city; that is, the model overestimates the need for subsidies for the capital.

Table 5: Initial Situation and Model Calibration.

City	Subsidies SIM	Contribution SIM	Surplu/Deficit SIM	Real Subsidies	Real Contribution	Real Surplu/Deficit
MEDELLIN	$ 17,171,053,699	$ 11,691,427,395	-$ 5,479,626,304	$ 15,922,322,259	$ 12,290,725,093	-$ 3,631,597,166
BOGOTA	$ 28,185,624,372	$ 20,766,203,962	-$ 7,419,420,409	$ 21,914,035,741	$ 20,766,203,962	-$ 1,147,831,779
BARRANQUILLA	$ 13,576,907,431	$ 6,178,185,454	-$ 7,398,721,977	$ 12,562,000,643	$ 7,216,687,004	-$ 5,345,313,639
CALI	$ 14,372,437,526	$ 9,156,328,540	-$ 5,216,108,986	$ 12,669,165,968	$ 8,673,864,298	-$ 3,995,301,670
CARTAGENA	$ 6,098,504,684	$ 4,325,593,719	-$ 1,772,910,965	$ 6,701,790,202	$ 5,708,610,830	-$ 993,179,372

7.3 Sisben Score

The SISBEN score cut varies by city, and seeks to place it on the level of income that demarcates the poverty line in the country defined at $ 257,000 per capita per household; Therefore, in Bogota and Medellín, the SISBEN cut score is found in 30 points, in Cali 45, and for the coastal cities 55 points.

The results derived from the simulation indicate that at least for the simulated cities, with the additional SISBEN filter, the gap could be met with the current level of contributions (for Barranquilla the deficit is minimal).This measure proposed by PL 186 of 2016 is clearly effective and resolves the problem of subsidies in the cities studied, leaving surpluses to the Solidarity Fund. Barranquilla seems to be the city where this policy would have a lesser impact. The Savings in energy consumption are also significant

Table 6: Sisben Score Filter

City	Subsidies SIM	Contribution SIM	Surplu/Deficit SIM	Monthly Savings (GWH)
MEDELLIN	$ 1,443,099,814	$ 11,691,427,395	$ 10,248,327,581	11.27
BOGOTA	$ 4,893,330,919	$ 20,443,071,770	$ 15,549,740,851	15.39
BARRANQUILLA	$ 5,615,979,589	$ 6,178,185,454	$ 562,205,865	5.264
CALI	$ 4,361,707,636	$ 7,907,830,717	$ 3,546,123,081	6.11
CARTAGENA	$ 2,613,371,150	$ 4,325,593,719	$ 1,712,222,569	2.36

7.4 Suppression of Stratum 3

The elimination of stratum 3 within the subsidiary groups has little effect on closing the gap. The only city where is a visible impact is Bogotá, but it is insufficient to solve the structural deficit of the system. When observing the favorable impact of the SISBEN filter, it could be considered unnecessary to eliminate stratum 3 and better dedicate the efforts in the correct targeting of subsidies to those households with a low SISBEN score, even if they reside in stratum 3. The energy savings are meager compared to other options available.

Table 7: Eliminating Stratum 3 Subsidy

City	Subsidies SIM	Contribution SIM	Surplus/Deficit SIM	Monthly Savings (GWH)
MEDELLIN	$ 14,322,229,389	$ 11,691,427,395	-$ 2,630,801,994	2.04
BOGOTA	$ 22,059,698,935	$ 20,766,203,962	-$ 1,293,494,972	4.05
BARRANQUILLA	$ 12,898,119,128	$ 6,178,185,454	-$ 6,719,933,674	0.45
CALI	$ 12,237,335,228	$ 7,907,830,717	-$ 4,329,504,511	1.30
CARTAGENA	$ 5,570,625,582	$ 4,325,593,719	-$ 1,245,031,863	0.36

7.5 Reduction of Subsistence Consumption

The subsistence consumption was reduced from 130 kWh monthly to 110 in the interior cities, for Cartagena and Barranquilla was from 173 Kwh to 150. This measure has a positive effect on narrowing the gap, although this measure alone is insufficient and has less impact than the other measures that have been simulated before. This measure, however, must be considered integrated to the assignment of the Sisben scoring filter. Curiously enough this measure has a higher impact on energy saving in all cities than the elimination of stratum 3, with the exception of Bogota, who had less savings than with the suppression of stratum 3.

Table 8: Reduction of Subsistence Consumption

City	Subsidies SIM	Contribution SIM	Surplu/Deficit SIM	Monthly Savings (GWH)
MEDELLIN	$ 15,478,805,890	$ 11,691,427,395	-$ 3,787,378,495	2.35
BOGOTA	$ 21,133,649,129	$ 20,443,071,770	-$ 690,577,360	0.21
BARRANQUILLA	$ 11,858,353,840	$ 6,178,185,454	-$ 5,680,168,386	1.84
CALI	$ 12,485,067,655	$ 7,907,830,717	-$ 4,577,236,938	2.04
CARTAGENA	$ 5,407,989,955	$ 4,325,593,719	-$ 1,082,396,235	0.82

7.6 Over-Consumption Fee

The penalization for high consumption will be put in place for consumptions above 200 kWh in Medellín and Bogotá, for Cali, Cartagena and Barranquilla due to the high consumption registered in those cities the restriction will be of 250 kWh. The penalization over the consumption above the limit will be 20%.

The tariff increase for high consumption has a positive effect on the collection, and it is a very good measure to increase it substantially, this measure integrated to the double stratum filter and SISBEN could completely close the gap between subsidies and contributions and leave surplus in the system. Still does not have any major effect on consumption reduction, with exception of Barranquilla, which surpasses Bogotá on the size of the change. This probably would be explained due to the low electricity consumption of Bogota in comparison with coastal cities.

Table 9: Contribution from a High consumption

City	Subsidies SIM	Contribution SIM	Surplu/Deficit SIM	Monthly Savings (GWH)
MEDELLIN	$ 17,171,053,699	$ 11,807,225,720	-$ 5,363,827,980	0.98
BOGOTA	$ 28,185,624,372	$ 21,270,953,169	-$ 6,914,671,202	1.70
BARRANQUILLA	$ 13,576,907,431	$ 6,768,344,480	-$ 6,808,562,951	2.34
CALI	$ 14,372,437,526	$ 7,923,960,724	-$ 6,448,476,803	0.045
CARTAGENA	$ 6,098,504,684	$ 4,613,541,955	-$ 1,484,962,729	0.85

7.7 High Sisben Score Contributions

This measure has a significant effect on contributions, making the system solvent considerably. By itself it makes the system viable and must be considered jointly with the SISBEN filter for the allocation of subsidies to design the final measures that ensure the sustainability of the cross-subsidy model.

Table 10: Contributions from higher Sisben score

City	Subsidies SIM	Contribution SIM	Surplu/Deficit SIM	Monthly Savings (GWH)
MEDELLIN	$ 17,171,053,699	$ 11,982,022,438	-$ 5,189,031,261	0.204993928
BOGOTA	$ 28,033,683,212	$ 23,799,139,932	-$ 4,234,543,280	2.148692586
BARRANQUILLA	$ 13,576,907,431	$ 7,165,207,836	-$ 6,411,699,595	0.767898858
CALI	$ 14,372,437,526	$ 9,156,328,540	-$ 5,216,108,986	0.81125996
CARTAGENA	$ 6,098,504,684	$ 5,232,311,880	-$ 866,192,804	0.639599849

7.8 Full Scale Model

For our full restriction model we will escalate the diminishing of subsidies in three stages, this diminution will be universal for the three cities as the following table show:

Table 11: Range of Subsidies within Sisben Score

Sisben Score range	Percentage of Tariff Subsidized		
	Stratum 1	**Stratum 2**	**Stratum 3**
0-29	57%	48%	15%
30-49	30%	20%	10%
50-59	15%	10%	5%
60- Beyond	0%	0%	0%

We will also consider in our simulation the reduction of subsistence consumption as we modeled it before, the consumption restriction will also be kept, and there will be a fee for lower stratums with high Sisben score which also will include the stratum 4. The only policy proposal that will not be considered in this model is the suppression of stratum 4 due to its low impact on the balance and electricity savings. The overall changes in consumption will be included in Annex 2.

At first we take a glance of how our model would look like without elasticity. Even with just the accountable model the deficit in all the cities is solved entirely. Since in this scenario consumers don't have any sensibility toward price changes there's no electricity saving to be shown.

Table 12: Full Range Model with no elasticity.

City	Subsidies SIM	Contribution SIM	Surplu/Deficit SIM
MEDELLIN	$ 6,108,827,450	$ 12,439,797,078	$ 6,330,969,628
BOGOTA	$ 10,378,138,498	$ 21,155,230,717	$ 10,777,092,218
BARRANQUILLA	$ 2,859,625,465	$ 6,790,007,423	$ 3,930,381,958
CALI	$ 4,137,914,464	$ 7,915,293,595	$ 3,777,379,131
CARTAGENA	$ 1,248,178,797	$ 4,450,926,361	$ 3,202,747,564

Our model with 6 –lags elasticity differs mainly from the accounting one in the marginal diminution of contributions and subsidies, this result is expected since all consumer are sensible to an exponential change in prices, though the savings of this model are not as big as the ones seen in the Sisben's score, this one might be more acceptable for consumers and still accomplish the goal of solving the budgetary problem retailer utilities are facing in the market.

Table 13: Full Range Model with 6-lags elasticity.

City	Subsidies SIM	Contribution SIM	Surplu/Deficit SIM	Monthly Savings (GWH)
MEDELLIN	$ 6,033,012,161	$ 12,284,050,936	$ 6,251,038,775	10.27
BOGOTA	$ 9,887,076,682	$ 20,975,086,740	$ 11,088,010,058	14.57
BARRANQUILLA	$ 4,045,184,731	$ 7,572,280,383	$ 3,527,095,652	9.67
CALI	$ 4,137,914,464	$ 8,494,146,576	$ 4,356,232,112	7.66
CARTAGENA	$ 1,828,603,055	$ 5,420,856,348	$ 3,592,253,293	4.34

The main changes in consumption as can be seen in annex 2 come from higher centiles, who happened to be also the ones with a higher consumption in all cities, since lower stratums with high Sisben score are the ones who were subject to more rough changes they have a more radical diminution in their consumption than other centiles among income distribution.

The results of our model considering 1-lag elasticity differ mainly from the the 6-lags in the amount of electricity saving which are far more considerable, showing biggest increases in Medellín, Bogotá and Barranquilla, saving 10 GWh monthly more in the case of bogotá.

Table 14: Full Range Model with 1-lag elasticity.

City	Subsidies SIM	Contribution SIM	Surplu/Deficit SIM	Monthly Savings (GWH)
MEDELLIN	$ 5,845,848,329	$ 12,181,602,164	$ 6,335,753,834	17.27
BOGOTA	$ 9,551,960,172	$ 20,854,178,165	$ 11,302,217,992	24.51
BARRANQUILLA	$ 4,045,184,731	$ 8,244,643,603	$ 4,199,458,872	16.30
CALI	$ 4,137,914,464	$ 9,418,643,499	$ 5,280,729,035	12.89
CARTAGENA	$ 1,790,060,189	$ 5,326,395,558	$ 3,536,335,368	7.32

Our model allows us to recreate a user-reported consumption scenario in which we can integrate an income proximity scoring method we the current targeting system and considering multiple targeting approaches and assess impact on consumer's future consumption. Independently from the elasticity that is chosen, the proposal restriction seem more than sufficient to solve the imbalance current utilities are facing at least in main country's cities. While an escalated targeting model seems to be of minor impact on reducing the amount of subsidies than the Non- escalated Sisben alternative, the escalated targeting option seems to be more effective on accomplishing reduction on the overall consumption, as it is shown in the comparison of Tables 6 and 13. The incorporation of elasticities in our targeting model allowed us to perceived future difficulties on utilities ability of collection for contributions to the solidarity fund, since high income users will be more sensible to an increase on kWh price.

8 Conclusions

An accurate valuation of consumer's electricity price elasticity is a valuable asset for all the agents in the system including regulators. The price elasticity in the light of the implementation of a public policy that restricts the access to cross-subsidies in the system is an important tool to assess the impact in population welfare, system sustainability and efficient energy usage. While there´s been several attempts to valuate price-elasticity in

Colombia, few consider the impact of hydrology in the tariff and asses consumers reaction due to this exogenous shocks in system's generation capacity. An important fact to considerate is that generation often represents 33% of tariff's composition, so country's hydrology does have a substantial impact on Final user's tariff. Even though the change is not immediate, is enough so the households can reduce their consumption after a long period of *El niño* phenomenon.

The other contribution of this paper is the assessment of the effectiveness of policies to counter the rising problem of bad focalization in the current cross-subsidies system. While rising penalization for over-consumption, the removal of stratum 3 as a subject of transferences, and diminishing subsistence consumption can have a reasonable impact on closing the existent gab between the utilities deficits and the contributions received by the solidarity fund, the only policy that seems efficient enough to completely solve the issue is the use of the Sisben Score as a double mechanism for focalizing subsidies to the poorest households.

Further studies, like a dynamic modelling of the implementation of double-filter system would be suggested to assess the long term impact on consumption and system's budget. Also an income elasticity study could be required to illustrate the impact of the implementation of such policies in household's budgets.

References

Acolgen. (23 de October de 2018). *Cómo funciona el mercado*. Obtenido de Acolgen web site: https://www.acolgen.org.co/index.php/sectores-de-generacion/como-funciona-el-mercado#contratacion-de-la-energia

Acuña, O., González, P., & Forero, R. (2013). Elasticidades de demanda por electricidad e impactos macroeconómicos del precio de la energía eléctrica en Colombia. *Revista de Métodos Cuantitativos para la eocnomía y la empresa No.16*, 216-249.

Amador, L. E. (2011). *Fallas del mercado y capacidad de pago: una propuesta para los servicios de acueducto y alcantarillado.* Medellín: Opinión Jurídica- Universidad de Medellín.

Angulo, R., Gaviria, A., & Morales, L. (2014). La década ganada: evolución de la clase media, la pobreza y la vulnerabilidad en Colombia 2002-2011. *Coyuntura Económica. Vol. XLIV, No. 1*, 173-209.

Arzaghi, M., & Squalli, J. (2015). "How price inelastic is demand for gasoline in fuel-subsidizing economies? *Energy Economics, Vol. 50*, 117-124.

Ayala, U., & Millá, J. (2002). *La sostenibilidad de las reformas del sector eléctrico en América Latina – Las reformas en Colombia.* Washington D.C.: Banco Interamericano de Desarrollo.

Barrientos, J., Velilla, E., Tobón- Orozco, D., Villada, F., & López-Lezama, J. M. (2018). On the estimation of the price elasticity of electricity demand in the manufacturing industry of Colombia. *Lecturas de Economía - No. 88.*, 155-182.

Botero, J., García, J. J., & Vélez, L. G. (2013). Mecanismos utilizados para monitorear el poder de mercado en mercado eléctricos: reflexiones para Colombia. *Cuadernos de Economía No. 32*, 571-597.

Bruegge, C. (2018). *Distortionary Fundraising for Energy Efficiency Subsidies: Implications for Efficient and Equitable Program Design.* Stanford: Job Market paper.

Burke, P. J., & Abayasekara, A. (2017). *The price elasticity of electricity demand in the United States: A three-dimensional analysis.* CAMA Working Papers 2017-50, Centre for Applied Macroeconomic Analysis, Crawford School of Public Policy, The Australian National University.

Campbell, A. (2018). Price and income elasticities of electricity demand: Evidence from Jamaica. *Energy Economics Volume 69*, 19-32.

Congreso de Colombia. (1994a). Ley 142 de 1994- Ley de servicios públicos.

Congreso de Colombia. (1994b). Ley 143 de 1994- Ley Eléctrica.

Congreso de la República de Colombia. (2016). Proyecto de Ley 186 de 2016.

CREG. (1995). Resolución No. 024. Bogotá D.C.: Comisión de Regulación de Energía y Gas.

CREG. (4 de April de 1997). Resolución 031. Bogotá: Comisión de Regulación de Energía y Gas.

CREG. (1997). *Resolución 031 de 1997.* Bogot'a D.C.: Comisión de Regulación de Energía y Gas.

CREG. (2001). Resolución No 026 de 2001. Bogotá D.C.: Comisión de Regulación de Energía y Gas.

CREG. (21 de Diciembre de 2007). Resolución No:119. Bogotá: Comisión de Regulación de Energía y Gas.

CREG. (2008). *Resolución 097 de 2008.* Bogotá D.C.: Comisión de Regulación de Energía y Gas.

CREG. (2014). *Resolución 180 de 2014.* Bogot'a D.C.: Comisión de Regulación de Energía y Gas.

Deryugina, T., MacKay, A., & Reif, J. (2017). The Long-Run Dynamics of Electricity Demand: Evidence from municipal aggregation. *NBER Working Papers*, Working Paper 23483.

Di Bella, G., Lawrence, N., Ntamatungiro, J., Ogawa, S., Samake, I., & Santoro, M. (2015). *Energy Subsidies in Latin America and the Caribbean: Stocktaking and Policy Challenges.* Washington D.C.: IMF Working Papers.

Dirección de desarrollo Social -Gupo de Calidad de Vida. (2008). *Diseño del Índice en su stercera versión- SISBEN III.* Bogot'a D.C.: DNP.

Faisal, J., & Eatzaz, A. (2011). Income and price elasticities of electricity demand: Aggregate and sector-wise analyses. *Energy Policy Volume 39, Issue 9*, 5519-5527.

Filippini, M., & Pachauri, S. (2002). *Elasticities of electricity demand in urban Indian households.* Zurich: CEPE Working paper No.16. InSwiss Federal Institutes of Technology.

Fioretti, M., Tamayo, & A., J. (2019). *The Price o fWater and Dynamic Spillovers: Hydropower Generation in Colombia.* Boston, MA: Working Paper.

Franco, C. J., Cadavid, L., & Dyner, I. (2017). El Mercado Eléctrico Colombiano: Realidades y Deficiencias. En I. Dyner, & C. J. Franco, *Ocaso de un paradigma: Hacia un nuevo modelo eléctrico* (págs. 69-116). Bogotá D.C.: Fondo de Cultura Económica.

Gaviria, S. (2016). *Hacia un Nuevo esquema de Subsidios.* Bogotá D.C.: Departamento Nacional de Planeación.

Haas, R., & Schipper, L. (1998). Residential energy demand in OECD-countries and the role of irreversible efficiency improvements. *Energy Economics Vol. 20*, 421-442.

Harish, S. M., & Tongia, R. (2017). *Do rural residential electricity consumers cross-subside their urban counterparts? Exploring the inequity in supply in the Indian power sector.* Washington D.C.: Brookings Instituion.

Knittel, C. R., & Roberts, M. M. (2001). *An Empirical Examination of Deregulated Electricity.* Berkley: Univ. of California Energy Institut.

Komives, K., Foster, V., Halpern, J., & Wodon, Q. (2005). *Water, electricity and the poor: Who Benefits from utility subsidies?* Bogot'a D.C.: World Bank.

Labandeira, X., Labega, J. M., & López-Otero, X. (2012). Estimation of elasticity price of electricity with incomplete information. *Energy Economics*, 627-633.

Laffront, J.-J., & N'Gbo, A. (2000). Cross-subsidies and network expansion in developing countries. *European Economic Review*, 797-805.

Li, F., Wang, W., & Yi, Z. (2018). Cross-Subsidies and Government Transfers: Impacts on Electricity Service Quality in Colombia. *Sustainability Vol. 10 Issue 5.*

Medina, C., & Morales, L. F. (2007). Demanda por Servicios Públicos Domiciliarios en Colombia y Subsidios: Implicaciones el Bienestar. *Borradores de Economía No. 467*.

Medina, C., & Morales, L. F. (2008). Demanda por servicios públicos domiciliarios y pérdida irrecuperable de los subsidios: el caso colombiano. *Desarrollo y Sociedad*, 1-42.

Meléndez, M. (2008). *Subsidios al consumo de los servicios públicos: Reflexiones a partir del caso colombiano.* Caracas: CAF.

Meléndez, Marcela; Casas, Camila; Medina, Pablo. (2004). *Subsidios al Consumo de Servicios Públicos en Colombia ¿Hacia donde Movernos?* Bogotá: Fedesarrollo.

Méndez, L. F. (2014). *Políticas Públicas del Sector Eléctrico Colombiano 1990-2009.* Bogotá: Universidad Nacional de Colombia.

Mills, E. (2017). Global Kerosene Subsidies: An Obstacle to Energy Efficiency and Development. *World Development Vol. 99*, 463-480.

Okajima, S., & Okajima, H. (2013). Estimation of Japanese price elasticities of residential electricity demand, 1990–2007. *Energy Economics*, 433-440.

Pachauri, S., & Spreng, D. (2011). Measuring and monitoring energy poverty. *Energy policy*, 1080-1092.

Pielow, A., Sioshansi, R., & Roberts, M. C. (2012). Modeling Short-run Electricity Demand with Long-term Growth Rates and Consumer Price Elasticity in Commercial and Industrial Sectors. *Energy Volume 46, Issue 1*, 533-540.

Reiss, P. C., & White, M. W. (2001). *Household Electricity Demand, Revisited.* Cambridge, MA: NBER, Working Paper 8687.

Schulte, I., & Heindl, P. (2017). Price and income elasticities of residential energy demand in Germany. *Energy Policy*, 512-528.

Trespalacios, A., Pantoja, J. O., & Fernández, O. (2017). *Análisis de Mercados de Electricidad.* Medellín: Editorial Eafit.

Vélez, L. G. (2015). *El precio de la Electricidad en Colombia y comparación con referentes internacionales 2012-2015.* Medellín: ECSIM.

Willems, B., Ehlers, E., & Fraga, V. M. (2008). *Cross-subsidies in the Electricity Sector.* Tilburg: Tilburg University.

XM. (23 de October de 2018). *Información de Operación del SIN y Administración del Mercado*. Obtenido de XM página web: http://informesanuales.xm.com.co/2014/SitePages/operacion/1-4-Agentes-del-mercado.aspx

Annex 1: Construction of the Tariff for Regulated market.

Purchase Cost of Energy:

The recognition of maximum energy purchase costs to the end user through market mechanisms will be gradually implemented, for it there are three alternatives for the calculation of the Purchase Cost of Energy:

Maximum cost of moving energy purchases for the first phase of the transition: Until the transactions of the Regulated Organized Market (ROM) begin to be settled, the maximum purchase cost to be transferred to the regulated end user will be determined in accordance with the following expression:

$$\boldsymbol{G_{m,i,j} = Qc_{m-1,j} * \left(\alpha_{i,j} * Pc_{m-1,j} + \left(1 + \alpha_{i,j}\right) * Mc_{m-1}\right) + \left(1 - Qc_{m-1,j}\right) * Pb_{m-1,j} + AJ_{m,i}}$$

In the following expression i is the label of the retailer, during the month m, in the retail market j. The variables that compose the equation are:

- $\boldsymbol{Qc_{m-1,j}}$**:** Is the lesser value between one and the result of the relation of energy purchased by the retailer through bilateral contracts with destiny to the regulated market and commercial demand of the retailer during the last month. The algebraic expression is:

$$\boldsymbol{Qc_{m-1,j} = MIN\left[1, \frac{Cc_{m-1,i}}{DCR_{i,m-1}}\right]}$$

  - $\boldsymbol{DCR_{i,m-1}}$**:** Last month regulated commercial demand of retailer.
  - $\boldsymbol{Cc_{m-1,i}}$ **:** Energy bought through bilateral contracts by the retailer, destined to regulated market.

- $\boldsymbol{Pc_{m-1,j}}$ **:** Average cost weighted by energy, expressed in \$ / kWh, of the own purchases of the Retail Marketer and through bilateral contracts destined to the regulated market, settled during the last month.

- $\boldsymbol{Mc_{m-1}}$ **:** Average cost weighted by energy, expressed in \$ / kWh, of all bilateral contracts settled in the Wholesale Energy Market in month $m-1$ for the regulated market.
- $\boldsymbol{\alpha_{i,j}}$ **:** weighting factor for $\boldsymbol{Pc_{m-1,j}}$ it is calculated through the next equation, accordingly to the formula stated in CREG's Resolution 031 of 1997 (CREG, 1997):

$$\boldsymbol{\alpha_{i,j,m,t} = 1 - \left[\frac{C_{m,t} * (1 - PR_{i,t})}{P_{t-1} * \frac{PPI_{m-1,t}}{PPI_{6,t-1}}} \right]}$$

  - $\boldsymbol{C_{m,t}}$ **:** Cost of commercialization during the current year and month[18].
  - $\boldsymbol{PR_{i,t}}$**:** Percentage of cumulative losses recognized to the retailer in the year t.
  - $\boldsymbol{PPI_{6,t-1}}$**:** National Total Producer Price Index for June of the year prior to t.
  - $\boldsymbol{P_{t-1}}$**:** Average cost of own purchases destined to the regulated market, corresponding to the year prior to t.

- $\boldsymbol{Pb_{m-1,j}}$**:** Price of the energy purchased on the Spot market by the Retailer i, in the last month, expressed in \$ / kWh, when the amounts acquired in MOR tenders and in bilateral contracts do not cover the totality of the regulated demand.

$$\boldsymbol{Pb_{m-1,j} = \frac{\sum_{h-1}^{n} P_{h,m-1} * D_{i,h,m-1}}{\left(\sum_{h-1}^{n} D_{h,i,m-1}\right)}}$$

  - $\boldsymbol{P_{h,m-1}}$: Exchange price in hour h (\$ / kWh), month $m-1$.
  - $\boldsymbol{D_{h,i,m-1}}$**:** Stock purchases of retailer i at hour h of month $m-1$.

[18] Through this charge, the maximum costs associated with the attention of regulated users will be recognized, with a scheme that encourages the efficiency of companies, in the following manner:

$$\boldsymbol{C_{m,t} = \frac{C_0^*}{CFM_{t-1}} * [1 - \Delta IPSE] * \frac{CPI_{m-1}}{CPI_0}}$$

$\boldsymbol{C_0^*}$: Base Cost of commercialization expressed in \$/Bill.
$\boldsymbol{CFM_{t-1}}$: Average Invoiced Consumption of each company in year t-1 to users connected to the distribution system where the charge is applicable (Total kWh sold to regulated and unregulated users divided by the total of invoices issued, without considering those due to errors billing).
$\boldsymbol{\Delta IPSE}$ **:** Cumulative variation in the Productivity Index of the Electricity Sector, from the validity of the specific rate formula of each company.
$\boldsymbol{CPI_{m-1}}$ **:** Consumer Price Index during the last month.
$\boldsymbol{CPI_0}$ **:** Consumer Price Index at the month that C_0^* is referenced.

- $\boldsymbol{AJ_{mj}}$: Adjustment factor apllied to the maxium cost of power purchase, expressed in \$/kWh, of retaiter. Its formula is:

$$\boldsymbol{AJ_m = min\left[(MAX_m - CR_m), \frac{AD_m}{VR_{m-1}}\right]}$$

$$\boldsymbol{MAX_m = REF_m * (1 + 0.3)}$$

$$\boldsymbol{AD_m = [AD_{m-1} + (CR_{m-1} - G_{m-1}) * VR_{m-1}] * (1 + r)}$$

  - $\boldsymbol{VR_{m-1}}$**:** Energy sales in the regulated market during last month by retailer i.
  - $\boldsymbol{AD_m}$: Cumulative balance of the differences between the Recognized Cost and the value transferred in the tariff $\boldsymbol{G_{m,j}}$, expressed in \$.
  - $\boldsymbol{r}$: Monthly nominal interest rate recognized to the retailer.
  - $\boldsymbol{MAX_m}$**:** Maximum value to be transferred, expressed in \$ / kWh, in month m, by the retailer.
  - $\boldsymbol{REF_m}$: Reference Value or Price, expressed in \$ / kWh, to be applied by retailer i, in month m. Were $\boldsymbol{REF_m}$ is constructed by the following variables:

$$\boldsymbol{REF_m = Qc_{m-1,j} * \left(\alpha_{i,j} * Pc_{m-1,j} + \left(1 - \alpha_{i,j}\right) * Mc_{m-1}\right) + \left(1 - Qc_{m-1,j}\right) * Mc_{m-1}}$$

  - $\boldsymbol{CR_m}$: Recognized cost of energy purchase (\$ / kWh) for month m of the retailer i. This value is equivalent to the value of the component $\boldsymbol{G_{m,j}}$ discounted by the variable $\boldsymbol{AJ_m}$.

$$\boldsymbol{CR_m = Qc_{m-1,j} * \left(\alpha_{i,j} * Pc_{m-1,j} + \left(1 - \alpha_{i,j}\right) * Mc_{m-1}\right) + \left(1 - Qc_{m-1,j}\right) * Pb_{m-1,j}}$$

The $\boldsymbol{G_{m,i,j}}$ component is quite dynamic, since several of the factors that determine it are dynamic, among other events that can vary the G are: The termination of a contract, the entry of a new contract, the stock price, the average price of market contracts for the regulated market.

Second Phase

From the second month of settlement of the energy traded in the MOR and while the bilateral contracts are valid for the Regulated Market, the maximum cost of purchasing energy to be transferred to the user will be determined in accordance with the following expression:

$$\boldsymbol{G_{m,i,j} = Qc_{m-1,j} * \left(\alpha_{i,j} * Pc_{m-1,j} + \left(1 + \alpha_{i,j}\right) * Mc_{m-1}\right) + Q_{ROM_{m-1,j}} * P_{ROM_{m-1,j}} + Qb_{m-1,j} * Pb_{m-1,j} + AJ_{m,j}}$$

$$\boldsymbol{Qc_{m-1,j} + Q_{MOR_{m-1,j}} + Qb_{m-1,j} = 1}$$

$$\boldsymbol{Qc_{m-1,j} = \left[\frac{C_{C_{m-1,j}}}{DCR_{m-1,j}}\right] \qquad Q_{MOR_{m-1,j}} = \left[\frac{C_{MOR_{m-1,j}}}{DCR_{m-1,j}}\right]}$$

In this phase and the following $Qc_{m-1,j}$, $Q_{MOR_{m-1,j}}$ and $Qb_{m-1,j}$ represents the different proportion of the agent commercial demand which is divided between the total amount of purchases in each market: contracts, ROM or spot market, in the period prior to the fixing of $G_{m,i,j}$.

$\boldsymbol{P_{ROM_{m-1,j}}}$: The price of ROM is an average weighted price from all the quantities purchased in forward market for the period before the fixation of $G_{m,i,j}$.

For the estimation of the AJ_m component we follow the same procedure specified during the first phase, with the differences that in the estimation of the $\boldsymbol{REF_m}$ component the formula includes the average weighted price of spot purchases and MOR, and also the proportions of weighted 3 quantities, and for $\boldsymbol{CR_m}$ equals last month's $\boldsymbol{G}$ without the inclusion of $\boldsymbol{AJ_{m-1,j}}$. The formulas are indicated as:

$$\boldsymbol{REF_m = Qc_{m-1,j} * \left(\alpha_{i,j} * Pc_{m-1,j} + \left(1 + \alpha_{i,j}\right) * Mc_{m-1}\right) + Q_{ROM_{m-1,j}} * P_{ROM_{m-1,j}} + Qb_{m-1,j} * Pb_{m-1,j}}$$

and:

$$\boldsymbol{CR_m = Qc_{m-1,j} * \left(\alpha_{i,j} * Pc_{m-1,j} + \left(1 - \alpha_{i,j}\right) * Mc_{m-1}\right) + \left(1 - Qc_{m-1,j}\right) + Q_{ROM_{m-1,j}} * P_{ROM_{m-1,j}} + Qb_{m-1,j} * Pb_{m-1,j}}$$

Third Phase:

From the moment in which the Retailer finish all his bilateral contracts destined to the regulated market, the energy required by the regulated users will be acquired in the ROM, where the maximum purchase cost to be transferred to the end user will be:

$$\boldsymbol{G_{m,i,j} = Q_{ROM_{m-1,j}} * P_{ROM_{m-1,j}} + Qb_{m-1,j} * Pb_{m-1,j} + AJ_{m,j}}$$

$$\boldsymbol{Q_{ROM_{m-1,j}} + Qb_{m-1,j} = 1}$$

In this Phase Price of Reference, REF_m, equals the price of ROM, $P_{ROM_{m,j}}$, and CR_m equals again G of the last month without the inclusion of $AJ_{m-1,j}$, as it is represented by the following expressions:

$$\boldsymbol{REF_m = P_{ROM_{m,j}}}$$

and:

$$\boldsymbol{CR_m = Q_{ROM_{m-1,j}} * P_{ROM_{m-1,j}} + Qb_{m-1,j} * Pb_{m-1,j}}$$

Transmission:

CREG's Resolition 011 of 2009 stablishes the methodology for estimating the regulated income as:

$$\boldsymbol{IAT_j = CAEA_j * (1 + \%ANE) + VAOM_j + CAET_j + CAES_j - OI_j}$$

$\boldsymbol{CAEA_j}$: Annual Equivalent Cost of the Electric Asset valued at the Replacement Cost.

$\%\boldsymbol{ANE}$**:** 5.0% Percentage recognized as Non-Electric Assets.

$\boldsymbol{VAOM_j}$**:** Management, Operations and maintenance expenditures.

$\boldsymbol{CAET_j}$**:** Annual Equivalent Land Cost.

$\boldsymbol{CAES_j}$**:** Annual Cost Equivalent of Easements.

$\boldsymbol{OI_j}$**:** Other Income from the exploitation of the assets remunerated through charges for use in activities other than the transmission of electric power.

Distribution

In distribution there are two associate collections, by use and by level of tension. In the following we will explain how the Charges.

Charges By Use at level of tension 4:

$$Dt_{4,R,m,t} = \frac{CD_{4,R,m,t}}{1 - PR_{4,R,m,t}}$$

$Dt_{4,R,m,t}$: Charges for the use of voltage level 4 of the Network Operator, which makes part of the Regional Transmission system (RTS) R, at the year t in $/kWh.

$CD_{4,R,m,t}$: Charge at tension level 4.

$PR_{4,R,m,t}$: Factor of reference for energy use, this factor is calculates as the following formula indicates:

$$PR_{4,R,m,t} = P_{4,R,m,t}$$

$$P_{4,R,m,t} = 1 - \frac{\sum_{j=1}^{JR} IMSC_{j,4,R,m,t}}{\sum_{j=1}^{JR} IMSC_{j,4,R,m,t} * \left(1 - P_{4,j,m,t}\right)^{-1}}$$

$P_{4,R,m,t}$: Loss factor weighted at tension level 4, for the Network operator that makes part of the RTS

$IMSC_{j,4,R,m,t}$: Monthly income of the Network operator, without including auctions in commercialization market different form its own.

$P_{4,j,m,t}$: Loss factor of Network operator$j$, who makes part of the RTS R.

JR: Number of Network operators in the RTS R.

Charges By Use at level of tension 3:

$$Dt_{3,R,m,t} = \frac{CD_{4,R,m,t}}{1 - PR_{3,R,m,t}} + CD_{3,R,m,t} + Dtsc_{3,j,mt}$$

Where $PR_{3,R,m,t}$ represents the loss factor weighted at tension level 3, $CD_{3,R,m,t}$ the charge at tension level 3, and $Dtsc_{3,j,mt}$ is a charge for

Commercialization:

The Cost of commercialization is composed by two components, a fixed on and a variable. The fixed is known as the Base cost of commercialization and it is estimated throught the next formula:

$$\boldsymbol{Cf_j = \frac{GC_j * \gamma_j}{Fact_j}}$$

$\boldsymbol{Cf_j}$**:** Stands for the commercialization costs of the market j.

$\boldsymbol{GC_j}$: Expenditures of the commercialization activity of the retailer in market j.

$\boldsymbol{\gamma_j}$**:** Efficiency market's factor which correspond to the superior limit of confidence interval predicted by the model stipulated by the following modelling (CREG, 2014), were q_{it} corresponds to the product measures by the number of users for the utility i during the year t. y_{it} is the expending's in commercialization activity in COP. $w1_{it}$ and $w2_{it}$ are production supplies and $z1_{it}$ to $z5_{it}$ are variables that characterize the market like the longitude of the network rural and urban, total billing, number of bimensual bills and numbers of trimestral bills[19].

$$\boldsymbol{lny_{it} = \alpha_0 + \alpha_q lnq_{it} + \alpha_1 lnw1_{it} + \alpha_2 lnw2_{it} + \delta_1 z1_{it} + \cdots + \delta_5 z5_{it} + v_{it} + \mu_{it}}$$

$\boldsymbol{Fact_j}$**:** Number of bills issued by the Retailer for the market j.

Since Cf_j use base values of 2013 it has to be actualized for the next years, the formula for the readjustment is

$$\boldsymbol{Cf_{j,m} = Cf_{j,m-1} * (1 - X) * \frac{CPI_{m-1}}{CPI_0}}$$

$\boldsymbol{Cf_{j,m-1}}$**:** Base cost of commercialization for the market j during the last period.

[19] For further information about the efficiency factor check the Annex 1 of CREG's Resolution 180 of 2014.

$\boldsymbol{X}$**:** Productivity Facto accumulated for the activity of energy commercialization. During the first year of Calendar (2013) this factor will be equal to 0, and it will be increasing by a reason of 0.00725. By the fifth year the factor will stay still until the CREG stablishes a new methodolodgy.

$\boldsymbol{CPI}$**:** Consumer Price index.

The variable cost of commercialization, $C^*_{i,j,m}$, will be determined using the formula of last year's Unitary cost, without the including of commercialization cost, and multiplying it by the following variables:

$$\boldsymbol{C^*_{i,j,m} = \left(G_{i,j,m-1} + T_{i,j,m-1} + D_{1,j,m-1} + PR_{1,j,m-1} + R_{i,m-1}\right) * (m_0 + RC_{i,j,m} + CFE_{i,j,m})}$$

$\boldsymbol{m_0}$**:** Operational margin which can be charged at a maxium of 2.37% according to CREG's.

$\boldsymbol{RC_{i,j,m}}$**:** Defined as retailer's portfolio risk, which is calculated by the addition of all Users Risk premiums and total Sell during last month divided by the total amount of Sells in kWH in the regulated market by the retailer.

$\boldsymbol{CFE_{i,j,m}}$: Base cost of commercialization in the market.

Annex 2: Changes in Regulation

Latest Changes in Regulation

Component	Resolution No.	Date of release
Genereation	119	21/12/2007
Recognized Losses	119	21/12/2007
Comercialization	119	21/12/2007
	180	23/12/2014
Distribution	97	26/09/2008
Transmision	11	25/02/2009

Source: CREG.

Annex 3: Change in Consumption By City with Full-Restriction Model, Using 6 lags elasticity.

Reduction of Consumption per Centile in kWh, Medellin

Centile	Stratum 1	Stratum 2	Stratum 3	Stratum 4	Stratum 5	Stratum 6
1	0	0	0	0	0	0
10	-12.8837282	-11.6529172	-1.88935262	0	0	0
25	-15.1513645	-13.463891	-2.45685608	0	0	0
50	-19.366947	-16.5332549	-4.31614924	0	0	0
75	-21.9336	-18.4704	-5.772	0	0	0
90	-21.9336	-18.4704	-5.772	0	0	0
91	-21.9336	-18.4704	-5.772	0	0	0
99	-68.8754574	-67.2188527	-61.1446352	-58.3836273	-47.6763485	-47.6763485

Reduction of Consumption per Centile in kWh, Bogota

Centile	Stratum 1	Stratum 2	Stratum 3	Stratum 4	Stratum 5	Stratum 6
1	0	0	0	0	0	0
10	0	0	0	0	0	0
25	-9.73417722	-8.83286452	-1.40204199	0	0	0
50	-13.7149005	-11.7193462	-2.92172066	0	0	0
75	-17.8192076	-15.0056485	-4.68926515	0	0	0
90	-21.9336	-18.4704	-5.772	0	0	0
99	-42.7698016	-40.4146993	-31.7793241	-27.8541535	-24.5193439	-24.5193439

Reduction of Consumption per Centile in kWh, Barranquilla

Centile	Stratum 1	Stratum 2	Stratum 3	Stratum 4	Stratum 5	Stratum 6
1	-7.31421477	-5.40429987	-1.16514073	0	0	0
10	-20.054028	-18.2373847	-3.48355011	0	0	0
25	-20.0270652	-18.2223511	-3.48222108	0	0	0
50	-29.18856	-24.57984	-7.6812	0	0	0
75	-29.18856	-24.57984	-7.6812	0	0	0
90	-43.4427977	-39.8381856	-26.6212748	-20.613588	-17.8252588	-17.8252588
99	-126.402653	-124.597919	-117.980564	-114.972675	-106.622215	-106.622215

Reduction of Consumption per Centile in kWh, Cali

Centile	Stratum 1	Stratum 2	Stratum 3	Stratum 4	Stratum 5	Stratum 6
1	-5.84677968	-4.41306741	-0.99918919	0	0	0
10	-15.5510488	-13.988604	-2.71286255	0	0	0
25	-15.4762731	-13.9474915	-2.70918209	0	0	0
50	-19.0293394	-16.3482745	-4.29287128	0	0	0
75	-21.9336	-18.4704	-5.772	0	0	0
90	-21.9336	-18.4704	-5.772	0	0	0
99	-26.66863	-23.4853873	-11.8134973	-6.5080928	-5.49747795	-5.49747795

Reduction of Consumption per Centile in kWh, Cartagena

Centile	Stratum 1	Stratum 2	Stratum 3	Stratum 4	Stratum 5	Stratum 6
1	0	0	0	0	0	0
10	-19.3747502	-17.3280147	-3.0268374	0	0	0
25	-21.0700629	-18.7927057	-3.53183081	0	0	0
50	-29.18856	-24.57984	-7.6812	0	0	0
75	-29.5305649	-24.9565833	-8.18531774	-0.5620152	-0.4689351	-0.4689351
90	-37.9768911	-34.0662462	-19.727215	-13.2094736	-11.2929829	-11.2929829
99	-77.2864769	-74.7662879	-65.525595	-61.32528	-55.2795684	-55.2795684