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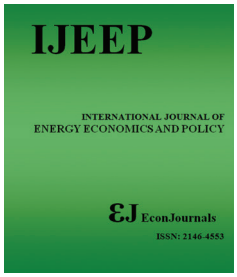

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Pass-through in Colombia's Unregulated Retail Electricity Market

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ABSTRACT

This study analyzes the pass-through of wholesale costs to retail prices for unregulated users in the Colombian electricity market, using monthly data from 2012 to 2019. This period encompasses moments with and without an El Niño phenomenon. We use an empirical model to analyze the pass-through heterogeneity according to the characteristics of users and firms, showing that the pass-through is incomplete, differs according to the presence of El Niño, and is heterogeneous. The pass-through was greater from September 2015 to May 2016 because an El Niño caused hydrological resource scarcity and several critical thermal plants halted operations. In other words, the pass-through tends to be more comprehensive during an El Niño event. Additionally, the pass-through differs between firms with a high concentration of the market and the remaining firms and between urban and non-urban users.

Keywords: Pass-through, Electricity Markets, Wholesale Costs, Retail Prices
JEL Classifications: D82, D83, Q49, L11, L94

1. INTRODUCTION

During the last decade, Colombia has been hit by two El Niño phenomena, one in 2009-2010 and one in 2015-2016, which were largely responsible for price increases in various markets. Bejarano-Salcedo et al. (2020) found that food prices and the general consumer price index increased substantially during these climate events. The impact on general prices runs through two channels, food prices and electricity prices. Lozano-Espitia et al. (2010) studied the relationship between inflation and the final price of electricity in Colombia and found that a 10% shock in the final price of electricity implies annual inflation of 0.78%. Since the El Niño phenomenon affects hydrological resource availability, and Colombia is a hydro-dominated country in electricity generation, electricity prices increase substantially during an El Niño event.

The relationship between El Niño and electricity prices implies that the pass-through from wholesale costs to retail electricity prices varies substantially between periods. Additionally, the regulation on retail electricity prices establishes mechanisms that protect users from abrupt changes in wholesale costs resulting from events like El Niño; however, this consumer protection mechanism varies depending on the characteristics of the consumers. Large consumers, called unregulated users, can freely negotiate a component of final electricity tariffs with wholesale firms; therefore, the protection mechanism is less decisive for these users. The protection mechanism is relevant for forming the final tariff for the remaining consumers, called regulated users. Similarly, for regulated users, lower-income households have stronger protection mechanisms than higher-income households or other consumers, such as industrial or commercial companies. These factors imply that, from a market operation point of view, there is a high degree

of heterogeneity in the pass-through between wholesale costs and retail electricity prices in the Colombian market. This work focuses on studying the pass-through for unregulated users, which has not been addressed in the extant literature concerning Colombia.

This paper uses data from Colombia's retail and wholesale electricity market from 2012 to 2019. This period includes years with and without an El Niño event. These data are disaggregated by firms and well-defined market segments at various levels of the retail market. The market operator provides the wholesale market data and does not have a high degree of disaggregation. The data at the firm level are confidential. We use these data to define an empirical model to estimate the pass-through between wholesale costs and retail electricity prices in Colombia. Likewise, we study how pass-through changes between the different years and the heterogeneity for different aspects of consumers and firms.

Our results show an incomplete pass-through of wholesale costs to retail prices for the Colombian market, which tends to take values near 45% and is heterogeneous. We found evidence that the pass-through tended to increase in El Niño years with a shortage of hydrological resources. Conversely, we find evidence of heterogeneity in the pass-through according to the firms' market share and ubication of users. In terms of total consumption, the three largest firms in the retail market tended to charge a lower pass-through than other firms for unregulated users. This is consistent with the hypothesis that explains the pass-through's incompleteness with the firms' market power. Concerning users, we find evidence that urban users have a greater pass-through than non-urban. This discrepancy can be explained because the urban user segment is more competitive than the non-urban one, given that more firms serve the urban market than the non-urban market.

The rest of this manuscript is organized into five sections. Section 2 briefly presents the theoretical framework explaining the existence of a pass-through in retail markets. Section 3 presents some details of the operation of the Colombian electricity market. Section 4 presents this paper's empirical strategy, and Sections 5 and 6 present the results and conclusions.

2. THEORETICAL FRAMEWORK OF PASS-THROUGH IN RETAIL MARKETS

The literature on the pass-through of costs to prices is quite extensive. Among the first outstanding works are the seminal theoretical papers from Bulow and Pfleiderer (1983) and Bresnahan and Reiss (1985). One of the main predictions established by these models is the pass-through's dependence on market power. Subsequently, Weyl and Fabinger (2013) generalized both models, obtaining new predictions associated with the pass-through's dependence, under imperfect competition, on the elasticities of demand, supply, and parameters associated with firms' conduct and consumer surplus.

A significant result of the Weyl-Fabinger model is that the pass-through of costs to retail prices in oligopolistic markets is incomplete; an increase in costs implies less than proportional growth in prices. This result is explained as pass-through increases with the degree of competition. For markets where firms exercise greater market power, the pass-through tends to be incomplete. Conversely, various empirical studies have found evidence that the elasticity of demand is close to zero in electricity markets (Burke and Abayasekara, 2018; Zhu et al., 2018). Barrientos et al. (2018) and Perez et al. (2016) found similar evidence in Colombia; following the Weyl-Fabinger model, this evidence implies that pass-through in competitive electricity markets should be close to unity.

Market power has been confirmed as a determinant of incomplete pass-through for different goods markets. According to Duso and Szacs (2017), the literature on industrial organization offers reasonable explanations for this evidence. Retail price rigidities explain an incomplete pass-through since cost movements tend not to transfer completely because retail firms are reluctant to modify their prices (Goldberg and Hellerstein, 2013). In contrast, long-term contracts (Bettendorf and Verboven, 2000) or strategic markup adjustments (Hellerstein and Villas-Boas, 2010) allow for absorbing short-term cost movements, allowing a slower price adjustment in the face of cost movements. Finally, nonlinear pricing contracts and vertical restraints, such as wholesale price discrimination in the supply chain, explain the incomplete pass-through (Bonnet et al., 2013). These studies estimate structural models to evaluate a relationship between these determinants and incomplete pass-through.

A good portion of the literature on pass-through has focused on grocery goods, petroleum, coffee, cement, or automotive retail markets; few studies apply to electricity markets. Some studies focused on estimating the pass-through between wholesale electricity prices and carbon emissions; Zachmann and von Hirschhausen (2008) examined EU emissions and electricity future prices in Germany, and Fabra and Reguant (2014) analyzed the Spanish market. The evidence from Zachmann and von Hirschhausen (2008) shows an incomplete and asymmetric pass-through; positive shocks to electricity prices are transmitted more intensely and quickly than adverse shocks. Fabra and Reguant (2014) show that the pass-through is almost complete and propose that firms have little incentive to make markup adjustments.

Works that study the pass-through of wholesale costs to retail prices of electricity include Mirza and Bergland (2012), Duso and Szacs (2017), and Mulder and Willems (2019). Mirza and Bergland (2012) used data from time series to study the Norwegian market. They estimated a partial adjustment model and found an incomplete and asymmetric pass-through. Duso and Szacs (2017) analyzed the pass-through of cost changes to retail prices in the German electricity market using a large and disaggregated panel dataset; they found an incomplete average pass-through rate of around 60%. In addition, they found evidence of heterogeneity of pass-through due to demand and supply factors, such as consumers' willingness to switch and firms' market power. They found that pass-through in the competitive market segment has been approaching unity, indicating a rise in competitive pressure. Mulder and Willems (2019) analyzed the pass-through of wholesale to retail prices in the Dutch electricity market with an

error-correction model. They found no evidence for asymmetric price pass-through; however, the pass-through rate was slow and incomplete.

Correa-Giraldo et al. (2021) conducted a work specific to Colombia. Their research examined the pass-through between retail prices and the wholesale cost of supplying electricity. While it has objectives and data similar to ours, Correa-Giraldo et al. (2021) focused only on the retail market for residential regulated users. In this market, the different parts that set the retail price of electricity are regulated, including generation, which the regulator determines. This may partly explain why the authors found evidence of a more than complete pass-through, which contradicts the theory and evidence for retail markets under imperfect competition. As the method of calculating wholesale costs is regulated, the movements of wholesale costs to retail prices have an almost direct relationship; that is, a complete pass-through is expected. As the authors emphasize, the presence of a more than complete pass-through entails increasing electricity prices for end-users, which firms' presence of market power can explain.

Our study follows Duso and Szacs (2017) and Correa-Giraldo et al. (2021). We estimate cost pass-through to retail electricity prices using a large and disaggregated panel dataset for Colombia's unregulated retail electricity market. Unlike Duso and Szacs (2017), we study the case of an electricity market dominated by renewable technologies. As with Correa-Giraldo et al. (2021), we focus on unregulated users, who can freely negotiate the components of the retail price associated with generation and commercialization. This possibility of negotiating two components of the rate makes our study closer to international research, where an incomplete pass-through is expected for retail markets with imperfect competition.

3. COLOMBIA'S ELECTRICITY MARKET

The Colombian electricity market corresponds to a single area and node so that all electricity transmission networks are connected; it is called the National Interconnected System (SIN). This system corresponds to several interconnected elements, including generating plants, interconnection networks, regional and interregional transmission networks, distribution networks, and users' electrical loads (CREG, 2009). The SIN covers 28 of 32 departments of Colombia, and areas not part of the SIN are called Non-Interconnected Zones (ZNI). The SIN comprises about 26,700 km of transmission networks. In 2018, the electricity coverage for Columbian households was 96.53%, 99.52% for urban households, including SIN and ZNI (UPME, 2019).

Retailers and generators in the wholesale electricity market (WEM) negotiate the energy required by end-users. WEM agents have long-term energy transactions through bilateral contracts, or short-term transactions in the spot market, under the administration of the system operator, called XM. In addition, in WEM, there is a capacity market under auctions whose purpose is to provide reliability to the system in critical periods, obligating firms' plants to generate electricity in adverse weather conditions, such as the El Niño phenomenon. Conversely, after Law 143 of 1994 (Congreso de la República de Colombia, 1994), firms that integrated vertically throughout the chain before 1994 could continue unchanged, maintaining separate accounts for each activity. The legislation allows integration between generation and retail activities for new firms only.

The market regulator (CREG) subsequently set limits on participation in the electricity supply chain to ensure competition, establishing that no firm could have more than 25% of participation in generating or retail activities. It was also determined that no generating firms could have shares, quotas, or parts of social interest representing more than 25% of the social capital of a distributing firm (CREG, 1996). However, in 2007, CREG established a differential regulation for generators, allowing them to have a market share between 25% and 30% if the market power Herfindahl-Hirschman Index is less than 1800 (CREG, 2007a).

3.1. Retail Market

The retail market includes two types of users, regulated and unregulated/liberalized (Congreso de la República de Colombia, 1994), that differ in monthly electricity consumption. Unregulated users consume more than 55 megawatt-hours (MWh) in a month, or their power demand exceeds 2 megawatts (MW); their tariff is established by the CREG (regulated tariffs). Unregulated users can freely negotiate the costs of generating and marketing electricity activities, and these users are industrial, commercial, and other large consumers associated with the state. This paper focuses on unregulated industrial and commercial users. In 2018, regulated users represented 68.3% of total demand, while unregulated comprised 31.7%. This paper studies the pass-through from wholesale costs to retail prices for unregulated users, describing how the retail prices of both types of users are determined. This allows us to understand the scheme of subsidies and contributions in the retail electricity market, which protects low-income consumers through contributions from large consumers.

The end-user retail price for regulated users in the Colombian electricity market was established in Resolution 119 of 2007 (CREG, 2007b). The price per kWh (p) for the end-user was set using six components, described in the following equation:

$$P_{v,t,f,d} = G_{t-1,f,d+}T_t + D_{v,t} + C_{t,f,d} + P_{v,t,f,d} + R_{t,f} \quad (1)$$

where v denotes user connection voltage level, t is the month the price per kWh of service is calculated, f denotes retailer and d is a trading market that depends on a department or region. The following is a description of each component of Equation 1.

3.1.1. Generation (G)

The costs transferred to regulated users for generation only consider purchases made by retailers in the spot market and bilateral contracts in the previous month. Through Resolution 119 of 2007, the generation costs transferred to the end-user comprised a weighted average between the prices in two markets. The firms take a monthly average of the price for the spot market, weighted by the quantities purchased in this market. When the spot price exceeds the shortage price (*precio de escacez* in Spanish) in a given hour, firms charge end-users the

shortage price, not the spot price at which they bought electricity. This mechanism was designed under CREG Resolution 071 of 2006 and protects all end-users from spot price fluctuations caused by changes in weather conditions associated with El Niño and the scarcity of hydrological resources. Regarding the price of the contracts, the firms establish prices with the generators, which are confidential; however, the market operator reports the average price of the firms' contracts, both for regulated and non-regulated users. The G component is a weighted average between the average price of purchases in the spot market and the price of contracts, where the weight is the share of monthly purchases in each market.

3.1.2. Transmission (T)

This activity comprises the national transmission system (STN) and the regional transmission system (STR). The CREG defined the STN as the interconnected electric power transmission system comprising a set of lines, with corresponding connection modules, operating at voltages equal to or greater than 220 kV. The STR comprises regional or interregional transmission networks of lines and substations with associated equipment, operating at voltages lower than 220 kV and not belonging to a local distribution system (SDL) (CREG, 1998).

The STN fees are unique at the national level and independent of the users' connected voltage level. The STR is divided into North and South areas[1], and STR fees depend on the transmission area. These costs are established monthly and are set by CREG (2009). The transmission component is calculated using a relationship between the transmitter's monthly income and the SIN's electricity demand.

3.1.3. Distribution (D)

This service comprises the set of lines and substations, with their associated equipment, operating at voltages lower than 220 kV and not belonging to the STR because they are dedicated to the service of a municipality, district, or local distribution system (CREG, 1998). According to Decree 1111 of 2008 (Presidencia de la República, 2008a), Decree 3451 of 2008 (Presidencia de la República, 2008b), and Decree 2492 of 2014 (Presidencia de la República, 2014), the cost of distribution depends on the areas of distribution (ADD). The legislation establishes a single fee per voltage level for each ADD[2].

3.1.4. Retail (C)

Resolution CREG 180 of 2014 established the remuneration for retailers as a maximum cost, so it is possible to apply a lower value in this component. However, this cost depends largely on the particular resolutions approving the base retail cost and portfolio risks for each incumbent firm, which is one of the primary reasons for the differences in this component (CREG, 2014).

1 Northern STR covers La Guajira, Atlántico, Magdalena, Cesar, Sucre, and Córdoba y Bolívar. Southern STR covers the remaining SIN departments.

2 Central: Santander, Norte de Santander, Caldas, Risaralda, Quindío, and Antioquia. West: Valle del Cauca, Cauca, and Nariño. East: Boyacá, Arauca, Huila, Cundinamarca, and Bogotá D.C. South: Caquetá, Meta, Putumayo, and Casanare. North: Atlántico, Bolívar, Cesar, Córdoba, La Guajira, Magdalena, and Sucre. Tolima represents an ADD by itself.

3.1.5. Losses (P)

This makes up the difference between the sum of hourly electricity imports and exports at the commercial frontier points of the national transmission system. This component recognizes to the service provider the cost that is typically considered tolerable in bringing electricity to the end-user. This cost depends on the voltage level, the retailer, and the user type for each month the service is offered.

3.1.6. Constraints (R)

This component of the tariff compensates for system surcharges generated by electricity dispatches associated with the technical limits of the transmission network. This cost is assigned to each retailer per month, independent of user type and voltage level.

Users are divided into industrial, commercial, residential, and others according to consumer type. Colombia's residential users are divided into six socioeconomic strata, determining the tariff paid. Thus, strata 1, 2, and 3 receive subsidies, while strata 5 and 6 pay contributions. Stratum 4 does not receive subsidies or pay contributions. The tariff paid by residential end-users varies according to their socioeconomic status. Similarly, unregulated users pay contributions.

Unlike regulated users, the unregulated users' component of retail prices for commercialization and generation is agreed upon freely through a negotiation process between firms and end-users. CREG regulates the other components of the retail price for both types of users: transmission, distribution, losses, and constraints. This implies that the main difference between the retail prices between the two types of users is how the parties negotiate the wholesale cost of electricity and commercialization. However, it is impossible to observe the tariffs negotiated by the parties involved; therefore, we designed a strategy to approximate the wholesale cost that retail firms pay for electricity. This closely follows how the generation component for regulated users is set, which is a reasonable approximation of how retail firms pay for the electricity they use to satisfy their unregulated users. Subsequently, we developed a strategy to estimate the pass-through from the wholesale cost to the retail price of electricity for unregulated users.

4. METHODOLOGY

4.1. Data

We employ monthly data from January 2012 to December 2019. This novel dataset is from different public information sources available through Colombia's official authorities. We define the level of disaggregation at which the information is available as a market. A market is defined as those users with an equal characteristic concerning the type of market (regulated or not) to which they belong, the department, the ubication (rural, urban or populated center), voltage level (1-4), and the type of consumer (industrial, commercial, or residential). For each market, we have the amount billed with and without subsidies/contributions in Colombian pesos (COP), the level of electricity consumption, and the number of users in the market. We focus on the data that corresponds to unregulated users and define the retail price as the quotient between the amount billed and the amount of electricity

consumed, giving us a measure of the average cost of electricity in COP/kWh for end-users in a given market. Since unregulated users tend to pay contributions for their electricity consumption, consumers' retail prices include distortions associated with taxation. Therefore, we use the amount billed without contributions to calculate the retail price. Additionally, given that the series of retail prices presents outliers in the sample's lower and upper values, we take the distribution of retail prices for the entire period and eliminate the smallest 1% and largest 1%.

The data to elaborate on the wholesale cost of electricity is taken from Portal BI of XM (2019). We do not observe the exact cost for each firm supplying the electricity to each user since this has associated confidential aspects, such as contract prices at the firm level. For this reason, we designed a strategy to measure the wholesale cost of supplying electricity with information on purchases in the spot market and public contracts at the firm's level. The wholesale cost is the weighted average between the monthly weighted average spot price of electricity[3] and the previous month's average contract price of firms for unregulated users[4]. The weight used for the contracts' prices and spot prices is their share in total negotiations for the month. This method of calculating the wholesale cost of electricity is similar to the calculation approach for regulated users, except that the price of unregulated contracts is considered while regulated contract prices are not.

We focus only on departments with distribution charges assigned to a corresponding ADD. We do not use the departments that are not part of an ADD because they are unreliable. These departments are small, representing 0.08% of the total consumption in the complete database. The monthly CPI deflates the retail prices and wholesale costs data with Banco de la República (Central Bank of Colombia) data. Table 1 shows the average values of some relevant variables of the unregulated market. The Table is organized into four parts, corresponding to user classifications according to voltage levels, ubication, type of consumer, and the area of the country in which they are located. We calculate the average retail price and wholesale cost for each month and the total consumption and users for each classification category. The Table presents the average values of these calculations for 2012 and 2019.

In general, retail prices and wholesale costs are higher in 2019 than in 2012. Given that we are deflating the units by the CPI, this indicates an increase in retail prices of electricity for unregulated market users, partly explained by an increase in wholesale costs. The average retail price tends to decrease with the voltage level; conversely, the wholesale cost tends to be similar between voltage levels. This is due to differences in distribution costs between low and high voltages, an aspect that is not part of the wholesale cost calculation. The highest average number of users is at voltage level 2, and the highest average consumption level is at voltage level 3. Urban users have the highest average retail price and wholesale costs, the highest average number of users, and the highest consumption levels. Industrial users have average retail prices and wholesale costs lower than commercial ones and present higher consumption levels; however, in 2012, commercial users represented the market majority, but in 2019 they numbered fewer than industrial users. Regarding the distribution areas, the average retail price is higher in the south and lower in the north. In contrast, wholesale costs are similar between groups. Most generating plants are located in the east, center, and north of the country, so the south, being further away, has higher distribution costs. The west had the highest number of average users in 2012, followed by the center in 2019; the highest average consumption levels were in the eastern region.

Figure 1 shows the retail prices' mean and percentiles, 5th and 95th, for unregulated users and the average wholesale electricity cost in 2012-2019. It should be noted that the series of average retail prices largely reflect the average wholesale cost movements that we calculate. Additionally, substantial increases in wholesale cost tend to increase the dispersion of retail prices, as observed by the size of the area comprised by the 5th and 95th retail price percentiles. Furthermore, the retail price dispersion increased slightly in 2016, 2018, and 2012-2014, and it decreased in 2019. In contrast, Figure 2 shows the distribution of retail prices in the years 2012 and 2019. Significantly, the distribution of prices is more symmetrical for 2019 and has a positive asymmetry in 2012.

4.2. Empirical Strategy

This section develops an empirical model that allows studying the pass-through from wholesale costs to retail prices, following Duso and Szacs (2017). When there is an increase in wholesale costs, either due to a change in spot prices or contracts prices, firms tend to transmit these changes to end-users. Following the theoretical results of Weyl and Fabinger (2013), the pass-through in oligopolistic markets with imperfect competition tends to be incomplete. The existence of market power tends to make the pass-through more incomplete, while increasing levels of competition tend to make the pass-through more complete. Additionally, the pass-through may be heterogeneous depending on the users' characteristics. This paper explores this possibility in the case of industrial and commercial users.

A model of pass-through with the following specification is proposed for the price of retailer *i,* in department *d*, ubication *l,* voltage level *k,* type of consumer *s*, at time *t*:

$$P_{idlkst} = \beta_0 + \beta_1 W_{ft} + x_{idlkst}'\delta + \theta + \varepsilon_{idlkst}, \quad (2)$$

where β_1 captures the pass-through of wholesale costs to retail prices. x is a vector of the control variables: consumption and the number of users. θ is a vector of fixed effects by department-time, firm, ubication, voltage level, and type of consumer. ε is allowed to cluster at the market level. Including department-time fixed effects allows controlling for other components of the retail price, such as distribution and transmission costs, losses, and constraints.

We estimate equation 2 in different specifications to check the robustness of the pass-through coefficient of wholesale cost and

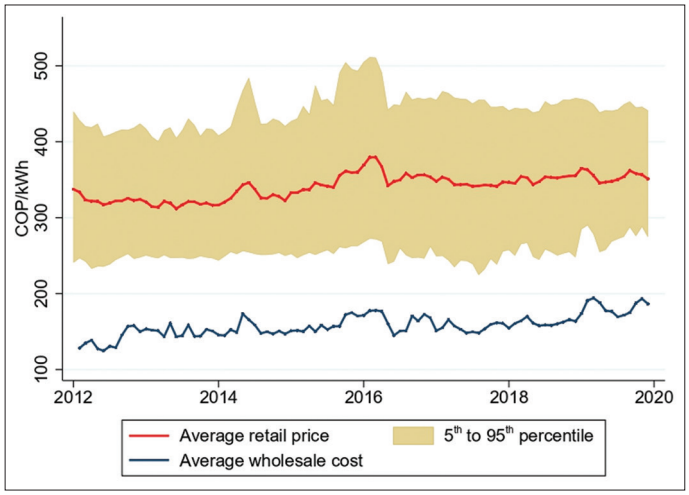
3 The weights are the monthly weight of daily purchases in the spot market. Additionally, we set the maximum price to charge end users the scarcity price.

4 Data on contract prices at the firm level are confidential; however, the market operator only reports the average contract prices for regulated or unregulated users.

Table 1: Descriptives of users

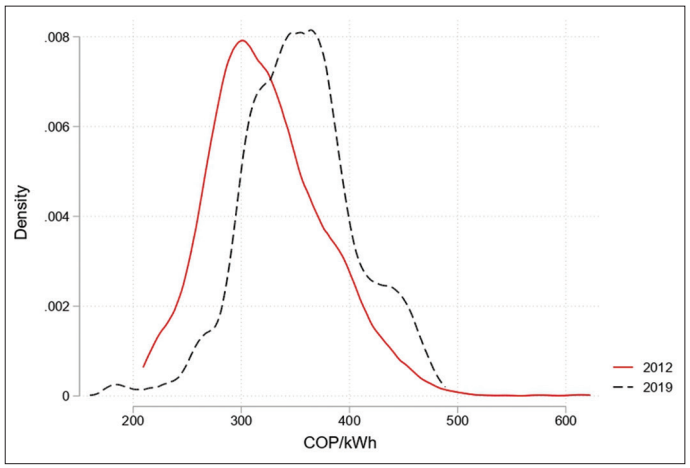
	Retail price (COP/kWh)		Wholesale cost (COP/kWh)		Number of users (Thousands)		Consumption (GWh-month)	
	2012	2019	2012	2019	2012	2019	2012	2019
Voltage level								
1	393,91	421,05	139,18	181,15	1,68	0,36	20,64	17,83
2	337,42	365,75	138,33	182,40	5,87	3,45	344,49	431,03
3	282,73	322,54	138,50	181,94	1,09	1,05	404,57	478,61
4	236,85	275,75	137,41	181,64	0,04	0,09	173,92	295,62
Ubication								
Urban	329,43	354,04	138,81	182,73	7,48	3,99	618,85	991,85
Rural	313,10	356,82	138,13	179,93	1,13	0,95	311,53	228,88
Populated center	318,29	354,59	135,71	177,45	0,07	0,01	13,24	2,37
Type of consumer								
Commercial	335,35	362,82	138,59	183,05	6,10	1,96	210,35	204,54
Industrial	315,99	349,01	138,44	181,35	2,58	2,98	733,27	1018,56
Zone ADD								
Center	334,00	356,67	138,93	182,25	1,24	1,31	251,40	291,03
North	305,01	342,51	138,78	183,68	0,60	1,19	102,52	260,67
West	322,84	348,10	136,76	181,03	4,84	1,00	169,94	203,12
East	317,85	362,28	138,86	181,12	1,64	1,22	352,71	377,60
South	344,43	366,96	139,33	182,22	0,19	0,12	43,37	71,51
Tolima	338,63	364,81	139,62	181,73	0,17	0,10	23,67	19,17

Figure 1: Retail prices and wholesale costs



Source: Author's elaboration with Supersociedades and XM data.

Figure 2: Distribution of retail prices



Source: Author's elaboration with Supersociedades and XM data.

retail prices. First, we estimate the pass-through by year to assess how it evolves and depends on the presence of El Niño. Second, we evaluate the heterogeneity of pass-through by consumer type and user ubication. Finally, we estimate the model by dividing the pass-through between the three largest firms' load and the remaining firms. This additional exercise allows testing the differences in pass-through between firms that can exercise potential market power and those that cannot. From a theoretical perspective, the pass-through is expected to be lower for firms with greater market power than those with less.

MacKay et al. (2014) suggest potential sources of bias in the reduced form estimation of pass-through. The partial information bias arises if the unobserved cost components are not independent of the observed components in the wholesale cost. In our setting, including the department-time fixed effects allows controlling for the components that we do not observe in the cost of supplying electricity.

5. RESULTS

5.1. Estimations for Pass-through

This section presents the results estimating the pass-through from wholesale costs to retail electricity prices. We estimate Equation 2 using ordinary least squares for different specifications summarized in Table 2. All columns include department-time fixed effects. For Column 1, we estimate the pass-through without including controls or the set of fixed effects by the firm, ubication, voltage level, and type of consumer. Column 2 includes controls, and Column 3 introduces the set of fixed effects. This exercise allows us to evaluate the robustness of the pass-through to the different specifications. The results in Table 2 show that pass-through is incomplete, close to 45%. This result is robust to including controls and the set of fixed effects. We found a negative relationship between retail prices and consumption regarding the controls used. Additionally, the estimated coefficient is close to 0; this may result from the inelastic demand found in the Colombian market. Conversely, retail prices tend to be higher when the firm serves more users in a particular market segment.

Table 2: Pass-through of wholesale costs to retail prices

	(1)	(2)	(3)	(4)
	Retail price	Retail price	Retail price	Retail price
Wholesale cost	0.496***	0.456***	0.437***	0.312***
	(0.0449)	(0.0430)	(0.0350)	(0.0332)
WC x El Niño				0.364***
				(0.0692)
Consumption		0.00348***	0.000345***	0.000343***
		(0.000408)	(0.000112)	(0.000113)
Users		63.08*	9.247***	9.474***
		(35.78)	(2.523)	(2.549)
Constant	262.3***	274.0***	272.1***	286.3***
	(7.506)	(7.183)	(5.561)	(5.157)
FE Depto-Time	Yes	Yes	Yes	Yes
Other FE	No	No	Yes	Yes
Observations	63,024	63,024	63,024	63,024
R-squared	0.158	0.222	0.690	0.692

Standard errors are corrected by market level. A market is defined as an observation unit that is not repeated in the same month: it is an observation unit in which one firm establishes a price for a type of user, in a department, with a ubication, a voltage level, and a type of consumer. Other fixed effects correspond to firm, type of user, ubication, voltage level, and type of consumer. ***P<0.01, **P<0.05, *P<0.1

The Colombian electricity market is characterized by a high share of hydroelectric generation, representing 75% of the annual generation in years with normal hydrological conditions. However, the qualifier "normal" is relevant for this calculation. Colombia is subject to two weather phenomena that drastically alter the availability of hydrological resources: El Niño and La Niña. When El Niño occurs, the hydrological resources are scarce, and thermal generation gains strength; when La Niña occurs, hydrological resources are abundant. The scarcity price mechanism and firm energy obligations reduce the impact on retail prices resulting from increases in the spot price. Our wholesale cost measure takes this characteristic into account; however, during the El Niño from September 2015 to May 2016, the market experienced a complex situation when some thermal plants were unable to cover their obligations, and the spot price shot up to historical levels. Emergency measures were implemented to avoid energy rationing during these months; these measures could affect the pass-through, an aspect that we evaluated. Column 4 of Table 2 shows the results of estimating Equation 2, assuming that the pass-through can be different from September 2015 to May 2016.

The results show significant differences in the pass-through for a normal period and September 2015 to May 2016. The pass-through during the 2015-2016 El Niño was, on average, higher than for the normal period; the pass-through tended to be more comprehensive. For normal periods, the estimated pass-through is 31.2%, increasing to 67.8% in the presence of El Niño. This increase in pass-through is exclusively due to the notable increase in spot prices of electricity during this period, which notably affected how firms transmit cost movements to end-users. This can be understood from the behavior of retail firms, which, to avoid high losses, largely decided to pass on the cost increase to their users. Almost all the firms took this action in the market; Figure 1 shows the increasing distribution of retail prices in this period.

5.2. Heterogeneity of Pass-through and Market Power

The previous section examined the pass-through between wholesale costs and retail prices, finding evidence of an incomplete pass-through and the differences between normal and El Niño (2015-2016) periods. This section studies the pass-through heterogeneity between firms with privileged market positions according to the type of consumers or ubication. These supply and demand factors are related to the possibility of exercising market power and the characteristics of users, respectively.

Table 3 shows the results of assuming that pass-through is different between commercial and industrial users (Column 1), urban and non-urban users (Column 2), and different for the three firms with the largest participation in total consumption compared to the remaining firms (Column 3). It is reasonable to expect that firms transmit costs differently to users according to their type (industrial or commercial, urban or non-urban). Table 1 indicates differences in retail prices; although wholesale costs tend to be similar, the differences may be due to a differentiated pass-through or simply variances in consumption levels, like those observed in the Table. Column 1 shows the results of this exercise for industrial and commercial users, leaving the pass-through of an industrial user as the base category. Our results show no significant differences between the pass-through of industrial and commercial users. In other words, this consumer characteristic does not present a heterogeneous pass-through. Column 2 shows the results for urban and non-urban users, indicating that firms tend to charge a higher pass-through to urban users than non-urban ones. This can be explained because the urban user segment is more competitive than the non-urban and more firms serve the urban market than the non-urban market. On average, during 2012, 20 firms were serving non-urban users compared to 28 in the urban market; for 2019, the numbers were 17 and 27, respectively.

The results so far indicate that the pass-through tends to be incomplete, a finding reflected in other studies applied to oligopolistic markets with imperfect competition. This result can be largely explained by the firms' potential exercise of market power. Thus, we conduct an additional exercise evaluating whether the pass-through differs between large firms that concentrate a significant part of the market and the rest. In 2019, the three largest firms represented 64.3% of total consumption and 48.4% of total users. It is reasonable to suggest that these firms may charge a

Table 3: Pass-through: type of consumers and market power

	(1)	(2)	(3)
	Retail price	Retail price	Retail price
Wholesale cost	0.279***	0.214***	0.305***
	(0.0430)	(0.0551)	(0.0344)
WC x El Niño	0.359***	0.397***	0.396***
	(0.0680)	(0.0686)	(0.0718)
WC x Commercial	0.0573		
	(0.0461)		
WC x El Niño x Comm.	0.0263		
	(0.0180)		
WC x Urban		0.130**	
		(0.0523)	
WC x El Niño x Urb.		0.0449**	
		(0.0223)	
WC x 3 largest firms			0.0122
			(0.0714)
WC x El Niño x 3LF			0.0999***
			(0.0165)
Consumption	0.000342***	0.000343***	0.000342***
	(0.000112)	(0.000112)	(0.000113)
Users	9.243***	9.573***	9.539***
	(2.525)	(2.553)	(2.564)
Constant	286.0***	286.8***	287.3***
	(5.289)	(5.171)	(5.174)
Observations	63,024	63,024	63,024
R-squared	0.692	0.692	0.693

Standard errors are corrected by market level. A market is defined as an observation unit that is not repeated in the same month: it is an observation unit in which one firm establishes a price for a type of user, in a department, with a ubication, a voltage level, and a type of consumer. Other fixed effects correspond to firm, type of user, ubication, voltage level, and type of consumer. ***P<0.01, **P<0.05, *P<0.1

different pass-through to their users, anticipated to be lower than others. Column 3 of Table 3 presents the results of estimating the model with a differentiated pass-through for the three largest firms and the remaining firms. The results indicate that the largest firms in the market tend to carry a lower pass-through than other firms, which is consistent with the hypothesis relating the incompleteness of the pass-through with market power.

6. CONCLUSIONS

This paper studies the pass-through between wholesale electricity costs and retail prices for the Colombian unregulated retail market, which is hydro-dominated in electricity generation. Price formation tends to be substantially affected by weather conditions, such as the El Niño phenomenon, which causes hydrological resource scarcity. International literature has found evidence of an incomplete pass-through for retail markets with imperfect competition. Additionally, the extant literature has found evidence of heterogeneity in the pass-through according to the characteristics of consumers and market segments. We study these aspects for the Colombian market. The research applied to the markets of emerging countries is scarce, and our work aims to complement the existing literature by studying the market of unregulated users. The case of regulated users has been widely studied by Correa-Giraldo et al. (2021).

We use retail price data set by firms for fairly disaggregated market segments of unregulated users. These include prices by department, type of consumer (industrial or commercial), ubication (urban or rural), and voltage level. Regarding the wholesale costs of supplying electricity, we use measurements of the costs of buying electricity in the spot market or contracts according to unregulated users. Subsequently, we establish an empirical strategy to estimate the pass-through of wholesale costs to retail prices.

We find evidence of an incomplete pass-through of wholesale costs to retail prices in the Colombian market, which tends to take values close to 45%; however, the pass-through presents a high degree of heterogeneity depending on the presence of El Niño and the characteristics of consumers and firms. From September 2015 to May 2016, the country experienced a difficult situation when the strongest El Niño occurred, and several critical thermal plants shut down, increasing spot prices to historic levels. Our results show that the firms loaded a higher pass-through during this period; the pass-through tended to be more comprehensive. Concerning users, we find evidence that urban users have a greater pass-through than non-urban. This result can be explained by more firms competing for the urban user market than the non-urban market. Finally, in terms of total consumption, the three largest firms in the retail market tend to charge a lower pass-through than the remaining firms for unregulated users. This is consistent with the hypothesis that explains the pass-through's incompleteness with the firms' market power.

Future research can design a structural model to evaluate the economic benefits of implementing demand response mechanisms against the current regulatory scheme. Following the structure proposed by Weyl and Fabinger (2013) and the interpretations made by Duso and Szacs (2017), the elasticity of demand in the Colombian market can explain the incomplete pass-through and the relevant heterogeneity. Policies designed to change the elasticity of demand, such as the implementation of distributed energy resources, advanced metering infrastructure, or facilitating the change of retail providers to end-users, have a relevant effect on the pass-through (Hortacsu et al., 2017; Duso and Szacs, 2017; Garcia et al., 2019). The Weyl-Fabinger model indicates that increasing the elasticity of demand tends to decrease the pass-through. Since users are more likely to respond to price movements, firms tend to modify their prices less to avoid significant demand movements; thus, the pass-through between retail prices and wholesale costs tends to be lower. Therefore, more active participation from end-users can provide more protection from strong movements in wholesale costs, replacing the existing regulation in the sector. This can have implications on the pass-through between retail prices and wholesale costs. The structural model indicates which aspects are the most relevant to explaining the pass-through changes: elasticity of demand or supply and the behavior of the firms associated with the exercise of market power.

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