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Dissertação

Price and income elasticity of residential electricity demand in Latin America and the Caribbean: an analysis using the meta-analysis method

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Pelotas, 2022

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PRICE AND INCOME ELASTICITY OF RESIDENTIAL ELECTRICITY DEMAND IN LATIN AMERICA AND THE CARIBBEAN: AN ANALYSIS USING THE META-ANALYSIS METHOD

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Resumo

MARQUES, Maria Laura Victoria. **Elasticidade preço e renda da demanda residencial de eletricidade na América Latina e no Caribe: uma análise pelo método de meta-análise**. 2022. 49f. Dissertação (Mestrado em Economia Aplicada) - Programa de Pós-Graduação em Organizações e Mercados, Departamento de Economia, Universidade Federal de Pelotas, Pelotas, 2022.

Compreender o comportamento da demanda de energia no contexto das disparidades de preços e renda é fundamental para o desenvolvimento e avaliação de políticas públicas, decisões de negócios e melhorias de acordos cooperativos. Portanto, este artigo tem dois objetivos: (i) identificar as elasticidades preço e renda da demanda de eletricidade residencial na América Latina e no Caribe e (ii) verificar quais são os principais determinantes dessas elasticidades. Para atingir os objetivos propostos, foram utilizados os métodos de meta-análise e meta-regressão, respectivamente. Após a coleta e filtragem dos artigos, obtemos uma amostra composta por 50 estudos abrangendo o período de 1979 a 2020. Os resultados mostram que a elasticidade-preço média da região é de aproximadamente -0,36 e a elasticidade-renda média é de aproximadamente 0,42. Além disso, a identificação das elasticidades é sistematicamente afetada pela estrutura dos dados, pelo método de estimação utilizado no estudo e pelo período de amostragem.

Palavras-chave: elasticidade-preço, elasticidade-renda, demanda, eletricidade América Latina, Caribe, meta-análise.

Abstract

MARQUES, Maria Laura Victoria. **Price and income elasticity of residential electricity demand in Latin America and the Caribbean: an analysis using the meta-analysis method.** 2022. 47f. Dissertation (Master degree in Applied Economics) - Programa de Pós-Graduação em Organizações e Mercados, Instituto de Ciências Humanas, Universidade Federal de Pelotas, Pelotas, 2022.

Understanding energy demand behavior in the context of price and income disparities is critical for the development and evaluation of public policies, business decisions, and cooperative agreement improvements. Therefore, this article has two objectives: (i) to identify the price and income elasticities of demand for residential electricity in Latin America and the Caribbean and (ii) to verify which are the main determinants of these elasticities. To achieve the proposed objectives, we used the meta-analysis and meta-regression methods, respectively. After collecting and filtering journal articles, we obtain a sample composed of 50 studies covering the period from 1979 to 2020. The results show that the average price elasticity for Latin America and Caribbean is approximately -0.36 and the average income elasticity is approximately 0.42. Furthermore, the identification of elasticities is systematically affected by the structure of the data, the estimation method used in the study, and the sampling period.

Keywords: Elasticity, demand, residential, electricity, Latin America, Caribbean, meta-analysis.

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Sumário

1. Introduction

Issues related to electricity are an important area of study due to their impact on the economy, the environment, and the well-being of societies. It is estimated that the energy sector is responsible for approximately 35% of CO2 emissions[1] on the planet. In this sense, the Paris agreement[2] represented a concern about the environmental impacts of energy production, given its well-documented relationship with economic growth (Abbasi, Abbas et al., 2021; Abbasi, Shahbaz et al., 2021; Aramendia et al., 2021; Brini, 2021; Cui et al., 2021; Khan et al., 2021; Li et al., 2021; Magazzino et al., 2021; Tiwari et al., 2021). Through this agreement, countries sought to develop policies to mitigate the environmental impacts of the production of unclean energy sources (Abbasi et al., 2021; Aller et al., 2021; Bokde et al., 2021; Liu et al., 2021; Patiño et al., 2021; Wu et al., 2021). Policies for the energy transition – replacing fossils sources for clean and renewable ones in the energy matrix– as well as market interventions through regulatory pricing policies to stimulate consumption, were developed worldwide and its subsequent effects were studied. More specifically, the possible adverse effects of these policies on the energy market (Brini, 2021; Duan et al., 2021; Khan et al., 2021; Wang & Yi, 2021). Studies about electricity demand cover broad aspects of society such as quality of life and health of households (Abbas et al., 2021; Acheampong et al., 2021; Awaworyi Churchill & Smyth, 2021; Zhang et al., 2021; Zhao et al., 2021). Moreover, energy justice and energy poverty reduction policies have a growing space in recent literature (Carley et al., 2021; Che et al., 2021; Johnson et al., 2020; Tarekegne, 2020; Zhao et al., 2021). As a result of the previously discussed characteristics of energy consumption, nations are working regionally in integrated energy systems to enhance efficiency, strengthen energy security, and promote social and economic prosperity. In Latin America, the Central American Electrical Interconnection System (SIEPAC) was the first to integrate their power systems followed by the Andean Community (CAN) and countries in the Southern Cone (CAN, 2018; Cancino, 2015; EPR, 2021; IDB, 2017; Ochoa et al., 2013).

Understanding energy demand behavior in the context of price and income disparities is critical for the development and evaluation of public policies, business decisions, and cooperative agreement improvements. Empirical research in many regions of the world is seeking to address this issue by measuring demand sensitivity to price and income variations,i.e., price and income elasticity. Different estimating methodologies, data structures, time periods, and sample intervals are common in these investigations. It prompted authors such as Espey &

[1] Intergovernmental Panel on Climate Change (IPCC). Climate Change, 2014.
[2] Signed on 04/22/2016.

Espey (2004), Galindo et al. (2015), Horáček (2014), Labandeira et al. (2016) and Zhu et al. (2018) to employ the meta-analysis ("analysis of analyses") method to generate concise estimates of the price elasticity and income elasticity of electricity demand for various groups of countries. The meta-analysis approach allows researchers to quantitatively synthesize empirical evidence on the same issue in a wider examination of individual analyses (Borenstein et al., 2010, 2011; Cooper et al., 2009; Hedges & Olkin, 1985). Regarding study heterogeneity, Labandeira et al. (2016), Zhu et al. (2018), and Galindo et al. (2015) use the meta-regression approach to investigate the factors that might define the source of variability. In this way, these investigations check if current study heterogeneities can be explained by one or more factors.

The objectives of this work are: (i) to estimate a general effect of the short- and long-term price elasticities and income elasticities of demand for Latin America and the Caribbean through meta-analysis and (ii) to investigate the possible determinants of heterogeneities between studies through the meta-regression. We carried out systematic collection based on the Meta-Analysis of Economic Research (MAER) protocol of empirical literature in Google Scholar and Science Direct using the keywords “elasticity electricity income price [Country]”, “elasticidad electricidad ingreso precio [Country]” e “elasticidade eletricidade renda preço Brasil”. We compiled 252 articles, of which 50 were selected to compose the meta-analysis sample for meeting the established inclusion criteria. The estimates contained in these articles present data for the period from 1970 to 2020. Elasticities in logarithms (effect size index) and standard error (estimation precision index) were used. We find the short-run and long-run price elasticities for Latin America and the Caribbean to be -0.36 and -0.42, respectively, and the short- and long-term income elasticities are 0.22 and 0.63, respectively. Comparing the results with the literature, we have that the estimates are close to those found by Espey & Espey (2004), Labandeira (2017), Horáček (2014), and Galindo et al. (2016).

Additionally, we propose two analyzes as a robustness strategy: the first consists of estimating the results considering only a sample with articles that were peer-reviewed and published in scientific journals, and the second strategy was to estimate the results only for Brazil, as it is the country with a higher proportion of research in the area. It is important to emphasize that this work innovates the energy literature in several ways. First, this is the first article that, through a systematic collection and research procedure, seeks to find an accurate value of the price-elasticity and income-elasticity of demand for residential electricity for Latin America and the Caribbean through meta-analysis method. In addition, this work seeks to investigate possible sources of heterogeneity among the studies on this topic using moderating variables and meta-regression techniques (Baker et al., 2009; Galindo et al., 2015; Thompson & Sharp, 1999). Therefore, the results are important both for defining public policies for residential electricity and managers of companies linked to the energy generation, transmission, and distribution sectors, as they have new information on the characteristics of users in the region and for further empirical research, as long as the results present possible tendencies depending on estimation techniques, type of data and period of sample.

In addition to this introduction, the work is divided as follows: in the next section, we will present an overview of the energy market, estimates of price-elasticity and income-elasticity in Latin America and the Caribbean, and the main meta-analyses on the subject. In section 3, we will describe the method of collecting our data, the inclusion and exclusion criteria, and the creation of moderating variables used in the meta-regression. In section 4 we will formally address the method of meta-analysis and meta-regression. In section 5 we will comment on the results obtained. In section 6, we will carry out the robustness analysis, then make the final considerations and present policy implications of our results in section 7.

2. Literature Review

2.1 The energy market in Latin America and the Caribbean and integrated experiences

According to the Statistical Review of World Energy (2020), electricity consumption grew 1.3% in 2020. The share of electricity consumption in Latin America and the Caribbean corresponds to 4.9% of the world total. Within this scenario, the countries with the highest consumption rates are Brazil, Mexico, and Chile (Rosas-Flores, 2017). For example, Brazil is responsible for the consumption of 2.3% of all energy on the planet and almost half of the energy generated on its continent, growing at an annual rate of 4.0%. In addition, the 2019 Energy Balance Matrix prepared by *Organización Latinoamericana de Energía* (OLADE), points out that the residential sector corresponded to the consumption of 28.82% of the electricity generated in Latin America and the Caribbean.

In Latin America and the Caribbean, the regulatory structure of the electricity industry is the result of two different historical moments. The first historical moment was characterized by the emergence of state-owned companies based on the European model of supply, pressured by the processes of urbanization and modernization of societies from the 1940s onwards. In general, the offer was intended to meet the needs of society at appropriate levels and was organized in a planned and coordinated manner, mostly by the action of the State (Correa et al., 2009; Leme, 2009). The second historical moment took place in the mid-1980s/90s, when regulatory models consisted of mixed models where state action was linked to private initiative.

This moment was greatly influenced by the intensity of political, economic, and technological flows generated by the globalization process (Barrera, 2012; Castro, 2017; Neves, 2007). This approach resulted in a variety of regulatory regimes whitin countries in terms of social, pricing, infrastructure, and environmental regulations.

The population's access to energy services was facilitated in some of them by the state's offer, price differential policies, and/or subsidies. In Argentina, because of the Economic Emergency Law (Lei Nº25.561[3]), tariff review processes and any other price changes were interrupted due to the economic crisis that the country was going through in 2001 (Castro, 2017)[4]. Its energy matrix consists mainly of natural gas from wells and oil, together making up 84.15% of the domestic supply, according to the 2020 annual energy balance. The energy distribution is characterized by a lack of investment in infrastructure, which translates into large amounts of supply cuts (especially in summer[5]), and there are difficulties in balancing the energy supply with the peaks in demand observed in specific periods of the year, due to the growth in total consumption close to 5% per year (Chévez et al., 2017; MINEM, 2016). In this scenario, the residential sector represents a total of 26.77% of the electricity demand (Ministerio de Economía, 2020).

In Colombia, they considered that higher monthly consumption also indicates a higher income, grouping consumers into six strata: stratum 1 corresponds to households that consume from 0 to 200 kWh, stratum 2 corresponds to households that consume between 200 kWh to 400 kWh, stratum 3 households consume between 400kwh to 800kwh, stratum 4 households consume between 800kwh and 1600kwh, and stratum 5 households consume more than 1600kwh (Maddock et al., 1992)[6]. All strata bear the cost per unit of consumption, but strata 1, 2, and 3 receive subsidies, and strata 5 and 6 contribute the equivalent of 20% of the cost per unit of consumption. The only stratum that does not receive a subsidy, and is also exempt from the contribution rate, is stratum 4 (CREG, 2021). According to the studies of Maddock et al. (1992) and Medina & Morales (2007), price sensitivity across strata is not homogeneous, indicating that those price policies can significantly impact the population's well-being[7].

Since April 26, 2002, Law No. 10,438[8] has been in force establishing the Social Electricity

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[3] República Argentina (2002). Law No. 25.561 of January 6, 2002. "Ley de Emergência Pública e Reforma del Régimen Cambiario".
[4] According to the report from the "*Instituto Argentino de La Energia*", in the first quarter of 2021 the sum of subsidies considering the average dollar exchange rate for the period was USD 1.7 million.
[5] Argentina. Ministério de Energía y Minería. Resolution MEyM 0122/2016 e MP 0312/2016 (joint). Official Bulletin nº 33.415, July 11, 2016, pages 54-55.
[6] The pricing system for public household services (water and electricity) is based on an increasing block pricing system (IBP), since the resolution of ***Comisión de Regulacíon de Energía y Gas* No. 079 of 1997**.
[7] Maddock finds a price elasticity of electricity demand of approximately -0.166 for strata 1 and 2, -0.508 for strata 3 and 4, and -0.791 for strata 5 and 6. Medina and Morales, using data from the *Encuesta de Calidad de Vida 2003* and a DCC model, find similar values, in which stratum 2 resulted in -0.417, stratum 4 resulted in -0.573 and, finally, stratum 6 presented a value of -0.785.
[8] República Federativa do Brasil (2002). Law No. 10.438 of April 26, 2002. Provides for the expansion of the supply of

Tariff in Brazil. It grants subsidies in the form of tariff exemptions and discounts for groups included in the "*Low Income Residential Subclass*" and other social groups such as indigenous people and *quilombolas*[9]. Consumers in the Low-Income[10] Residential Subclass benefits from exemption from the cost of the Energy Development Account[11] (*Conta de Desenvolvimento Energético* – CDE) and the cost of the Alternative Energy Sources Incentive Program (*Programa de Incentivo às Fontes Alternativas de Energia Elétrico* – PROINFA)[12].

In addition to providing equal access and smoothing the consumption capacity of families to energy services, pricing policies in the electricity sector are also used to control demand due to impacts on supply arising from climate, environmental and commercial issues. Since 2004, Chile has faced difficulties due to the lack of rain and the breakdown of its main natural gas supplier, Argentina, in addition to the escalation of the international price of its substitutes (coal and oil) (Agostini, 2012; Benavente et al., 2005; Marshall, 2010). The year 2008 was the apex of the crisis, inducing the government to seek measures to reduce consumption, avoiding supply cuts. The study of Benavente et al. (2005) shows that demand response based on price alone helped to reduce 10.7% in the amount consumed, combined with advertising campaigns aimed at saving electricity (38%) and voltage reduction (12.1%). This concern is also observed in Brazil, since 64.9% of the energy generated in the country comes from hydroelectric plants (EPE, 2021). Since 2015, ANEEL has established the so-called Tariff Flag Policy to signal the real cost of energy generation to the consumer market, seeking to balance demand with supply capacity[13].

Furthermore, the difficulty of accessing technologies and financing, given the high cost and long investment horizons, implementing transmission networks and universal access to

emergency electric energy, extraordinary tariff recomposition, creates the Alternative Sources of Electric Energy Incentive Program (Proinfa), the Energy Development Account (CDE), and provides for the universalization of the public electricity service.

[9] *Quilombolas* are "Ethnic-racial groups, according to self-attribution criteria, with their own historical trajectory, endowed with specific territorial relations, with a presumption of black ancestry related to resistance to the historical oppression suffered" (FCP, 2021, my translation).

[10] The beneficiaries of the Law are families registered in the Federal Government's Single Registry for Social Programs (CadÚnico) with monthly per capita income of less than or equal to half the national minimum wage, elderly people aged 65 or over or people with disabilities who receive the Continuous Welfare Benefit (BPC), and families registered in CadÚnico with a monthly income of up to 3 minimum wages and who have to make continued use of devices and equipment that require electricity consumption to treat illnesses or disabilities (physical, motor, hearing, intellectual, multiple) (ANEEL, 2020).

[11] The Energy Development Account (CDE) is the source of the resource that pays the TSEE subsidy and is collected from tariff contributions from other consumers.

[12] In addition, the beneficiaries receive cumulative discounts as follows: consumption from 0 to 30kWh receives a discount of 65% of the monthly tariff, consumption between 31kWh to 100kWh receives a 40% discount, between 101kWh and 220kWh receives a 10% discount of the tariff. There are no discounts for consumption above 221kWh. For indigenous people and *quilombolas*, consumption of up to 50kWh gets a 100% discount of the tariff, between 51kWh and 100kWh gets 40%, between 101kWh and 220kWh gets a 10% discount. Consumption above 221kWh does not receive an additional discount (ANEEL, 2020).

[13] There are 4 modalities: The Green Flag indicates favorable generation conditions, not suffering any tariff increase, the Yellow Flag indicates less favorable conditions and adds R$0.018 to each kWh consumed, The Red Flag – Level 1 indicates costly conditions of generation and adds R$0.039/kWh. Finally, the Red Flag – Level 2 indicates the costliest condition of energy generation, adding R$0.094 for each kWh consumed in the month. More recently, due to a large reduction in the volume of water in the main hydroelectric plants in the country, ANEEL promoted a 52% readjustment on the Red – Level 2 tariff to adjust the demand, from R$6.24 for each 100kWh to R$9.49 (AID, 2021) The only federative unit that is not subject to this policy is Roraima, which is said to be located in an isolated system.

energy is a challenge for the region and a barrier to private initiative, impacting tariffs and relegating to the State the investment in infrastructure. In Brazil, a program of universal access to electricity services was developed through Decree No. 4,873 of November 11, 2003, the *Luz Para Todos* Program. The purpose is to promote the access of families living in rural areas to electricity free of charge through network extensions, the implementation of isolated systems, and the establishment of household connections. Currently, the program has prioritized the beneficiaries of the *Brasil Sem Miséria* Program, rural schools, *quilombolas*, indigenous people, settlements, riverside dwellers, small farmers, families in extractive reserves affected by an electricity sector undertaking, and community water wells (Ministério do Planejamento, 2021). The universalization process began in 2003, with the Decree No. 4,873[14].

The energy matrices of Latin American and Caribbean countries are still heavily dependent on fossil fuels and thermal energy. Pollution and socio-environmental impacts of electricity generation and transmission projects are some of the agendas in governments and sector-related institutions. Chile sought to diversify its energy matrix to reduce its dependence on hydroelectric energy (susceptible to weather conditions) through thermal generation (Huneeus, 2007). In the last decade, Chile started to invest in solar energy sources, representing 12.5% of electricity generation in the country in 2021[15], becoming the first country to build a concentrated photovoltaic energy plant – the plant called *Cerro Dominador*[16]. In the case of Mexico, the energy sector has undergone a structural reform initiated in 2008, through the approval of the Law on the Use of Renewable Energy Resources (LAFRE) in congress. In 2013, the government approved the opening of competition to the hydrocarbon market, which until then was monopolized by the state company *Petróleos Mexicanos* (PEMEX), with sector regulation carried out through the *Comisión Federal de Energía* (CFE). Through the competition mechanism, the law aimed at (a) reducing electricity prices, (b) offering fuels at more favorable prices, (c) increasing the share of clean energy in electricity generation with a target of 25% by 2018, 30% by the year 2021 and 35% by 2024, and (d) reducing greenhouse gas emissions (Galindo, 2005; Moshiri & Martinez Santillan, 2018; Ortiz-Velázquez et al., 2017; Rosas-Flores, 2017)[17]. Currently, electricity tariffs are subsidized by the Mexican government and are instituted by the *Secretaria de Hacienda y Credito Publico* (SHCP).

Because of the disparities in energy supply, institutions, the environment, and

[14] In 2019, it completed 15 years of operation, benefiting 16 million Brazilians, of which 212,000 were beneficiaries of Program actions in 2018 (Ministério de Minas e Energia, 2019, 2021).
[15] Data from *Comisión Nacional de Energía (Chile).*
[16]The production capacity is expected to supply 380,000 homes for twenty-four uninterrupted hours, in addition to reducing 640,000 tons of CO2 per year (OLADE, 2021)
[17] According to the *Balanço Nacional de Energía 2019*, organized by *Sistema de Información Energética* (SENER), at the end of 2019, Mexico had an energy independence index equivalent to 0.72, that is, 28.13% of all energy made available to consumption activities were imported, instead of produced in the territory (SENER, 2020). Also, according to the report, in the last decade, this indicator decreased, on average, by 4.63%.

socioeconomic factors across Latin American nations, regional energy system integration has emerged as a critical tool for facilitating access to technology, investment, and social development (Cancino, 2015; IDB, 2017; Ochoa et al., 2013; WEC, 2008). In addition, interregional connectivity has the potential to improve energy efficiency and security (Gnansounou et al., 2007; Gnansounou & Dong, 2004; Hira & Amaya, 2003; Meeus et al., 2009; Ochoa et al., 2013). In the 1980s, The CEAC (Central American Electrification Commission) was created to lead this initiative in Insular Central America.

Colombia, Bolivia, Ecuador, and Peru make up the Andean Community, which was legally founded in 1969 from the Andean Pact to encourage development in the area. It has several institutions, notably the Andean Electric Interconnection System (SIENA), which is now leading the discussions for Chile's membership in the Community (CAN, 2018). Given the difference in time zones, the integration of energy systems of this extension has the potential to accommodate energy peaks. In addition to the strong reliance on energy from hydroelectric power plants, the integration of electric power systems allows climate adversities between regions to be mitigated – for example, the La Niña and El Niño phenomena (Cancino, 2015; Correa et al., 2009; Ochoa et al., 2013).

Several cooperative and collaborative initiatives in the energy production, distribution, and transmission sectors were undertaken in the Southern Cone throughout the 1970s and 1980s. Binational projects such as the Itaipu (Brazil-Paraguay), Yaciretá (Argentina-Paraguay), Salto Grande (Argentina-Uruguay), and the Yacimientos-Bolivian Gulf (YABOG) between Bolivia and Argentina hydropower plants are examples of such cooperation (Fuser & Abro, 2020; Reis, 2014). Despite the benefits of integrating policies, the impacts of subsidies, price policies, and cost management among the nations involved stand out and might be a challenge (Meeus et al., 2009; Ochoa et al., 2013). As a result, the influence of regions will be examined using the meta-regression approach to confirm probable heterogeneity.

2.2 Price and income elasticities of electricity demand in Latin America and the Caribbean

The income elasticity of demand measures the percentage change in the quantity demanded of a specific good per percentage unit changed in the individual's income. Similarly, the price elasticity of demand measures the percentage change in the quantity demanded by percentage changes in the price of the good analyzed. Table 1 presents some of the estimates of price and income elasticity of demand obtained in the studies that make up our sample. It is possible to observe that the values of the presented elasticities are heterogeneous. It is worth noting that different socioeconomic characteristics of the countries and the methodological decisions of researchers in each study can influence the size of the effect. This is because the energy demand varies in terms of energy types and their spatial coverage, the model approach, level of data aggregation, and estimation methods. (Moshiri & Martinez Santillan, 2018).

Table 1 - Price and income elasticities of demand for residential electricity

Author	Country	Price Elasticity		Income Elasticity	
		Short-Term	***Long-term***	***Short-term***	***Long-term***
Uhr et al. (2019)	Brazil	(-0.46; -0.56)		(0.20; 0.32)	-
Irffi et al. (2006)	Brazil	-0.21	-	(0.01; 0.04)	(0.684; 0.876)
Carlos et al. (2009)	Brazil	-0.461	-0.97	-	1.76
Schmidt & Lima (2004)	Brazil	-	-0.05	-	0.539
Siqueira et al. (2006)	Brazil	-0.30	-0.41	0.18	1.40
Cabral et al. (2020)	Brazil	(-0.07; -0.16)	-	-	-
Mattos & Lima (2005)	Brazil	-	-0.26	-	0.53
Dantas et al. (2016)	Brazil	(-0.15; -0.27)	-	-	-
Tabosa et al. (2019)	Brazil	-0.306	-	-	-
Soares et al. (2017)	Brazil	-0.175	-	-	-
Delfino (1979)	Argentina	-	(-0.18; -0.20)	-	-
Delfino & Givogri (1979)	Argentina	-0.11	-0.42	0.12	-
Marshall (2010)	Chile	-0.05	-	(0.052; 0.080)	-
Agostini et al. (2012)	Chile	-	-0.403	-	0.109
Benavente et al. (2005)	Chile	-0.548	-	-	-
Ortiz-Velázquez et al. (2017)	Colombia	-0.13	-0.06	0.346	0.213
Rosas-Flores (2017)	Mexico	-0.641	-	0.524	-
Moshiri et al. (2018)	Mexico	-0.360	-	-	-
Ramírez et al. (2011)	Mexico	-0.165	-0.630	-	0.887
Campbell (2017)	Jamaica	-	-0.82	-	0.420
Hancevik & Navajas (2015)	Argentina	-	-	(0.253; 0.261)	-
Berndt & Samaniego (1984)	Mexico	-	-	0.324	0.753
Kozak (1991)	Argentina	-	-	-	0.459
Dantas et al. (2017)	Brazil	-	-	(0.063; 0.146)	-
Villareal & Moreira (2016)	Brazil	-	-	0.189	-
Gutiérrez (2010)	Colombia	-	-	0.520	-
Westley (1989)	Costa Rica	-	-	-	0.250

A large part of the empirical analyzes proposes to estimate price and income elasticities distinguish between short- and long-term. As argued by Heffner & Goldman (2001), Roos & Lane (1998), and Yépez-García et al. (2011), the price elasticity of demand for electricity in the short-term is usually lower because it is essential for the quality of everyday life of individuals, and it is generally not possible to rapidly change consumption patterns. However, in the long-term, the possibilities expand, making it possible to replace energy resources in certain household functions or acquire more efficient household appliances. Short-term consumption depends on the stock of equipment, income, the price of electricity, and the rate of use of electrical equipment. In the long-run, the suggested modelling involves explaining the factors that affect the stock of equipment (Dhrymes et al., 1964; Siqueira et al., 2006; Yépez-García et al., 2011). Still, developing country contexts require reasonable interpretation due to rapid growth, structural changes brought about by development, and government interventions, which can generate volatile income and price elasticity (Holtedahl & Joutz, 2004; Yépez-García et al., 2011).

For Brazil, the pioneering work in calculating the price and income elasticity of electricity demand is Modiano's (1984). Using annual time series for the period 1963-1981, he estimates the aggregate demand coefficients of the residential, commercial, and industrial sectors. Extending the coverage of the sampling period to 1995 and following the methodology of Modiano, Andrade & Lobão (1997) use annual data on residential electricity consumption, residential tariff, family income, and household stock of household appliances. They find price elasticities with sizes between -0.050 and -0.065. In Argentina, the study by Delfino & Givogri (1979) analyzes the demand for electricity in the province of Córdoba and finds price elasticity of short- and long-term demand of -0.11 and -0.42, respectively. Benavente et al. (2005) estimated residential electricity demand using panel data at monthly intervals obtained from eighteen distribution companies for Chile. The data cover the period from January 1995 to December 2001. The price elasticity of demand resulted in approximately -0.0548 and -0.39 in the short- and long-term, respectively. This study allowed us to confirm that the electricity demand is price-sensitive even in the very short-term. Based on this study, Marshall (2010) uses monthly data from each commune in the country for 60 months. His result confirms Benavente's hypothesis. For Mexico, Berndt & Samaniego (1984) estimated price and income elasticity using aggregated annual data for the period 1962-1972. They find -0.348 and -0.811 for short-term and long-term price elasticity, and 0.324 and 0.753 for short- and long-term income elasticity, respectively.

From the 1990s onwards, advances were made in empirical and theoretical tools and the availability and access of microdata were expanded, contributing to the emergence of microeconomic studies of energy demand (Moshiri & Martinez Santillan, 2018; Siqueira et al., 2006). The structure of panel data at the household level seems to have an impact on the sensitivity of the model as it can capture nuances of consumer behavior, heterogeneous effects from the composition of sub-samples and allows a better description of the determinants of residential consumption. For Brazil, Uhr et al. (2019) used microdata to estimate the price and income elasticity of electricity demand and found intervals of 0.20 and 0.32 for income elasticity and -0.46 and -0.56 for price elasticity. For Mexico, Rosas-Flores (2017) uses data from *Encuesta Nacional de Ingresos y Gasto de los Hogares* (ENIGH) for the period 1994-2014 and applies it to the AIDS[18] model. The authors estimated the price and income elasticity of electricity demand in the Mexican residential sector and, using the set of information available in the Mexican household budget survey, analyzed the effects in sub-samples related to household location (urban or rural) and by income strata (1-3 minimum wages (MW), 3-5 minimum wages, 5-8 minimum wages, and 8 or more minimum wages. The price elasticities are in the range of -

[18] *Almost Ideal Demand System.*

1.132 (1-3 MW) to -0.247 (8 or more MW)[19].

2.3 Meta-analysis Studies for Price and Income Elasticities of Demand for Electricity

Meta-analysis is a statistical method that aims to quantitatively summarize studies on the same topic in a broader analysis of individual empirical analyses. (Borenstein et al., 2010, 2011; Cooper et al., 2009; Hedges & Olkin, 1985). A set of meta-analyses have already been developed from the literature on energy consumption sensitivity. We see in Table 1 that the results for identifying the price elasticity of demand for electricity in the short run were between -0.07 and -0.64, while for the long-term the estimates are between -0.06 and -0.97. Regarding the estimates of the income elasticity of electricity demand, the short-term values are between 0.01 and 0.52. For the long-term, the values lie between the 0.10 and 0.88 ranges. Table 2 presents the results for the estimated price and income elasticities of electricity demand using the meta-analysis method.

Table 2 - Mean price and income elasticities for electricity from meta-analysis selected

		Mean price elasticity		**Mean income elasticity**	
	Country	***Short-term***	***Long-term***	***Short-term***	***Long-term***
Espey & Espey (2004)	Worldwide	-0.35	-0.81	0.28	0.97
Horáček (2014)	Worldwide	-0.06	-0.43	-	-
Galindo et al. (2016)	Worldwide	-0.18	-0.34	0.51	0.68
Labandeira (2017)	Worldwide	-0.20	-0.50	-	-

Source: Prepared by the author.

Espey & Espey (2004) quantitatively summarize studies on demand for residential electricity for the period 1947 to 1997. They look at factors that can systematically affect the estimated price and income elasticities. It uses data characteristics, model structure, and estimation techniques as moderating variables of the meta-regression technique. As an exclusion criterion, estimates that diverged from the theory were removed (positive price elasticities and negative income elasticities). Estimates through Ordinary Least Squares (OLS), a semi-logarithmic model, and the maximum likelihood gamma model were used. The authors find an average short-term and long-term price elasticity value of -0.35 and -0.81, respectively; the short- and long-term average income elasticities assumed values of approximately 0.28 and 0.97, respectively.

[19] The cross-price elasticity between electricity and natural gas resulted in approximately 0.55 for households with 1-3 MW and 0.096 for households with 8 or more MW, showing that the replacement of electricity by other energy resources occurs more intensely in lower-income strata.

The work of Horáček (2014) differs from the previous one, as it uses the multilevel mixed-effects method. Its objective was like Espey & Espey's, that is, to quantitatively summarize the elasticities estimates presented in literature, as an indication of price elasticities of demand for electricity reported in several countries. The short-term average effect assumes the value of -0.06, -0.21 for intermediate terms, and finally, -0.43 for the long-term. This work moderated the results by country of origin (Europe, United States, and the rest of the world), by the method used, and by consumption sector. Europe's average price elasticities are lower than the rest of the world but higher than the United States. Estimates generated by instrumental variables tended to be more negative, and those estimated by GMM more positive. Horáček also finds that demand from the residential sector was more elastic than the commercial and industrial sectors.

The work of Galindo et al. (2015) seeks to estimate the weighted averages of income and price elasticities through the method of meta-analysis, as well as to analyze the factors that affect the sample's variance. It does not limit its sample regionally, therefore it has estimates for all countries, predominantly the United States. The results point to the great heterogeneity present and the strong publication bias. Factors such as region and energy consumption sector systematically affect estimates. This work presents evidence that points to a greater income elasticity for Latin America in comparison to the OECD, and that the price elasticity is smaller concerning these same countries.

Another important study is that by Labandeira et al. (2017). In this work, the authors use meta-analysis and meta-regression to identify the main factors that affect the price elasticities of demand for energy goods in the short- and long-term. Importantly, in this article, estimates are used not only for electricity but also for natural gas, gasoline, diesel, and heating oil. They follow the specification for meta-regression by Nelson & Kennedy (2009). A total of 428 articles were collected covering the period from 1990 to 2016. 966 short-term estimates and 1010 long-term estimates were obtained. The authors emphasize the importance of the results obtained for the public energy and environmental policies.

Zhu et al. (2018) analyzed residential demand for electricity and sought to identify the main factors affecting it. A systematic summary of the empirical literature was carried out and a meta-analysis was applied to 103 compiled articles. Estimates were compiled under three time dimensions: short- and long-term, plus estimates for which this information was not specified. The results showed that both the price and income elasticity of demand are almost inelastic in the short run but become elastic in the long run. The studies covered the period from 1950 to 2014 and concerned several countries around the globe. Finally, the work uses meta-regression to analyze the heterogeneity present in the estimates. Four factors were analyzed: demand specification, data characteristics, characteristics of the analyzed environment, and estimation techniques. The results indicate that short-term price elasticity estimates are sensitive to data types, data ranges, and the level of aggregation. Long-term price elasticity is systematically affected by the range and level of data aggregation and estimation methods.

As seen in the previous subsection, empirical works that seek to identify elasticities present different identification methods. Furthermore, data estimation, period, structure, and range techniques can affect the results. The meta-analysis works seek to find a common result among these estimates but also seek to investigate possible sources of heterogeneity among the results on the same topic, using moderating variables and meta-regression techniques. Next, we describe the systematized process of collection, data obtained, and the variables created to analyze the possible sources of variance in the elaborated sample.

3. Data

The studies included in this meta-analysis were obtained through a systematic collection based on MAER Protocol (Havránek et al., 2020). At first, the keywords “electricity elasticity price income [name of the country]” and “*elasticidad electricidad precio ingresso* [name of the country]” were searched in the Google Scholar and Science Direct databases for each country that makes up Latin America and the Caribbean, in addition to the terms in Portuguese for the case of Brazil, “*elasticidade eletricidade preço e renda Brasil*”. Thus, the compiled articles were then printed and had the abstract, methodology, results, and conclusions sections analyzed to check the following inclusion criteria: (i) it is a quantitative empirical article; (ii) it includes price and/or income elasticity estimates for residential consumption; (iii) it presents descriptive statistics (t-statistic, sample size, standard deviation, standard error) of the estimated coefficients; (iv) the results are consistent with economic theory. Studies that did not meet any of these criteria were excluded for making it impossible to employ the method. In addition, to obtain a complete and relevant sample on the subject, a survey was carried out observing the bibliography of articles and compiled meta-analyses. At the end of this process, 252 studies were compiled, of which 150 were excluded for not meeting criterion (i). The remaining 102 had their abstracts and methodologies section printed and analyzed and 52 were excluded for not meeting criteria (ii), (iii) and/or (iv). The remaining 50 studies had their statistical results extracted, covering the period from 1970 to 2020, and are listed at Table A.1 of the Appendix. Table 3 provides descriptive statistics of the obtained estimates. Short-term price elasticity estimates are included in the range -2.00 to -0.0072, averaging -0.416. The long-term ones range from -0.97 to -0.002 with an average of -0.381. Short-term income elasticity estimates are distributed in the range between 0.33 and 2.81, with an average of 0.266. In the long-term, the values are now between 0.09 and 1.95, with an average of 0.730. In addition, Figure B.1 presents the scatter graph of the compiled elasticity estimates for short- and long-term against their standard error.

Table 3 Descriptive statistics of demand elasticity-price and income estimates

Variable			Obs.	Mean	Min.	Max.
Elasticity	Price	Short-term	136	-0.41	-2.00	-0.007
		Long-term	33	-0.38	-0.97	-0.002
	Income	Short-term	124	0.26	0.33	2.81
		Long-term	28	0.73	0.09	1.95

Source: Prepared by the author.

To analyze the heterogeneity present in the sample, indicative variables were created for a set of characteristics that can affect the estimates collected systematically. The description of the moderator (or explanatory) variables in meta-regression is presented in Table A.2 in the appendix. Also, the sample was divided into four sub-samples, with Sample 1 and 2 composed of short and long-term price elasticity estimates, and Samples 3 and 4 are composed of short- and long-term income elasticity estimates, respectively. Table 4 shows the descriptive statistics of the moderating variables for each sample.

Table 4 - Descriptive statistics

	Sample 1		Sample 2		Sample 3		Sample 4	
Variables	**Mean**	**S. D.**	**Mean**	**S. D.**	**Mean**	**S. D.**	**Mean**	**S. D.**
Demand specification								
Linear	0.820	0.385	0.242	0.242	0.806	0.396	0.933	0.253
Lag Structure								
Partial Adjustment model	0.273	0.447	0.121	0.331	0.248	0.433	0.066	0.253
Static model	0.697	0.460	0.545	0.505	0.720	0.450	0.533	0.507
Other lags	0.028	0.167	0.333	0.169	0.031	0.174	0.366	0.490
Double log model	0.935	0.246	0.757	0.435	0.891	0.312	0.733	0.449
Non-double log model	0.064	0.246	0.242	0.435	0.108	0.312	0.266	0.449
Data characteristics								
Time series	0.251	0.435	0.939	0.242	0.224	0.419	0.933	0.253
Panel data	0.536	0.500	-	-	0.511	0.501	-	-
Time interval								
Monthly	0.301	0.460	0.333	0.478	0.310	0.464	0.400	0.498
Annual	0.551	0.499	0.666	0.478	0.581	0.495	0.600	0.498
Macro data	0.529	0.500	0.969	0.174	0.465	0.500	0.933	0.253
Environmental characteristics								
National level data	0.764	0.425	0.606	0.496	0.798	0.402	0.533	0.507
State	0.227	0.421	0.393	0.496	0.193	0.396	0.466	0.507
City	0.007	0.085	-	-	0.007	0.088	-	-
Sample period								

Pre-1972	0.735	0.261	0.515	0.507	0.085	0.280	0.466	0.507
1972 – 1981	0.080	0.273	0.515	0.507	0.093	0.291	0.466	0.507
1982 – 2000	0.411	0.493	0.484	0.507	0.434	0.497	0.533	0.507
Post – 2000	0.955	0.206	0.757	0.435	0.945	0.227	0.800	0.406
Estimation technique								
OLS	0.161	0.369	0.303	0.466	0.155	0.363	0.300	0.466
IV	0.242	0.430	0.121	0.331	0.209	0.408	0.133	0.347
GMM	0.154	0.362	-	-	0.147	0.355	-	-
VARVEC	0.073	0.261	0.515	0.507	0.077	0.268	0.500	0.508
Region								
SIEPAC	0.014	0.216	-	-	0.022	0.310	0.166	0.379
CAN	0.151	0.359	-	-	0.099	0.150	-	-
Southern Cone	0.791	0.407	0.727	0.452	0.839	0.368	0.666	0.479
N Studies	35		25		29		18	
N obs.	138		33		126		28	

4. Method

4.1 Meta-analysis[20]

Meta-analysis is a set of statistical tools that aim to carry out a broader analysis of empirical analyses. Its outcome can be an estimate weighted by the degree of precision of the estimate or the investigation of elements that add heterogeneity to this estimate (the stage called meta-regression) (Borenstein et al., 2010, 2011; Cooper et al., 2009; Hedges & Olkin, 1985). There are two main statistical models used in meta-analyses: the fixed-effects model and the random-effects model. The choice of the model is essential to define the objectives of the analysis and the statistical interpretation of the results, as it impacts the computation of estimates (Borenstein et al., 2009; L. Hedges & Olkin, 1985; L. V. Hedges, 1992). In the fixed-effects model, it is assumed that there is only one (and unknown) true value for the size of the effect we are analyzing, underlying all the studies included in the sample. This model is also called the common-effect model. The random-effects model, on the other hand, makes this assumption more flexible, allowing for a distribution of possible true values, that is, each study has an estimated effect that comes as close as possible to its population parameter. This is due to structural characteristics of the works that may vary between studies – sample age, analyzed region, methodology, data characteristics, etc. About the latter, then, each study is said to be related to a population in a universe of populations (Borenstein et al., 2010).

The choice of one model or the other is fundamentally based on an appreciation of the

[20] The equations presented in this subsection are based on Borenstein et al. (2010).

set of studies that are being analyzed and their possible sources of variance. In our study, the use of the random effects model is justified by weighing the overall effect by two different sources of variation that affect our sample: the sampling error of each effect (within-study error variance) and the heterogeneity present between the studies for its structural characteristics (between-study variance).

Consider studies 1 and 2 comparable. Using the random-effects model, let θ_i be the elasticity parameter of study *i*; Y_i is the elasticity observed in study *i*, and V_i is the study variance, defined as $V_i = \sigma^2/n$. Also, let μ be the general mean elasticity obtained by the statistical procedures of the meta-analysis, we will have for each study *i* the following observed mean: $Y_i = \mu + \xi_i + \varepsilon_i \; \xi_i \sim N(0, \tau^2) \; \varepsilon_i \sim N(0, \hat{\sigma}^2)$. Where ξ_i is the difference between the overall mean (μ) and the true mean (θi) for study *i* ($\xi_i = \theta_i - \mu$), ε_i is the difference between the true mean for study *i* (θ_i) and the observed mean Y_i for study *i* ($\varepsilon_i = Y_i - \theta_i$). The standard deviation of the normal distribution at the combined level is taken as τ and the variance τ^2 – corresponds to σ and σ^2 in primary studies – and their estimates are T e T^2, respectively.

In summary, the observed elasticity estimates that we extracted from the individual studies approximate the true parameter; they just do not do it due to sampling error, ε_i, with variance V_i . In our study, we will also consider that the general effect, given that each study estimates concerning a distinct parameter, has a second source of dispersion, T^2, since this is the fundamental difference between the fixed and random effect model. We will use the inverse of the overall study error variance, otherwise, 1/variance, making the estimates of studies less accurate, that is, those in which their results have a more dispersed distribution also have their weight attenuated in the result of meta-analysis. The computed weight for each study will be given by the following equation: $W_i = 1/V_i + T^2$. Thus, for *k* studies, we have that the average general elasticity can be computed through the following equation:

$$M = \frac{\sum_{i=1}^{k} W_i Y_i}{\sum_{i=1}^{k} W_i} \tag{1}$$

Where *M* is the overall mean elasticity, *Wi* is the weight computed in study *I*, and Y_i is the elasticity observed in study *i*. The random-effects model, therefore, requires the prevalence of T^2 (estimate of τ^2), corresponding to the variance between studies. One method to estimate τ^2 is the weighted moments method (or DerSimonian and Laird method) $T^2 = Q - df/c$, where $df = k - 1$ and $Q = \sum_{i=1}^{k} W_i (Y_i - M)^2 = \sum_{i=1}^{k} (Y_i - M)^2 / V_i$, where *k* is the number of studies, and $C = \sum W_i - \sum W_i^2 / \sum W_i$. The statistic (and standardized metric) Q corresponds to the weighted sum of the square of the observed estimates Y_i around the mean M, giving greater weight to larger studies. The expected value of Q, if all studies shared the same effect, is *df.* This makes Q – df represent the excess of variation between studies, in addition to the sampling error. The division by the C factor returns the T^2 index to the same metric reported in the within-study variance. T^2 is truncated to zero since variance cannot assume negative values.

The virtue of the DerSimonian and Laird method is that it is qualitatively consistent with the heterogeneity test based on the Q statistic, in which the statistically significant test on heterogeneity is always accompanied by a positive estimate of τ^2. However, it tends to overestimate τ^2 on average and if the number of studies is small, the bias may be substantial.

4.2 Meta-regression

Meta-regression is a linear regression of elasticities against covariates present in the studies, also called moderators. The main objective is to investigate whether the heterogeneity between studies can be explained by one or more of these moderating variables. So, for the *i*-th study, be $\hat{\theta}_i$ the elasticity estimate, $\hat{\sigma}^2{}_i$ its variance and $\mathbf{x}_i$ a 1 x p vector of moderators with a corresponding and unknown vector of β coefficients, we have, for the random-effects model, the following equation:

$$\hat{\theta}_i = \boldsymbol{x_i}\beta + \epsilon_i^* = \boldsymbol{x_i}\beta + \mu_i + \epsilon_i \qquad (2)$$

weighted by $w_i^* = 1/\,\hat{\sigma}^2{}_i + \hat{\tau}^2$, where $\epsilon_i^* \sim N(0, \hat{\sigma}^2{}_i + \hat{\tau}^2)$. The random-effects meta-regression assumes that moderators explain only part of the heterogeneity and the error term $\mu_i \sim N(0, \hat{\tau}^2)$ is used for the excess. In this way, meta-regression differs from simple linear regressions in that it weights the estimated coefficients by (i) precision of the study and (ii) allows the existence of a residue of heterogeneity that is not modelled by the explanatory variables, incorporating the random element of the method (Thompson & Sharp, 1999). We will use four dimensions to explore the heterogeneity present in the sample of studies in our meta-analysis: specification of demand, data characteristics, characteristics of the investigated context, and estimation techniques (Zhu et al., 2018).

5. Results and discussion

5.1 Price and income demand elasticity

Table 5 presents the results of the application of the meta-analysis for the fixed effects and random effects models. Using the fixed-effects model, we find that the weighted average for the price elasticity of residential electricity demand for Latin America and the Caribbean in the short run resulted in -0.238, with a confidence interval between -0.239 and -0.237. In the long run, the resulting value is -0.051, between the values -0.060 and -0.042. With the random-effects model, the average price elasticity of residential demand for electricity in Latin America and the Caribbean in the short run resulted in -0.362, with a confidence interval between -0.411 and -0.313. In the long run, the resulting value is -0.422, between the values -0.498 and -0.346. As for the income elasticity, with the fixed-effects model, we have that the weighted average for the residential demand for electricity in the short run for Latin America and the Caribbean resulted in 0.152, with a confidence interval between 0.149 and 0.154. In the long run, the resulting value is 0.189, between the values 0.180 and 0.198. With the random-effects model, the average income elasticity of residential electricity demand for Latin America and the Caribbean in the short run resulted in 0.219, with a confidence interval between 0.186 and 0.251. In the long run, the resulting value is 0.630, between the values 0.466 and 0.794.

As discussed in section 4.1 regarding the meta-analysis method, the fixed-effects model is not feasible in our study[21]. Therefore, the preferred results are those generated by the random-effects model.

Table 5 - Meta-analysis combined effect for residential demand for electricity

	Short-term		**Long-term**	
	Fixed-effects	**Random-effects**	**Fixed-effects**	**Random-effects**
Price elasticity Coefficient	-0.238	-0.362	-0.051	-0.422
C.I.	[-0.239, -0,237]	[-0.411, -0.313]	[-0.060, -0.042]	[-0.498, -0.346]
Q	71094,41 (0.000)		680.59 (0.000)	
df	137		32	
I^2 (%)	99.81	99.98	95.30	96.88
T^2	-	0.07	-	0.055
Income elasticity Coefficient	0.152	0.219	0.189	0.630
IC	[0.149, 0.154]	[0.186, 0.251]	[0.180, 0.198]	[0.466, 0.794]
Q	7216,33 (0.000)		2000.32 (0.000)	
df	125		27	
I^2 (%)	98.20	98.55	98.65	98.83
T^2	-	0.0279	-	0.1512

[21] A set of characteristics intrinsic to the studies such as analyzed region, diversity of methods, and time periods would make the hypothesis of a single parameter underlying them all at least questionable.

The results of I^2, all above 95%, indicate the presence of heterogeneity in our sample. This hypothesis will be investigated in the next section. Comparing the results with the literature, we have that our short-term price and income elasticity is close to that found by Espey & Espey (2004), -0.35. The long-term income elasticity is close to that found by Labandeira (2017) and Horáček (2014), -0.501 and -0.43, respectively. Our estimate of long-term income elasticity is close to the result found by Galindo et al. (2016), namely 0.680. In the next section, using the meta-regression method, we will investigate the possible origins of heterogeneity in our sample.

5.2 Meta-regression coefficients

The results of the meta-regression for all samples are shown in Table 6. Price elasticities are only altered in the short run when aggregated data is used. Price elasticity estimations are affected in the long run by the use of partial adjustment and VAR/VEC models. Except for the time before 1972, the moderating variables relevant to the sample period have an impact on long-run price elasticity estimates. It's worth noting, however, that there are just a few studies with this characteristic.

Table 6 - Meta-regression coefficients estimate

Variable	Short-term price	Long-term price	Short-term income	Long-term
Demand specification				
Linear	0.006 (0.953)	0.366 (0.337)	0.046 (0.400)	-1.344* (0.088)
Lag Structure				
Partial Adjustment model	-0.030 (0.914)	0.439** (0.027)	-0.615 (0.206)	-1.965* (0.099)
Static model	0.068 (0.808)	0.087 (0.510)	-0.665 (0.167)	-0.278 (0.511)
Double log model	0.037 (0.737)	-0.120 (0.519)	0.071 (0.104)	-1.434 (0.103)
Data characteristics				
Time series	-0.161 (0.361)	0.091 (0.631)	0.036 (0727)	0.975 (0.329)
Panel data	0.035 (0.774)	-	-0.174* (0.052)	-
Time interval				
Monthly	-0.141 (0.426)	0.125 (0.361)	0.044 (0.623)	-1.395 (0.207)
Annual	-0.012 (0.947)	-	-0.026 (0.798)	-
Macro data	0.450*** (0.000)	-0.491 (0.292)	-0.104* (0.107)	-
Environmental characteristics				
National level data	0.098 (0.361)	0.089 (0.485)	0.089 (0.370)	0.546 (0.130)
Sample period				
Pre-1972	0.274 (0.518)	0.121 (0.519)	-1.194** (0.046)	0.249 (0.608)

1972 – 1981	-0.130 (0.642)	0.355* (0.088)	0.386 (0.252)	-2.041** (0.023)
1982 – 2000	-0.131 (0.162)	-0.432** (0.005)	0.225*** (0.008)	1.473*** (0.000)
Post – 2000	0.077 (0.867)	0.242* (0.117)	-0.907* (0.069)	0.057 (0.908)
Estimation technique				
OLS	-0.072 (0.417)	0.028 (0.891)	-0.067 (0.147)	1.201 (0.908)
IV	-0.150 (0.104)	-0.133 (0.568)	-0.138*** (0.003)	1.724* (0.051)
GMM	-0.152 (0.155)	-	0.246*** (0.000)	-
VARVEC	0.048 (0.773)	0.436** (0.024)	-0.030 (0.730)	1.018 (0.250)
Region				
SIEPAC	-0.178 (0.603)	-	-	-1.372 (0.126)
CAN	0.075 (0.668)	-	0.150 (0.391)	-
Southern Cone	0.050 (0.348)	0.025 (0.776)	-0.249** (0.011)	-0.720 (0.349)
R^2 (%)	28.79	69.08	59.82	51.26
N Studies	35	25	29	18
N obs	138	33	126	28

As for the income elasticities of demand, a larger set of significant factors was found to explain the heterogeneity. In the short-term, “panel data”, use of IV, GMM, and aggregated data showed statistical significance, that is, they are characteristics that affect the estimated coefficients. The variables “Pre-1972”, “1982-2000”, and “Post-2000” also explain part of the heterogeneity. In the long-term estimates for the income elasticity of demand, only the sample period 1972-1981 and 1982-2000 affected the estimates. Regarding possible heterogeneity arising from estimates related to different blocks of countries within LAC, the Southern cone moderator presented a statistically significant effect over the short-term income elasticity estimates. It points out a certain homogeneity of estimates throughout the studied territory. However, it is advisable to consider the sample's number of works for the SIEPAC and CAN regions.

6. Robustness Analysis

We propose two strategies as robustness analysis. First, we restricted the sample to only published and peer-reviewed scientific articles. Our sample is composed of heterogeneous materials such as dissertations, theses, government, and company technical reports. These works are not formally published, have limited distribution, or are not available through conventional channels known as grey literature. This strategy has importance in reducing publication bias (Cooper et al., 2009), however, there is no consensus on the benefits of its inclusion in the sample depending on the study area, which could compromise the quality of the characteristics (Cooper et al., 2009; Relevo & Balshem, 2011). The funnel plot graph of the estimates is presented in Figure B.2. With this strategy, of the 50 studies included in our sample, 33 are articles published in scientific journals.

The second strategy will be to restrict the analysis to the country that makes up most of the sample, Brazil. We want to see if our results are converging to the behavior of a specific region. Of the fifty studies included in our sample, twenty-six make estimates for Brazil. As discussed in the method section, the effect model does not apply to our work. Thus, the results that will be presented in Table 7 were generated by the random-effects model.

In the published articles restricted sample, the average price elasticity of residential demand for electricity in the short run resulted in -0.208, with a confidence interval between -0.237 and -0.180. This result is lower than the weighted value for Latin America and the Caribbean containing the grey literature (-0.362). In the long run, the resulting value is -0.419, between the values -0.536 and -0.302. This, however, is very close to the estimate for the continent containing the grey literature, namely -0.422. The short-term average income elasticity resulted in 0.179, with a confidence interval between 0.147 and 0.211. This result is less than the weighted value for the full sample (0.219). In the long run, the resulting value is 0.469, between the values 0.328 and 0.611, lower than estimated for the full sample (-0.630).

Table 7 - Robustness-check: Meta-analysis combined effect for residential elasticity of electricity for the restricted sample

	Scientific articles		**Brazil**	
	Short-term	**Long-term**	**Short-term**	**Long-term**
Price Elasticity Coefficient	-0.312	-0.419	-0.387	-0.364
IC	[-0.363; -0.261]	[-0.536; -0.302]	[-0.185; -0.137]	[-0.495; -0.233]
Q	2716.21 (0.000)	214.92 (0.000)	1150.24 (0.000)	228.65 (0.000)
df	63	17	92	18
I^2 (%)	98.11	91.62	97.45	95.54
T^2	0.0339	0.0526	0.0698	0.0729
Income Elasticity Coefficient	0.179	0.469	0.160	0.686
IC	[0.147; 0.211]	[0.328; 0.611]	[0.140; 0.181]	[0.570; 0.802]
Q	3311.84 (0.000)	356.41 (0.000)	628.22 (0.000)	149.77 (0.000)
df	63	15	88	17
I^2 (%)	94.72	94.85	78.86	91.24
T^2	0.0114	0.0542	0.0051	0.0358

Considering only the works in Brazil, the average price elasticity of residential demand for electricity in the short run resulted in -0.387, with a confidence interval between -0.448 and -0.326. In the long run, the resulting value is -0.364, between the values -0.495 and -0.233, lower than estimated for the mainland (-0.422). The short-term average income elasticity of residential electricity demand for Brazil resulted in 0.160, with a confidence interval between 0.140 and 0.181. This result is lower than the weighted value for Latin America and the Caribbean (0.219). In the long run, the resulting value is 0.686, between the values 0.570 and 0.802, above the estimate for the mainland (-0.630).

Table C.1 in the Appendix presents the meta-regression coefficients for samples restricted to published articles and the country of Brazil.

7. Conclusion and Policy Implications

The results obtained for price elasticity of demand for residential electricity in Latin America and the Caribbean in the short- and long-term were estimated at -0.36 and -0.42. The income elasticity of demand for residential electricity in Latin America and the Caribbean in the short- and long-term were 0.22 and 0.63. In terms of economic interpretation, the values indicate that a combination of low-price elasticity and high-income elasticity in a scenario of sustained economic growth is accompanied by an increase in energy consumption. For those interested in identifying price and income elasticities of electricity demand, we present meta-regression results that point out the elements that systematically affect short- and long-term price and income elasticity estimates. Thus, for a more accurate identification of elasticities, the researcher should consider the moderating variables commented on in the article.

Based on the features of demand in the Latin American and Caribbean area, the estimations obtained by this work may be used to support international reports, governmental and commercial strategies, and to predict and stimulate a sustainable trajectory for the energy sector. Nonetheless, local and regional policies that encourage universalization, the democratization of access to energy services, and price-based regulation of energy supply may benefit from the findings of a more precise classification of the demanding sector. Given the relevance of relative energy service costs in the context of regionalized integrated energy systems, the projected elasticity might benefit agreements and adequacies to future improvements in this type of organizational experience. As a recommendation for future study, the sample design of this work might be expanded and used to a sectorial approach, seeking to investigate the behavior of electricity consumption in sectors such as the industrial, commercial, agricultural, and transportation.

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Appendix A – Studies included in the meta-analysis sample and moderator variables description.

Table A.1 – Studies included in the meta-analysis sample.

Author(s)	year	Author(s)	year
Delfino & Givogri	1979	Gutierrez	2010
Delphin	1979	Ramirez et al.	2011
Berndt & Samaniego	1984	Agostini et al	2012
Modiano	1984	Margulis	2014
Westley	1989	Hancevic & Knives	2015
Ibrahim & Hurst	1990	Schutze	2015
Ramcharran	1990	Dias	2015
Kozak	1991	Villareal & Moreira	2016
Andrade & Lobão	1997	Dantas et al.	2016
Chang & Martinez-Chombo	2003	Ortiz-Velázquez et al.	2017
Mattos	2004	Rosas-Flores	2017
Schmidt & Lima	2004	Dantas et al.	2017
Benavente et al.	2005	Campbell	2017
Mattos & Lima	2005	Soares et al.	2017
Lamb	2005	larrere	2017
Siqueira et al.	2006	Moreno	2017
Irffi et al.	2006	Uhr et al.	2017
Castro	2007	Cabral & Cabral	2017
Hassan & Zapata	2008	Moshiri & Santillan	2018
Sandoval	2009	Larrere	2018
Carlos et al.	2009	Tabosa et al.	2019
Medina	2010	Uhr et al.	2019
Amaral & Monteiro	2010	Cabral et al.	2020
Gomes	2010	Carrasco-Gutierrez & Dias	-
Marshall	2010	Hollanda et al.	-

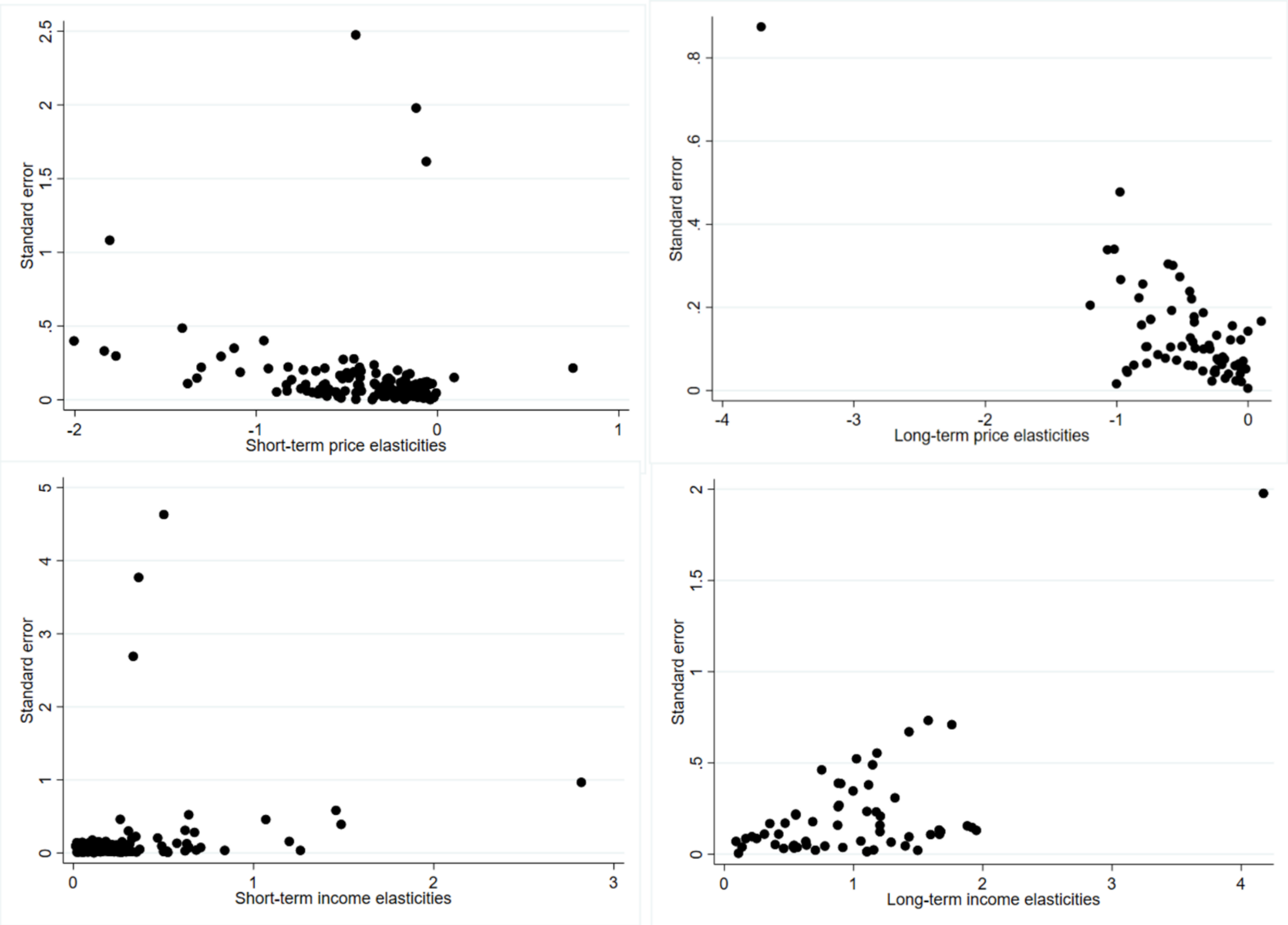
Table A.2 – Moderator variables in meta-regression model.

Variables	Description
Linear functional form	Indicates whether the functional form used in the study is linear.
Non-linear functional form	Indicates whether the functional form used in the study is non-linear.
Other lags	Assumes value 1 to indicate other structures for adjustment by lagged variables
Partial Adjustment model	Indicates whether lagged explanatory variables were used to adjust the dependent variable in the current time
Static model	Assumes value 1 if elasticity was not adjusted for lagged variables.
Double log model	Assumes value 1 to indicate that both the dependent variable and the independent variable are in logarithmic form.
Non-double log model	Assumes 1 if one of the variables (dependent or independent) is not in logarithmic form
Time series	Assumes the value 1 if the data structure is time series.
Cross-sectional	Assumes the value 1 if the data structure is cross-sectional.
Panel data	Assumes the value 1 if the data structure is panel data.
Monthly	Assumes the value of 1 when the data time interval is monthly.
Quarterly	
Annual	Assumes the value of 1 when the data time interval is annual.
Macro data	Assumes value 1 if the data is aggregated
Survey	Assumes value 1 if the study used micro survey data.
National level data	Assumes the value of 1 when the data concern objects of study located in the national territory.
State level data	Assumes the value of 1 when the data concern objects of study located at the state level.
City level data	Assumes the value of 1 when the data concern objects of study located in municipal level.
Pre-1972	Assumes the value of 1 when the reference period to years before 1972.
1972-1981	Assumes the value of 1 when the reference period to years from 1972 to 1981.
1982-2000	Assumes the value of 1 when the reference period to years 1982 to 2000.
Post-2000	Assumes the value of 1 when the reference period is post- 2000.
OLS	Variable assumes value 1 if the estimation method used in the study was OLS.
IV	Assumes value 1 if the estimation method used in the study was IV.
GMM	Assumes value 1 if the estimation method used in the study was GMM
VARVEC	Assumes value 1 if the estimation method used in the study was vector autoregression and/or Vector Error Correction.

Other	Assumes value 1 if the study used other method.
SIEPAC	Assumes value 1 if the primary study is addressed to Panamá, Costa Rica, Honduras, Nicarágua, El Salvador, or Guatemala.
CAN	Assumes value 1 if the primary study is aimed at Colombia, Equator, Peru and Bolivia.
Southern cone	Assumes value 1 if the primary study is aimed at Brazil, Argentina, Uruguay, Chile and Paraguay.

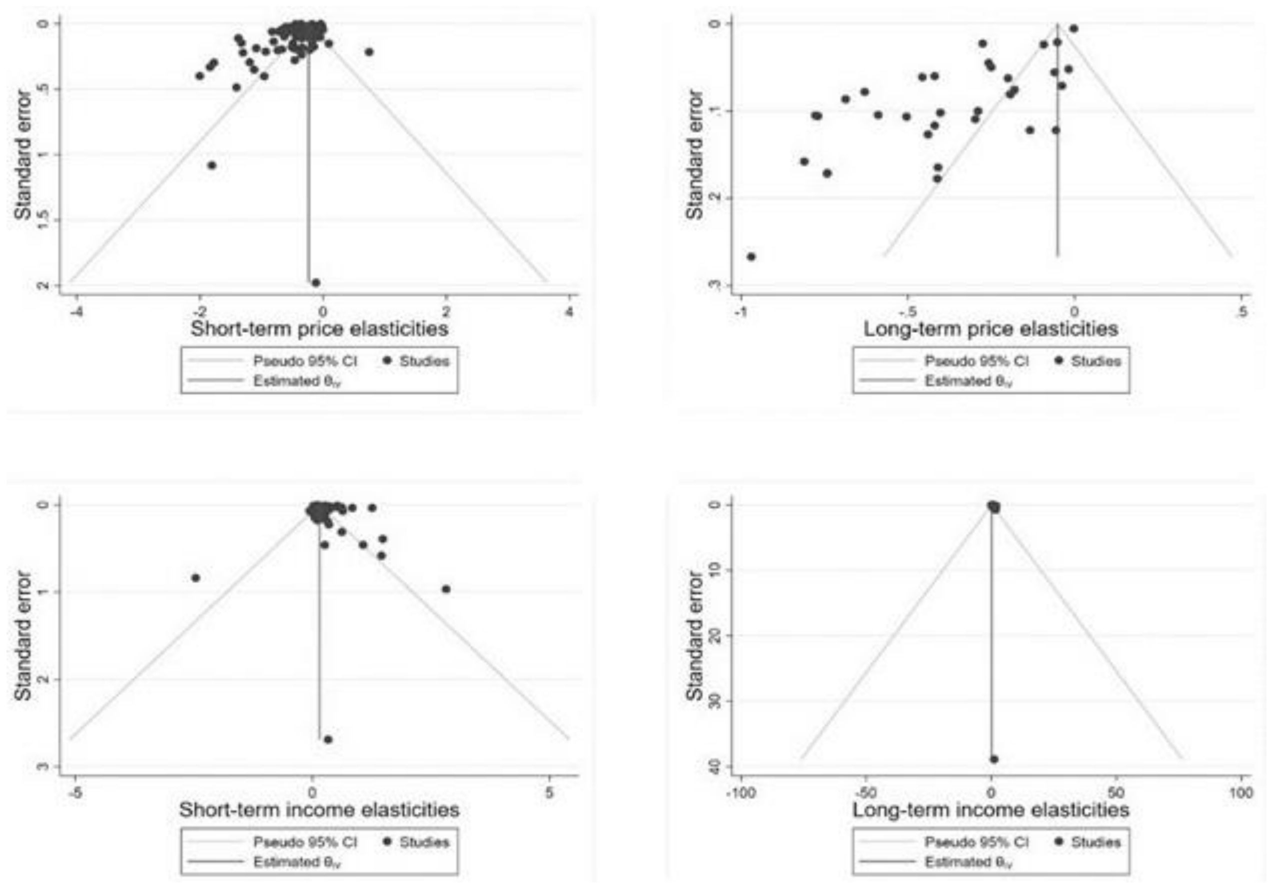
Appendix B – Histogram and *Funnel plot*

Figure B.1 Scatter graph of price and income elasticity estimates for samples 1, 2, 3 and 4.



Source: Prepared by the author.

Figure B.2 – Funnel plot for the price and income elasticities of electricity demand.



Source: Prepared by the author.

Table C.1 - Meta-regression coefficients

Variables	Scientific articles				Brazil			
	Short-term price	Long-term price	Short-term income	Long-term income	Short-term price	Long-term price	Short-term income	Long-term income
Demand specification								
Linear	-0.15 (0.23)	-0.41* (0.06)	0.32*** (0.00)	-1.23 (0.36)	0.00 (0.97)	-	0.03 (0.46)	-
Lag Structure								
Partial Adjustment model	-0.26 (0.20)	-	-0.41 (0.37)	-1.83 (0.37)	0.22 (0.91)	0.32* (0.05)	0.31 (0.90)	-
Static model	-0.16 (0.33)	0.24*** (0.00)	-0.73 (0.11)	0.17 (0.56)	0.22 (0.91)	0.33** (0.02)	-0.99 (0.71)	-0.51 (0.26)
Double log model	-0.00 (0.95)	-	0.08** (0.01)	-0.27 (0.69)	0.03 (0.75)	-0.50*** (0.00)	0.09*** (0.00)	0.42 (0.32)
Data characteristics								
Time series	-0.29 (0.13)	0.20 (0.10)	-0.06 (0.60)	1.18 (0.35)	0.05 (0.81)	-	-1.23** (0.03)	-
Panel data	-0.16 (0.29)	-	-0.18* (0.05)	-	0.17 (0.30)	-	-1.28** (0.02)	-
Time interval								
Monthly	0.03 (0.71)	0.28** (0.03)	-0.01 (0.84)	-0.49 (0.39)	-0.14 (0.66)	-	-1.40** (0.01)	-
Annual	-	-	-	-	-0.20 (0.92)	-	-1.20 (0.66)	-
Macro data	0.42** (0.02)	0.17 (0.53)	-0.37** (0.00)	-	0.37*** (0.00)	-	-0.11*** (0.00)	-
Environmental								
National level data	-0.01 (0.93)	-0.04 (0.61)	-0.28** (0.02)	-0.10 (0.74)	-0.06 (0.71)	-0.14 (0.35)	-1.21** (0.03)	0.60 (0.15)
Sample period								
Pre-1972	-0.04 (0.76)	0.91* (0.00)	-1.25** (0.01)	-1.01 (0.19)	0.42 (0.83)	-	-2.74 (0.33)	-0.60 (0.98)
1972 – 1981	-	-	-	-	-0.18 (0.50)	0.57*** (0.00)	0.38 (0.23)	-0.02 (1.00)
1982 – 2000	-0.16** (0.04)	-0.61*** (0.00)	0.42*** (0.00)	0.79 (0.10)	0.06 (0.97)	-0.25 (0.12)	1.2 (0.65)	-
Post – 2000	0.13 (0.50)	0.41*** (0.00)	-1.34*** (0.00)	-0.97 (0.29)	0.05 (0.97)	0.01 (0.10)	-2.35 (0.40)	-0.50 (0.99)
Estimation technique								
OLS	0.05 (0.56)	-0.01 (0.91)	-0.02 (0.69)	-0.237 (0.669)	-0.013 (0.907)	0.219 (0.365)	0.045 (0.237)	-0.692 (0.244)
IV	0.08 (0.43)	-0.37** (0.01)	-0.01 (0.84)	-	-0.01 (0.91)	0.42 (0.10)	-0.01 (0.94)	-0.26 (0.71)
GMM	-0.04 (0.76)	-	0.09 (0.14)	-	-0.03 (0.99)	-	-0.05 (0.99)	-
VARVEC	-0.03 (0.81)	0.36*** (0.00)	0.05 (0.31)	-0.08 (0.88)	-0.05 (0.77)	0.86*** (0.00)	0.07 (0.19)	-0.68 (0.15)
R^2 (%)	56.04	100	68.17	56.40	50.30	98.37	49.07	0.00
N Studies	21	12	20	13	18	10	17	9
N obs	64	18	64	16	93	19	89	18