Essays on Energy Demand: An Empirical Industrial Organization Approach

A Dissertation Presented to the
Escuela de Doctorado de la Universidad de Cantabria
in Candidacy for the
Título de Doctor en la Universidad de Cantabria

Author
Marco Otoya Chavarría

Supervisors
Dr. Ramón Núñez Sánchez
Dra. Alexandra Soberón Vélez

May 2026

Universidad de Cantabria

Ensayos sobre la Demanda de Energía: Un Enfoque de Organización Industrial Empírica

Tesis Doctoral Presentada a la
Escuela de Doctorado de la Universidad de Cantabria
para la Candidatura del
Título de Doctor en la Universidad de Cantabria

Autor
Marco Otoya Chavarría

Directores
Dr. Ramón Núñez Sánchez
Dra. Alexandra Soberón Vélez

Mayo de 2026

Agradecimientos

Para quienes hemos decidido dedicar nuestra vida profesional al ámbito de la academia, el desarrollo y la culminación de un proceso doctoral constituye un hito fundamental. No obstante, la decisión de cursar un doctorado nunca es sencilla, así como tampoco lo es definir el momento y el lugar adecuados para hacerlo. Se trata de un proceso que debe ser vivido de manera integral, tanto desde el rigor propio de la investigación académica como desde la dimensión personal que inevitablemente lo atraviesa. Esta sección busca resumir, aunque de manera necesariamente acotada, el profundo agradecimiento y aprecio hacia un gran número de personas e instituciones que me han acompañado, apoyado y permitido crecer, no solo en el marco de esta investigación, sino también en el plano profesional y personal, a lo largo de un viaje cuya decisión inicial se gestó en un contexto tan particular como la pandemia por COVID-19.

En primer lugar, agradezco a Dios, quien durante estos años me ha permitido contar con múltiples condiciones fundamentales para la culminación de este proceso doctoral. Agradezco profundamente por la salud, el trabajo, el tiempo, la energía y el ánimo necesarios para desarrollar este doctorado en paralelo con otras múltiples actividades y responsabilidades, así como por la fortaleza para perseverar en los momentos de mayor exigencia.

Deseo expresar un agradecimiento muy especial a mis dos directores de tesis, ya que sin su acompañamiento, guía y compromiso, el desarrollo y la conclusión de este trabajo no habrían sido posibles. En primer lugar, a mi director y tutor, Ramón Núñez Sánchez, por su tiempo, dedicación y constante disposición durante todos estos años. Su rigurosidad académica, la profundidad de las discusiones sostenidas y su exigencia analítica fueron elementos centrales que me permitieron seguir formándome como investigador. Su conocimiento y experiencia han sido indispensables para alcanzar la culminación de este doctorado. Además, más allá de la relación académica entre tutor y estudiante, he tenido la oportunidad de encontrar en él a una excelente persona y a un gran amigo. Asimismo, agradezco profundamente a mi directora de tesis, Alexandra Soberón Vélez, una académica rigurosa, dedicada y comprometida, cuya experiencia y enseñanzas en el ámbito de la econometría han constituido un pilar decisivo para el desarrollo de esta investigación. Su acompañamiento, observaciones y aportes metodológicos enriquecieron sustancialmente este trabajo.

A mi compañera de vida, Melissa Cordero Díaz, le expreso mi más sincero agradecimiento por su apoyo, amor y motivación incondicional, y por la posibilidad de compartir y vivir este proceso juntos. A su lado, un camino que en muchas ocasiones puede resultar solitario se volvió más llevadero. Gracias a ella, este proceso también nos permitió descubrir nuevos lugares, conocer nuevas personas y seguir construyendo nuestra vida en común desde el aprendizaje y la experiencia compartida. ¡Meli, gracias por todo! ¡Seguimos construyendo juntos!

A mis padres, por su apoyo constante, su confianza y por los valores inculcados desde siempre, que han sido la base sobre la cual he podido construir este recorrido académico y profesional. A mi hija con quién también he podido compartir este proceso y, que además, sigue estando presente a pesar de la distancia.

Debo también agradecer al Centro Internacional de Política Económica para el Desarrollo Sostenible (CINPE), así como a los compañeros y compañeras que me acompañaron durante este proceso. Su apoyo académico y humano fue fundamental a lo largo de este camino. De manera particular, deseo agradecer a Olman Segura Bonilla, quien fue el primero en apoyar y motivar mi decisión de cursar el doctorado, brindándome confianza y respaldo desde las etapas iniciales.

Agradezco igualmente a las diversas instituciones que me acogieron durante mis estancias de investigación. En particular, a la Escuela de Doctorado de la Universidad de Cantabria, al Instituto Complutense de Estudios Internacionales (ICEI) y a su personal, especialmente a Isabel Álvarez, Jesús Sánchez Fuentes y Diego Rodríguez Rodríguez, este último por su disposición para orientar y discutir conmigo aspectos fundamentales relacionados con el sector eléctrico en España y el papel de las empresas comercializadoras, desde su amplia experiencia en la Comisión Nacional de los Mercados y la Competencia. Asimismo, agradezco a Franklin Moya Benítez y a Gloria Duarte, con quienes también tuve la oportunidad de compartir enriquecedores espacios académicos. De igual forma, agradezco a The Invernizzi Center for Research on Innovation, Organization, Strategy and Entrepreneurship (ICRIOS) de la Universidad de Bocconi, en Milán, y en especial a Roberto Mavilia, por la acogida y el intercambio académico.

Mi agradecimiento a Javier García Enríquez, profesor titular de la Universidad del País Vasco, quién de forma colaborativa compartió amablemente el código de estimación utilizado en su artículo "Demand for culture in Spain and the 2012 VAT rise (2018)" que fue una guía fundamental para el desarrollo del modelo demanda y análisis de bienestar utilizado en mi tesis.

Adicionalmente, expreso mi profundo agradecimiento a las personas evaluadoras externas de esta tesis; el Ph.D. Diego Rodríguez Rodríguez y el Ph.D. Javier García Enríquez, por haber aceptado formar parte de este proceso, así como por el tiempo, la dedicación y el rigor con que realizaron la revisión del trabajo. Sus valiosos comentarios, observaciones y sugerencias constituyeron un aporte significativo para enriquecer la versión final de esta investigación.

A los amigos y amigas que siempre han estado presentes, brindando apoyo, palabras de ánimo y compañía en distintos momentos de este proceso, incluso cuando la distancia física hacía más difícil el encuentro. Finalmente, a Santander, una ciudad

maravillosa que nos acogió durante los periodos de estancia y que nos permitió conocer no solo su riqueza académica, sino también su gente, su cultura y sus paisajes, convirtiéndose en un espacio significativo dentro de este recorrido doctoral.

Contents

List of Tables

List of Figures

Resumen

La presente tesis doctoral analiza el comportamiento de la demanda de servicios energéticos y el desempeño del mercado minorista de electricidad en España, integrando enfoques de organización industrial empírica, microeconometría de la demanda y economía del bienestar. El estudio se sitúa en el contexto de la profunda reestructuración del sistema eléctrico español iniciada en los años noventa y culminada con la liberalización del mercado minorista en 2009, un entorno caracterizado por alta concentración, presencia de grupos verticalmente integrados y entrada y salida continua de comercializadoras independientes.

La tesis aborda dos dimensiones interrelacionadas: (i) el comportamiento de los hogares como consumidores de bienes básicos como son: electricidad, gas natural y agua; (ii) el rendimiento de las empresas comercializadoras en un mercado minorista crecientemente competitivo, pero con importantes asimetrías estructurales. A partir de este marco, la investigación persigue tres objetivos principales.

En primer lugar, se estiman elasticidades precio y gasto para electricidad, gas natural y agua empleando un sistema de demanda QUAIDS de acuerdo con Banks et al. (1997), corrigiendo problemas de endogeneidad y censura. Asimismo, se comparan las respuestas de hogares clasificados como vulnerables y no vulnerables según criterios de pobreza energética, mostrando heterogeneidad relevante en las respuestas de la demanda, especialmente para el gas natural y el agua, pero diferencias lim-

itadas para la electricidad. Estos resultados permiten evaluar la fundamentación económica de políticas como el bono social, señalando que su justificación descansa más en criterios de equidad que en eficiencia.

En segundo lugar, la tesis cuantifica los efectos distributivos y de bienestar de la reforma del IVA de 2012, que incrementó la imposición indirecta sobre los servicios energéticos. A partir de las elasticidades estimadas, se calculan variaciones compensadas y equivalentes e indicadores de bienestar social basados en el índice de Atkinson. Los resultados muestran que la reforma generó pérdidas de bienestar significativas y regresivas, afectando proporcionalmente más a los hogares de menor renta debido al peso relativo de la energía en su presupuesto.

En tercer lugar, desde la perspectiva de la oferta, se analiza el desempeño de las empresas comercializadoras mediante un enfoque de control de la función de producción tipo Olley & Pakes (1996), que permite estimar la productividad total de los factores, los márgenes de comercialización y la descomposición estática y dinámica de la productividad. Los resultados muestran una heterogeneidad sustancial entre comercializadoras: la mayoría opera con márgenes próximos a la unidad y con un poder de mercado limitado, mientras que solo un reducido número de firmas con mayores cuotas presenta markups elevados. Asimismo, los márgenes reaccionan de forma inversa a los precios mayoristas, lo que refleja dinámicas competitivas y no necesariamente ventajas sistemáticas asociadas a la integración vertical. En términos de productividad, la mayor parte de la variación agregada proviene de cambios dentro de las propias empresas, aunque la reasignación entre empresas es más intensa en los grupos verticalmente integrados, lo que sugiere que su posición en la cadena de valor les confiere ventajas organizativas y capacidad para mantenerse en el mercado. En conjunto, la estructura del mercado —marcada por la coexistencia de muchos pequeños operadores y unos pocos grupos dominantes— emerge como un determinante central del comportamiento empresarial, la dinámica competitiva y la formación de márgenes en el segmento minorista de electricidad.

La tesis contribuye a la literatura ofreciendo un análisis integrado que combina elasticidades de demanda, evaluación del bienestar y análisis microeconómico del comportamiento empresarial dentro de un único marco institucional. Desde una perspectiva de política económica, los resultados subrayan la necesidad de diseñar de forma conjunta las políticas de lucha contra la pobreza energética, la fiscalidad sobre servicios energéticos y la regulación de la competencia, dada la interacción entre heterogeneidad en la respuesta de los hogares, efectos distributivos de las reformas fiscales y estructura del mercado minorista. Las conclusiones, además, son extrapolables a otros mercados liberalizados con retos similares.

Bibliography

Banks, J., R. Blundell, and A. Lewbel (1997). Quadratic Engel Curves and Consumer Demand. *Review of Economics and Statistics* 79 (4), 527–539.

Olley, G. S., and A. Pakes (1996). The Dynamics of Productivity in the Telecommunications Equipment Industry. *Econometrica* 64 (6), 1263–1297.

Summary

This doctoral dissertation analyzes household demand for energy services and the performance of the retail electricity market in Spain, integrating approaches from empirical industrial organization, microeconometrics of demand, and welfare economics. The study is set against the backdrop of the profound restructuring of the Spanish electricity system initiated in the 1990s and completed with the liberalization of the retail market in 2009—an environment characterized by high market concentration, the presence of vertically integrated groups, and continuous entry and exit of independent retailers.

The thesis examines two interrelated dimensions: (i) household behavior as consumers of essential goods such as electricity, natural gas, and water; and (ii) the performance of electricity retailers operating in an increasingly competitive market but one marked by substantial structural asymmetries. Within this framework, the research pursues three main objectives.

First, the thesis estimates price and expenditure elasticities for electricity, natural gas, and water using a QUAIDS demand system following Banks et al. (1997), addressing issues of endogeneity and censoring. It also compares the responses of households classified as vulnerable and non-vulnerable according to energy-poverty criteria, revealing meaningful heterogeneity in demand responses—especially for natural gas and water—while differences for electricity remain limited. These results

allow for an evaluation of the economic rationale of policies such as the social discount rate, indicating that their justification rests more on equity considerations than on efficiency.

Second, the dissertation quantifies the distributional and welfare effects of the 2012 VAT reform, which increased indirect taxation on energy services. Using the estimated elasticities, it computes compensating and equivalent variations, as well as social welfare indicators based on the Atkinson index. The findings show that the reform generated significant and regressive welfare losses, disproportionately affecting lower-income households due to the relatively high share of energy in their budgets.

Third, from the supply-side perspective, the thesis analyzes the performance of electricity retail firms through a production-function control approach in the spirit of Olley & Pakes (1996), allowing for the estimation of total factor productivity, retail markups, and static and dynamic decompositions of productivity. The results reveal substantial heterogeneity across retailers: most firms operate with markups close to one and exhibit limited market power, whereas only a small group of large retailers display elevated markups. Markups respond inversely to wholesale prices, reflecting competitive dynamics rather than systematic advantages associated with vertical integration. In terms of productivity, most aggregate variation stems from within-firm changes, although reallocation effects are stronger among vertically integrated groups, suggesting that their position in the value chain provides organizational advantages and contributes to their persistence in the market. Overall, the market structure—characterized by the coexistence of many small operators and a few dominant groups—emerges as a central determinant of firm behavior, competitive dynamics, and margin formation in the retail electricity segment.

The thesis contributes to the literature by offering an integrated analysis that combines demand elasticities, welfare evaluation, and microeconomic analysis of firm behavior within a single institutional framework. From a policy perspective, the results highlight the need to jointly design policies addressing energy poverty, energy taxation, and competition regulation, given the interplay between heterogeneous household responses, the distributional impact of fiscal reforms, and the structure of the retail market. The conclusions are also applicable to other liberalized markets facing similar challenges.

Bibliography

Banks, J., R. Blundell, and A. Lewbel (1997). Quadratic Engel Curves and Consumer Demand. *Review of Economics and Statistics* 79 (4), 527–539.

Olley, G. S., and A. Pakes (1996). The Dynamics of Productivity in the Telecommunications Equipment Industry. *Econometrica* 64 (6), 1263–1297.

Chapter 1

Regulatory framework and market structure of the Spanish electricity sector

1.1 Introduction

The restructuring and liberalization of the electricity market began in the 1990s, driven by efforts to introduce competition through the privatization of state-owned enterprises, the unbundling of sector activities, and the reduction of entry barriers in segments suitable for competition. The literature identifies the United Kingdom (UK) as one of the pioneering countries in implementing a comprehensive reform package aimed at reorganizing the electricity sector. This model involved the separation of generation and transmission activities, as well as the establishment of a competitive framework for the generation of electricity and the retail supply to end consumers.

According to Newbery (2006), the British market serves as an exemplary case of market reform, demonstrating the importance of ownership structures, unbundling, and competition in electricity generation and retailing. Similarly, Green (2005) emphasizes that the experience of the UK has provided valuable information to other countries seeking to reform their electricity market. Since then, multiple countries, including the United States and several European nations, have adopted similar comprehensive reforms (Joskow 2008).

In the case of Spain, the structure of the electricity sector has been characterized by several vertically integrated electricity companies historically. By the early 1980s, the industry had consolidated into ten privately owned regional companies that maintained vertical integration across generation and distribution. However, the 1990s saw a significant transformation of this structure through a series of mergers and asset consolidations, carried out in preparation for future market liberalization (Arocena et al. 1999).

This chapter outlines the series of reforms implemented during the liberalization of the electricity market in Spain and examines the evolution of the regulatory framework. Identifies key milestones that today determine the configuration of generation, transmission, distribution, and retail, while analyzing their economic performance in market terms. In terms of market segments, the main focus is on electricity retail, which is essential for subsequent chapters. First, from the perspective of households, a demand system is estimated to derive price and expenditure elasticities, and the welfare effects of the 2012 VAT reform are assessed. Second, from the perspective of firms, retail companies are analyzed using control function approaches to estimate their markups and productivity, and their performance is compared between independent and vertically integrated retailers.

1.2 Liberalization and separation of regulated activities in the Spanish electricity sector

The liberalization process formally began with the enactment of Law 30/1995, the Law of the National Electric System (*Ordenación del Sistema Eléctrico Nacional* in Spanish), which established an independent regulatory body, the Commission for the National Electricity Sector (*Comisión Nacional de Energía* (CNE) in Spanish). The CNE was tasked with ensuring transparency and objectivity within the electricity system (Arocena 2003; Arocena et al. 1999). Additionally, the reform designated electricity transmission as a separate activity, assigning the System Operator (*Red Eléctrica de España* (REE) in Spanish) the responsibility for unified operation, transmission management, and oversight of international electricity exchanges (Garrués-Irurzun 2010).

A key moment in the liberalization of Spain's electricity sector occurred with the adoption of EU Directive 96/92/EC in 1996. This directive initiated a wider process of reforming electricity markets throughout the European Union. It established a legal framework for introducing competition in these markets by requiring member states to progressively open their electricity sectors. One of its main provisions was the mandate that all electricity consumers be allowed to choose their supplier. This measure aimed to improve market efficiency, improve consumer choice, and promote cross-border integration within the internal energy market.

By early 1997, the Spanish electricity sector had consolidated into four major vertically integrated companies: Endesa (state-owned), Iberdrola, Unión Fenosa, and Hidrocantábrico (privately owned). These entities exerted considerable control over supply and pricing (García-Álvarez & Moreno 2016). In particular, Endesa and Iberdrola together held approximately 80% of the total generation capacity, the remaining share being divided among smaller firms (Utray et al. 2004). This market dominance posed significant barriers to entry for new participants and restricted consumer choice. Furthermore, vertical integration of generation, distribution, and retailing obscured cost allocation, facilitating cross-subsidization (Alonso 2001).

To promote competition and comply with the EU Directive 96/92/EC, which aimed to establish an internal electricity market in the European Union, the Spanish government enacted Law 54/1997. This law focused on areas of the electricity market characterized by natural monopolies or oligopolies, particularly in generation and retail. A significant reform introduced by this law was the transition from a cost-based regulatory remuneration model for power generation to a market-based compensation system, which included administratively determined incentives (Utray et al. 2004). This change also allowed the emergence of independent electrical retailers.

The liberalization process was guided by key principles that aim to foster competitiveness and transparency. These principles included facilitating market entry, allowing consumers to select their electricity providers, allowing unrestricted investment in generation assets, and allowing flexible pricing mechanisms (Alonso 2001). Furthermore, the reform introduced measures to distinguish between regulated activities (transmission and distribution) and liberalized activities (generation and retail), promote competition in electricity generation, ensure independent market operations, provide open access to transmission networks, implement a phased approach to liberalization, and introduce competitive transition charges (CTCs).

The government accelerated the liberalization process in 1998, granting consumers the right to freely choose their electricity retailers. In 2003, complete consumer eligibility for supplier selection had been achieved (Jordana et al. 2006). As part of this reform, a competitive wholesale electricity market was introduced in January 1998. This market operates on a bidding system, in which generators and consumers submit price offers, facilitating electricity transactions through the pool market or bilateral contracts with generators or retailers (Vázquez et al. 2006). The wholesale market functions as a day-ahead market, with generators submitting minimum price bids for each hourly period of the following day, while consumers (distributors, retailers, and qualified end-users) submit their maximum price bids. The Market Operator subsequently determines the market-clearing price under the marginal price system (Fabra & Toro 2005).

The Spanish market liberalization process was distinctive in that it allowed vertical integration between generation and distribution, a feature not allowed in other deregulated electricity markets, for instance, in the United Kingdom and Germany. Consequently, dominant electricity companies could engage in both electricity generation and purchases within the same corporate group (Ciarreta et al. 2016). However, retail market activities remained heavily influenced by the tariff system, as stipulated by Royal Decree-Law 6/2009.

In addition to facilitating competition, Law 54/1997 also played a crucial role in shaping Spain's renewable energy policy. This legislation established a target for renewable energy sources to supply at least 12% of the total energy demand by 2010. The 1988 Royal Decree-Law 2818/1998 further supported the development of renewable energy by granting producers the right to integrate all generated electricity into the national grid and receive compensation based on market prices plus an additional remuneration (Ragwitz & Huber 2005).

Law 54/1997 defined two alternative mechanisms for selling electricity to distributors: a regulated tariff determined as a percentage of the annual average tariff (as per Royal Decree-Law 1432/2002) or market-based pricing via open-market transactions, whether through spot or forward contracts, with applicable additional remuneration and incentives for participation.

Although Law 54/1997 laid the foundation for liberalization, the retail market reform initially prioritized large consumers, with a gradual liberalization timeline for extending market liberalization to other user categories. Nevertheless, structural inefficiencies within the tariff system lead to market distortions and information asymmetries, which in turn influence consumer perceptions of electricity pricing and compensation.

A significant milestone in the liberalization of Spain's electricity market was the establishment of the Iberian Electricity Market Operator (OMIE) and the Iberian Market Operator for Energy Derivatives (OMIP) in 2007. OMIE is responsible for operating the spot and forward electricity markets, ensuring transparent price formation through competitive bidding processes. Meanwhile, OMIP was created to manage the Iberian electricity derivatives market, providing long-term price signals and risk management tools to market participants.

In 2007, Law 17/2007 abolished integrated tariffs and introduced the activity of Last-Resort Supply. The liberalization process ended in 2009 with the complete liberalization of the retail electricity market, marked by the elimination of regulated tariffs for large consumers.

Among the most significant regulatory developments in recent years, the reforms implemented in 2012 and 2013 are particularly noteworthy. In 2012, a consolidation package was adopted to address the tariff deficit through two complementary measures: reducing regulated costs and increasing fiscal revenues. Royal Decree-Laws 1/2012, 13/2012, and 20/2012 targeted various cost items within the system, including cuts to premiums under the special regime. Additionally, Law 15/2012 introduced taxes on electricity generation to enhance system revenues. Furthermore, the December package (RDL 29/2012) eliminated the deficit caps that had been established in 2010.

In 2013, Law 24/2013 was enacted to reorganize the energy framework, focusing on financial stability, energy security, transparency, efficiency, and cost minimization. The key changes included a change in the remuneration of renewable energy, cogeneration, and waste toward a market participation scheme. This scheme is complemented by a specific regulated payment designed to cover reasonable costs and promote competition under conditions of technological neutrality.

The previously known Last-Resort Tariff (TUR) has been changed to the Small Consumer Voluntary Price (PVPC), which serves as the maximum reference price for consumers who have a specified level of contracted power. In addition, the terms Last-Resort Retailer and Last-Resort Supply have been replaced by reference retailer and reference electricity supply, clarifying the roles of these entities. The Last-Resort Tariff is applicable only to consumers classified as vulnerable, as well as those who, despite not qualifying for the PVPC, temporarily do not have an active supply contract with a free-market retailer.

1.3 Regulated and liberalized activities in the Spanish electricity sector

Regulated activities include the operation of transmission and distribution networks, as well as the operation of the system. These segments are characterized by strong economies of scale, resulting in natural monopolies, making the introduction of competition inefficient. The transmission operator is the commercial company responsible for transporting electricity and building, maintaining, and operating transmission facilities. In contrast, the distribution operator, also a commercial company or cooperative, performs an analogous role in distribution, delivering energy to end-use connection points.

Directive 2003/54/EC and Law 17/2007 mandated the functional separation of activities within vertically integrated groups, aiming to ensure the autonomy of management and decision-making for those responsible for transmission and distribution networks, without compromising the development of competition in liberalized activities. Regulated activities are remunerated through administrative methodologies and financed via access tariffs and regulated charges set by the regulator, ensuring third-party access on transparent, non-discriminatory terms.

The legislation establishes free access to transmission and distribution networks, allowing agents (producers, retailers, and consumers) to use the networks in exchange for payment of tolls and access fees, which are set and updated periodically by the regulator. By paying these access fees, any generator, consumer, or retailer can transport the energy they generate, consume, or sell using the networks.

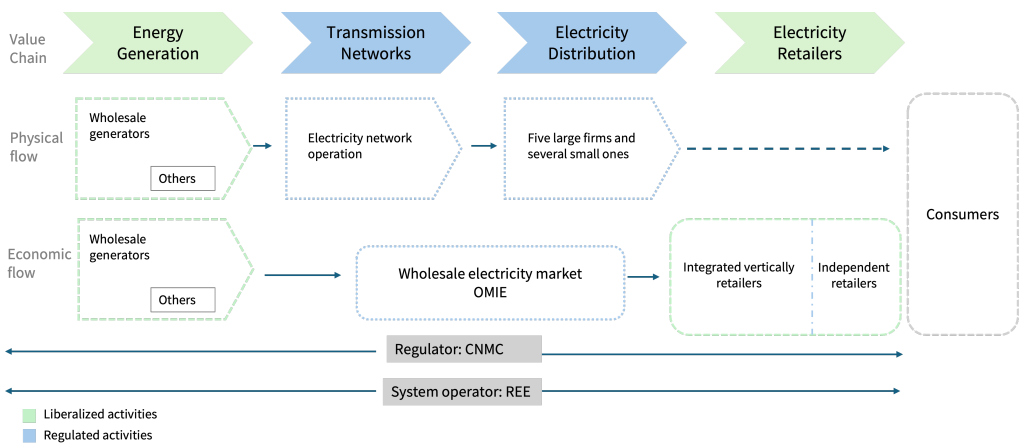
For vertically integrated business groups, laws 17/2007 and 12/2007 require a legal, accounting, and functional separation of regulated activities (transportation and distribution) from competitive activities (generation and retail). The purpose of accounting and legal separation is to prevent cross-subsidies that could distort the allocation of costs between the two types of activities. This distortion could negatively impact competition in liberalized areas and affect compensation in regulated sectors.

Functional separation, on the other hand, aims to ensure that network assets are managed independently from the rest of the vertically integrated group. The goal is to maintain complete independence in managing regulated activities from other operations within the group. Consequently, managers of regulated activities do not participate in group structures related to the day-to-day management of liberalized activities. In addition, accounting and legal separation are designed to protect the confidentiality of commercially sensitive information related to regulated activities.

Subsequently, Law 24/2013 mandates the separation of branding and brand identity from subsidiaries within the same group that are involved in retail activities. This approach prevents consumer confusion and protects competition when a business group operates in both regulated and free markets through its distributors and retailers. As a result, customers can easily identify whether they are in the regulated market (PVPC) or the free market, as well as their actual supplier, differentiating them from the distributor of the group. Furthermore, this practice aligns with the unbundling requirements set by European regulations, which prohibit vertically integrated retailers from confusing their information or brand presentation with respect to their affiliated business group.

Figure 1.1 shows the separation of regulated and liberalized activities in the electricity sector. Transmission, distribution, and system operation are the activities that remain regulated. In contrast, generation, which involves producing electricity through the construction, operation, and maintenance of power plants, as well as the retailing of electricity, is conducted under competitive conditions.

Figure 1.1: Separation of regulated and liberalized activities.



Note: Adapted from Energía y Sociedad (2023).

1.4 Liberalized activities in the Spanish electricity sector

Electricity retailing involves supplying energy to end customers in exchange for payment. This activity is carried out by retail companies operating in a competitive market. These companies purchase energy on the market and supply it to end customers, who use it for their own consumption.

The primary value added in electricity retail comes from the purchase of energy. To do this effectively, retailers must forecast customer consumption (or the consumption of specific customer segments) and plan their energy purchases through various types of contracts. Suppliers can acquire energy from the daily market, forward markets, or through bilateral contracts. Once energy is purchased, suppliers deliver it to consumers using transmission and distribution networks, which require contracting and payment of access fees.

In addition to purchasing energy, retailers engage in various processes within their relationship with end customers. On the one hand, retailers prepare offers for their customers and send them through their customer service and sales channels. Once the customer accepts the offer, the contracting process begins.

The billing to consumers is carried out according to the agreed-upon conditions and is based on monthly or bimonthly meter readings provided by the distributors, which are installed for this purpose. These readings are the responsibility of the distribution companies. The billing for domestic consumers and SMEs is calculated based on the actual meter readings taken every two months. However, for supply points equipped with digital metering and operational telemetry, readings are taken monthly. For consumers covered by the PVPC, billing is based on hourly consumption values.

Electricity retailers have several key obligations. First, they must ensure a continuous supply of the energy needed for their activities and cover the associated costs. They must also contract and pay the access tolls to the transmission and distribution networks corresponding to the distribution company, as well as the prices and charges established by regulation, regardless of whether they subsequently recover these amounts from the end consumer.

Second, retailers must formalize supply contracts with consumers in accordance with applicable regulations and issue invoices in accordance with the agreed-upon terms. In addition, they are responsible for handling complaints, claims, incidents, and requests for information, providing users with free channels of communication.

Third, they have a duty to preserve the confidentiality of the commercial information they access in the course of their business, without prejudice to their obligations to provide information to the authorities. Lastly, they are required to inform their customers about available options for dispute resolution and to offer opportunities for alternative dispute resolution mechanisms in consumer matters.

It is essential to differentiate Reference Retailers from other retailers, as they are a specific type designated by the government to provide electricity supply under regulated conditions. These retailers are required to supply electricity to consumers who are entitled to the voluntary price for small consumers (PVPC) or are eligible for a social discount rate.

In the Spanish electricity sector, retailers supply energy to consumers through two distinct channels. The fist is the liberalized market, in which users freely negotiate and enter into contracts with their chosen supplier. The second is the regulated scheme operated by Reference Retailers, which replaced the former Last Resort Tariff under Law 24/2013. This option is available to consumers with a contracted capacity of up to 10 kW who prefer not to engage in bilateral negotiations with a retailer; in such cases, the regulated PVPC tariff is applied.

The law defines last resort tariffs, which are special prices that apply to certain categories of consumers. The first category includes vulnerable consumers, for whom the PVPC tariff minus the social bonus applies. The second category consists of consumers who do not meet the requirements for the PVPC and currently do not have a contract with a free market retailer; these consumers are subject to the PVPC plus an additional surcharge.

Reference suppliers are also required to make offers to consumers entitled to the PVPC in which the price of electricity supply is fixed for a specific period. In turn, they must supply electricity to consumers who are considered vulnerable, or to consumers who, without being entitled to the PVPC, temporarily lack a supply contract with a supplier.

1.5 Retail electricity market

Retailers purchase electricity through the wholesale market, where energy is traded daily through the spot and intraday markets. In addition, retailers can enter into bilateral contracts with generators, allowing them to secure long-term supplies at fixed or indexed prices. Retailers also participate in the forward market. Energy is sold to customers through transmission and distribution networks for delivery, while they pay access fees.

In the liberalized market, suppliers are not subject to direct price regulation by the Ministry of Ecological Transition and Demographic Challenge. These retailers compete by offering customized tariffs, contractual flexibility, and value-added services, allowing consumers to choose among a variety of providers based on their consumption profiles and preferences.

1.5.1 Structure of the electricity retail market

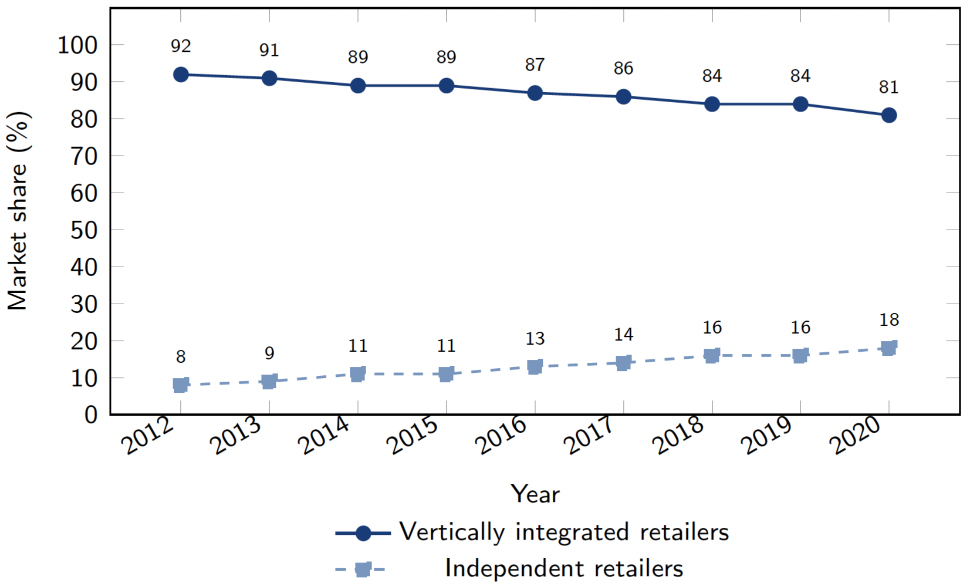
The period from 2009 to 2020 in Spain was characterized by a significant and sustained transition from a regulated electricity market to a liberalized one. This change was driven by increasing consumer engagement, competitive pressures, and regulatory adjustments. In 2014, the regulated segment had fallen below 30% of total electricity consumption, with more than 70% provided through market-based contracts. This shift indicates a marked change in consumer preferences and an increase in retail competition (Comisión Nacional de los Mercados y de la Competencia (CNMC) 2014). It should be noted that Spain lacks publicly owned electricity retailers, unlike many countries in the European Union, such as Germany and Sweden.

As the decade progressed, the trend continued, with a growing number of active suppliers, which led Spain to have the highest number of electricity retailers in the EU (PwC España 2020). Furthermore, data from the Spanish National Competition Authority and CNMC reveal that by 2019, 94% of consumers (more than 29 million) were small-scale users (less than 10kW), but these only represented 28% of the total volume of the market, with industrial consumers comprising nearly 47%, illustrating a diversified retail landscape and the regulated market becoming increasingly residual (Sáenz de Miera & Del Río 2022).

At the end of 2009, the regulatory changes introduced by Royal Decree-Law 485/2009 further influenced the market dynamics, with the share of consumers supplied through deregulated retail contracts increasing to 63%. In the third quarter of 2009, retailers affiliated with the five dominant electricity companies, including Gas Natural, which had acquired Union Fenosa, held approximately 85% of the market share in terms of energy supplied through the deregulated market (Comisión Nacional de Energía 2010).

Figure 1.2 illustrates the evolution of the market share of vertically integrated retailers compared to independent retailers.

Figure 1.2: Evolution of market shares (2012–2020).



Note: Author's own elaboration based on data from CNMC.

During this period, independent suppliers increased their market share from 8% in 2012 to 18% in 2020. In contrast, the share held by vertically integrated retailers declined. This trend reflects a dynamic market characterized by consumers' ability to switch suppliers and the introduction of new independent retailers.

Electricity retailers play a crucial role in promoting competition within the market. They have access to transmission and distribution networks and procure energy to sell to consumers and end users. From this perspective, independent retailers are crucial in stimulating competition and lowering market prices. However, they face challenges in competing with integrated retailers due to the lack of adequate incentives for their continued operation. Integrated retailers possess significant market power and competitive advantages, benefiting from information asymmetries and control over multiple activities in the electricity supply chain (Isla 2017).

In December 2021, the electricity market remained highly concentrated, with Endesa

(31%), Iberdrola (23%), Naturgy (10%), and EDP (6%) collectively holding over 70% of the total market share in terms of energy supply. Table 1.1 provides detailed information on these major energy groups, including their respective Last Resort Retailers and deregulated market retailers. In addition, it includes data on other business groups involved in the retail electricity market. In particular, in December 2020, the TotalEnergies group completed the acquisition of EDP Group's residential electricity and gas customer portfolio in Spain, further reshaping the competitive landscape.

Table 1.1: Vertically integrated retailers

Holding group	Code	Name	Entry	Exit
ENDESA	R2-292	Energía XXI Comercializadora De Referencia S.L.U.	2009	
	R2530	Energía Ceuta XXI Comercializadora de Referencia S.A.	2014	
	R2-252	Endesa Generación S.A	n.a.	
	R2-001	Endesa Energía S.A.U.		
	R2-307	Endesa France		2013
	R2-779	Endesa Energía Renovable, S.L.	2019	
IBERDROLA	R2-329	Curenergia Comercializador de Último Recurso S.A.	2009	
	R2-515	Iberdrola Clientes Sociedad Anónima.	2014	
	R2-516	Iberdrola Generación España Sociedad Anónima.	2014	
	R2-726	Iberdrola Servicios Energéticos Sociedad Anónima	2018	
	R2-002	Iberdrola, S.A		2012
	R2-042	Iberdrola Generación S.A.U	n.a.	
NATURGY	R2-356	Comercializadora Regulada, Gas & Power, S.A.	2009	
	R2-363	Naturgy Energy Group, S.A.		2019
	R2-696	Naturgy Renovables, S.Lu.	2017	
	R2-911	Naturgy Clientes, S.A.U.	2022	
	R2-142	Naturgy Iberia, S.A.	n.a.	
TOTALENERGIES	R2-284	Baser Comercializadora de Referencia, S.A.	2011	
	R2-320	Totalenergies Gas & Power Limited		
	R2-687	Total Gas y Electricidad España, S.A.U.	2017	
	R2-182	Totalenergies Clientes Sociedad Anónima.	2001	
	R2-004	Totalenergies Mercado España Sa. (EDP Energía, S.A.U.)	n.a.	
REPSOL	R2-290	Régsiti Comercializadora Regulada, S.L.U	2009	
	R2-731	Repsol Lng Holding, S.A	2018	2019
	R2-228	Repsol Generación Eléctrica S.A.U.	2014	
	R2-243	Repsol Comercializadora de Electricidad Y Gas, S.L.U	n.a.	
CHC ENERGÍA	R2-540	Comercializador de Referencia Energético, S.L.U.	2014	
	R2-291	Cide Hcenergía S.A.	2019	
BASER	R2-532	Teramelcor Sl	2014	
	R2-060	Gaselec Diversificación S.L.	n.a.	

Note: Author's own elaboration based on data from CNMC.

By Law 24/2013 of the Electricity Sector, Spanish electricity consumers are classified into distinct categories based primarily on contracted capacity and connection voltage level, which in turn determine their eligibility for regulated tariffs and participation in the liberalized market. Household consumers are typically defined as those connected at low voltage (less than 1 kV) with a contracted power of below 10 kW and are eligible for the Voluntary Price for the Small Consumer (PVPC) scheme under Article 45 of the Law and related implementing regulations, such as Royal Decree 216/2014. Small and medium-sized enterprises (SMEs) can also be connected at low voltage, but they usually contract for higher power levels and are supplied exclusively through the liberalized market. In contrast, industrial consumers are characterized by medium- or high-voltage connections ($\geq$ 1 kV) and contracted power levels exceeding 10 kW, and they operate entirely under free-market conditions.

According to CNMC (2022), the number of consumers in the Spanish retail electricity market exceeded 29.8 million in 2021. Of these, 33.7% was supplied through a regulated market, while 66.3% was supplied through a free-market retailer. In terms of energy consumption, 47% of the total electricity usage, domestic consumers with contracted power below 10 kW consumed 28%, and the remaining 25% was used by larger domestic and SME consumers.

Meanwhile, independent retailers, which had previously gained significant market share in recent years, experienced a decline, particularly in the SME segment. Their combined market share fell from nearly 44% in 2020 to 35% in 2021. In the residential sector, the reduction in market share was more modest, approximately 1%. Among the main providers, Endesa and Iberdrola experienced declines of 1 to 2 percentage points in the domestic segment, while Naturgy recovered 1 percentage point.

Taking into account the number of connection points in the market, the retailers within the Endesa and Iberdrola groups each held 33% of the total, followed by the Naturgy group with 14%. Regarding company size, among the existing suppliers in the domestic segment, nearly 90% had fewer than $15,000$ supply points, while only 13 companies had more than $100,000$ supply points. In the SME sector, almost

90% of the retailers in 2021 had fewer than 2,000 supply points. Meanwhile, in the industrial sector, the company size in terms of supply points was significantly smaller, with nearly 80% of retailers serving fewer than 100 customers.

The electricity market remains highly concentrated among major business groups, as shown in Table 1.1, particularly regarding the number of supply points and total sales. These business groups are also involved in electricity generation and distribution. By contrast, independent retailers account for approximately 25% of the market share.

1.5.2 Determinants of entry and exit

The market has experienced significant dynamism in terms of company entry and exit. The number of registered retailers increased from 117 in 2010 to 496 in 2021, as shown in Table 1.2. However, a considerable number of retailers have also exited the market, with 197 companies ceasing operations during this period.

Table 1.2: Changes in the number of retailers in the electricity market from 2010 to 2021, including entries and exits.

Year	Retailers	Exit	Entry
2010	177	1	31
2011	203	5	32
2012	208	13	18
2013	234	23	49
2014	276	8	49
2015	329	4	57
2016	338	38	47
2017	382	18	63
2018	390	28	37
2019	333	8	27
2020	374	1	44
2021	397	20	41

Note: Author's own elaboration based on data from CNMC.

The mobility of consumers among suppliers represents another dynamic aspect of the market. Legislation grants electricity consumers the freedom to choose their suppliers within the deregulated market. Additionally, households (with an installed power of less than 10 kW) have the option to receive supply from a Last Resort provider.

Several factors influence whether electrical retailers remain in the market or exit it. Vertically integrated retailers, owned mainly by major electricity generation groups, have significant market power, giving them clear advantages over smaller or independent competitors.

These large firms can respond more effectively to market shocks by adjusting the prices of their offers. In contrast, small retailers often struggle to absorb the rising wholesale electricity prices. As a result, they frequently pass part of these increases onto customers, making their contracts less competitive.

When electricity prices rise, retailers require additional liquidity to cover their energy procurement costs. Since most contracts remain fixed-price, companies often purchase electricity at higher prices than those agreed upon by contract. This mismatch reduces profit margins and, in some cases, pushes them into losses that force them to close their operations. Under these conditions, small retailers find it particularly difficult to survive.

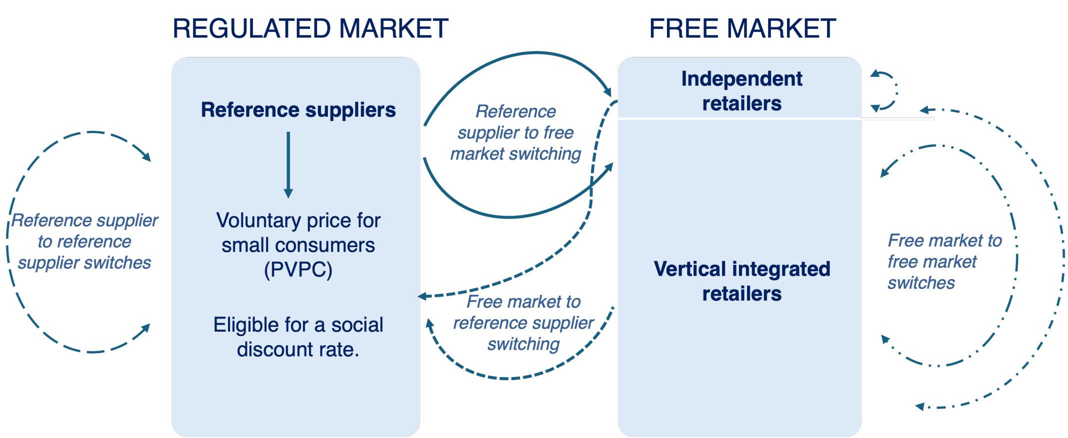
According to CNMC (2022), since the price increase began at the end of 2020, several retailers have modified the terms of their contracts and, in some cases, have terminated their fixed-price agreements due to the inability to continue supplying customers at agreed prices. This has largely been caused by the lack of contracted coverage to fulfill their commitments. In particular, small retailers face difficulties in honoring fixed-price contracts, as they encounter greater challenges in securing long-term coverage at competitive prices. In addition, they also face financial difficulties when buying energy and providing the required guarantees in the market.

The financial capacity and liquidity of a retailer also play a crucial role in its ability to stay in the market. Retailers must pay upfront for the electricity they supply and post guarantees in the spot and forward markets to cover purchases scheduled for the next 7 to 12 days. They only recover these costs at the end of the month, once they issue invoices and collect payments from customers. Small retailers usually have limited access to financing and operate with tighter liquidity, making it harder to manage this cycle.

In recent years, increasing customer switching rates have further transformed the competitive scenario. Most of that switching has benefited large vertically integrated retailers operating through a regulated and liberalized retail market. As a result, small and independent retailers continue to hold only a small share of the market.

Figure 1.3 illustrates the dynamics of the electricity retail market in Spain. In this context, consumers are free to choose their electricity supplier, while retailers implement various strategies, such as marketing-based approaches, 100% renewable energy sales, the integration of self-consumption within distributed generation systems, and the addition of services to attract customers. As a result, users can switch from the regulated market to the free market and vice versa, as well as between different companies within each market.

Figure 1.3: The switching in Spanish electricity retail market.



Note: Author's own elaboration.

In the free market, the supplier and the consumer agree freely on the terms of the electricity supply contract. These low-voltage supply contracts have a maximum duration of one year and may be tacitly renewed on an annual basis. After the initial term, the contract may be terminated by the consumer at any renewal point. Early termination before the first year is also allowed, although it can incur a penalty.

Switching from the free market to the regulated market is free of charge; however, consumers must have remained in the free market for a minimum of one year. Regulated market contracts have a fixed one-year duration. In contrast, switching from the regulated market to the free market can be done at any time without incurring any cost.

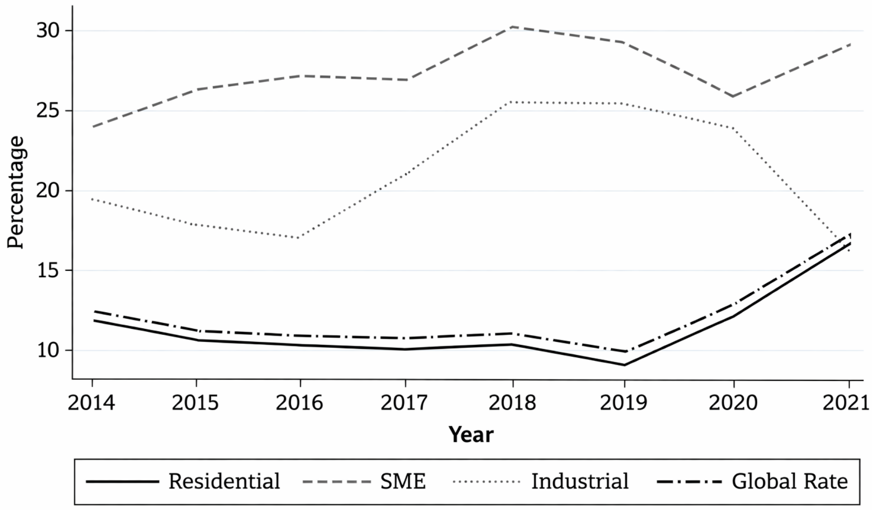
According to data from Comisión Nacional de los Mercados y de la Competencia (CNMC) (2022), the year 2021 registered an annual supplier switching rate of 17%, corresponding to more than five million activated requests. Although the number of switches exhibited a slight downward trend between 2015 and 2019, it increased by 23.2% in 2020 compared to the previous year. This upward trend was confirmed in 2021, with an additional increase of 36.7% over 2020.

In 2021, 91% of all switching activity took place within the liberalized market, with 66.6% corresponding to transitions between different suppliers operating in that market. Additionally, 24.8% of total switches reflected consumers moving from the regulated scheme (PVPC) to the liberalized market. In recent years, households have exhibited a growing propensity to change suppliers.

As shown in Figure 1.4, the supplier switching rates in 2021 varied between market segments: 16.6% in the residential-commercial segment, 29.2% between small and medium-sized enterprises (SMEs), and 17% in the industrial sector.

The analysis developed in this chapter has provided a detailed characterization of

Figure 1.4: Switching rate by consumption group (2014-2021).



Note: Author's own elaboration based on data from CNMC.

the institutional, regulatory, and competitive evolution of the Spanish electricity sector following the liberalization process that culminated in 2009. We have shown that the retail market operates in a distinctive environment: a highly concentrated structure dominated by vertically integrated groups, the coexistence of regulated and liberalized activities, the presence of reference retailers subject to the PVPC tariff, frequent entry and exit of independent suppliers, and a price formation process strongly shaped by regulatory and fiscal decisions. This set of characteristics directly conditions both household behavior and firm performance, and constitutes the context in which the empirical analyses of the following chapters are developed.

First, the regulatory framework and market structure described here help explain why households may react differently to changes in prices and income depending on their degree of energy vulnerability, the existence of regulated tariffs, and the role of reference suppliers. These elements are essential for interpreting the findings of Chapter 2, where price and expenditure elasticities are estimated through a QUAIDS demand system and differences between vulnerable and non-vulnerable households are examined. The segmentation of the retail market, the importance of regulated prices, and the role of social policies (such as the social discount rate) decisively influence how households adjust their consumption of electricity, natural gas, and water.

Second, the 2012 tax reform and the way energy prices are transmitted to consumers gain particular relevance in a sector where vertical market structure, wholesale market contracting mechanisms, and PVPC regulation determine the degree of pass-through. These elements, introduced in this chapter, are fundamental for Chapter 3, which evaluates the distributional and welfare effects of the increase in VAT on energy services. Understanding price dynamics, the role of retailers, and the differential weight of energy expenditures across households is indispensable for interpreting the magnitude and distribution of welfare losses.

Finally, the description of the functioning of the retail market, the incentives for entry and exit, and the persistence of vertical integration provide the necessary background for the analysis in Chapter 4, which examines productivity, retail markups, and efficiency patterns among firms. The competitive structure detailed in this chapter—characterized by the coexistence of large integrated groups and numerous small retailers—forms the basis for empirically assessing firm performance and understanding how market organization shapes aggregate productivity and market power.

In summary, this chapter has shown that the Spanish electricity sector offers an institutional and competitive setting that is particularly well suited for an integrated study of household demand, welfare, and firm behavior. The chapters that follow draw directly on this framework to develop a unified empirical analysis linking household decisions, the distributional consequences of public policies, and firm performance within a sector that is simultaneously regulated and liberalized.

Bibliography

Alonso, P. R. (2001). "The Liberalisation Process of the Spanish Electricity Sector". *Croatian Energy Day: Energy sector liberalisation and privatisation in transition-economy and EU countries: experiences and perspectives*, 99–108.

Arocena, P. (2003). "The reform of the utilities sector in Spain". *Utility Privatization and Regulation*. Edward Elgar Publishing. Chap. 6, 125–148.

Arocena, P., K.-U. Kühn, and P. Regibeau (1999). Regulatory reform in the Spanish electricity industry: a missed opportunity for competition. *Energy Policy* 27 (7), 387–399.

Ciarreta, A., S. Nasirov, and C. Silva (2016). The development of market power in the Spanish power generation sector: Perspectives after market liberalization. *Energy Policy* 96, 700–710.

Comisión Nacional de Energía (2010). *Informe de supervisión del mercado minorista de electricidad en el periodo octubre 2008 - septiembre 2009.*

Comisión Nacional de los Mercados y de la Competencia (CNMC) (2014). *Informe Anual del Sector Eléctrico 2014.*

— (2022). *Informe sobre cambios de comercializador. Año 2021.*

Energía y Sociedad (2023). *Manual de la Energía.* Spanish.

Fabra, N., and J. Toro (2005). Price wars and collusion in the Spanish electricity market. *International Journal of Industrial Organization* 23 (3), 155–181.

García-Álvarez, M. T., and B. Moreno (2016). La liberalización en la industria eléctrica española. El reto de lograr precios competitivos para los hogares. *Gestión y Política Pública* 25 (2), 551–589.

Garrués-Irurzun, J. (2010). Market power versus regulatory power in the Spanish electricity system, 1973–1996. *Renewable and Sustainable Energy Reviews* 14 (2), 655–666.

Green, R. (2005). “Restructuring the Electricity Industry in England and Wales”. *Electricity Deregulation: Choices and Challenges*. Ed. by J. M. Griffin, and S. L. Puller. University of Chicago Press. Chap. 2, 98–144.

Isla, A. Z. (2017). Integración vertical en el mercado eléctrico español. *Indret: Revista para el Análisis del Derecho* 3, 1–22.

Jordana, J., D. Levi-Faur, and I. Puig (2006). The Limits of Europeanization: Regulatory Reforms in the Spanish and Portuguese Telecommunications and Electricity Sectors. *Governance* 19 (3), 437–464.

Joskow, P. L. (2008). Lessons learned from electricity market liberalization. *The Energy Journal* 29 (2_suppl), 9–42.

Newbery, D. M. (2006). “Electricity Liberalization in Britain and the Evolution of Market Design”. *Electricity Market Reform: An International Perspective*. Ed. by F. P. Sioshansi, and W. Pfaffenberger. Elsevier. Chap. 4, 109–144.

PwC España (2020). *Competitividad del Mercado Minorista de Electricidad en España.*

Ragwitz, M., and C. Huber (2005). Feed-In Systems in Germany and Spain and a comparison. *Report of the Fraunhofer Institut für Systemtechnik und Innovationsforschung (ISI), Breslauer Str* 48, 76139.

Sáenz de Miera, G., and P. Del Río (2022). Lessons from the liberalization and regulation of electricity retailing in Spain. *Energy Reports* 8, 233–246.

Utray, J. F., L. P. Alfonso, and T. de la Quadra-Salcedo y Fernández del Castillo (2004). *Un mercado para la electricidad:¿ Liberalización o regulación?* Marcial Pons.

Vázquez, C., C. Batlle, S. Lumbreras, and I. J. P. Arriaga (2006). “Electricity retail regulation in a context of vertical integration: The debate on regulated tariffs”.

Chapter 2

Price and budget elasticities under utility poverty policies in Spain

2.1 Introduction

Access to energy sources at affordable prices is one of the main goals of the 2030 Agenda for Sustainable Development. However, determinants related to income, geographic conditions, and increases in energy prices (for economic, political, or climate-related reasons) can restrict such access to energy at affordable prices. In this sense, government intervention may be necessary to ensure adequate energy supply for vulnerable consumers (Directive 2009/72/EC of the European Parliament).

In the literature, many articles confuse the terms energy poverty and fuel poverty (Li et al. 2014). Although both are concerned about the accessibility problem of domestic energy consumption, their definitions have evolved over the years.

The concept of fuel poverty emerged in the early 1980s, defined as the inability to afford adequate warmth due to inefficiency of home energy (Boardman 1991). Nevertheless, measuring households' fuel poverty has not been a trivial task, so several measurements have been presented in the literature. More precisely, Isherwood & Hancock (1979) proposed to assess the proportion of income spent on fuel as an indicator of fuel poverty. Then, they considered highly fuel-demanding households as those whose fuel expenditure (i.e., fuel, light, and power) was more than twice the median of the fuel expenditure of the United Kingdom households. Bradshaw & Hutton (1983) broadened the concept related to households' ability to afford customary levels of warmth, while Boardman (1991) provided a detailed examination of this poverty issue, proposing the 10% indicator that later became the basis for the official definition of the United Kingdom Fuel Poverty Strategy (Hills 2011).

In recent years, the definition of fuel poverty has expanded beyond "adequate warmth". In this sense, it is currently defined as the inability of a household to reach levels of thermal comfort that are commensurate with a healthy standard of living at a reasonable cost (Burlinson et al. 2021) (i.e., the concept refers to the inability of a household to meet the socially and materially necessary level of domestic energy supply (Hills 2012; Guertler 2012)).

Energy poverty has been regarded as a lack of access to modern energy services, while fuel poverty has been seen mainly in terms of affordability. Thus, fuel poverty is found mainly in relatively wealthy countries with cold climates, while energy poverty is found across all climates but mostly in developing countries (Li et al. 2014). However, the European Union commonly refers to energy poverty (e.g., in the EU Energy Poverty Observatory (EPOV)). Belaïd (2018) specifies that the term fuel poverty has been used in countries such as Great Britain, New Zealand, and Ireland, while energy poverty tends to be used in Continental Europe.

In the literature on energy policy, concerns about energy poverty (i.e., the inability to ensure the provision of basic energy services at an affordable cost) tend to focus on developing countries. However, in the past decade, this issue has also risen on the policy agenda in developed countries. Bagnoli & Bertoméu-Sánchez (2022) noted that 50 million households in the European Union are currently experiencing energy poverty. This issue is even more acute in Spain (see Tirado Herrero & Jiménez Meneses (2016) and Hass (2019)). Then, the Spanish government implemented a subsidy on electricity prices for vulnerable households in 2009. It was called the social discount rate for electricity (SDR, Bono Social de Electricidad in Spanish)[1].

However, the development of energy poverty policies aimed at protecting the most vulnerable households and, at the same time, encouraging efficient energy consumption is not a simple task for policymakers. Such policies usually have wide-ranging effects on social welfare, and those effects are not the same for all households. Furthermore, the effectiveness of a policy depends on the sensitivity of demand and supply, so the price and budget elasticities of demand are relevant to domestic energy policies (Reiss & White 2005; Gundimeda & Köhlin 2008; Olabisi et al. 2019; Addey et al. 2019; Curtis et al. 2020).

The demand for utility services has been analyzed at different levels of aggregation. Labandeira, Labeaga, & López-Otero (2017) carried out a meta-analysis of the price elasticity of energy demand, seeking to acquire relevant information to anticipate the effects of policies on energy, taxes, or environmental issues that affect energy prices. Focusing on the Spanish context, Labandeira, Labeaga, & López-Otero (2012) considered the price elasticity of electricity demand for households, companies, and large consumers using the classical panel data model with random effects and incomplete information. Hanemann et al. (2013) used a continuous and discrete model to estimate the price and income elasticities of the residential energy demand for heating. For complete demand models, Labandeira, Labeaga, &

[1]Appendix A explains the different energy poverty policies implemented by the Spanish government since 2009, with special attention to the changes in the SDR policy.

Rodríguez (2006) estimated a demand system for electricity demand, natural gas, liquefied petroleum gas, vehicle fuel, public transport, and food from a panel of data considering the periods 1973-1974, 1980-1981, and 1985-1995. Gálvez et al. (2016) studied a demand system for utility services in 2013.

Recently, another strand of literature has focused on public policy instruments that address household energy poverty. Using the difference-in-difference methodology, Alvarez & Tol (2021) found no evidence that the social discount rate (SDR) helps reduce energy poverty. For their part, Bagnoli & Bertoméu-Sánchez (2022) analyzed the effectiveness of the SDR using the difference-in-difference approach to measure its causal impact on energy poverty. They find that the subsidy reduces the likelihood of energy poverty for eligible households, but the scale of the effect is relatively small. Finally, Cadaval et al. (2022) used a quasi-experimental method with a longitudinal sample of Spanish households and concluded that the SDR has not helped to mitigate fuel poverty, in the sense that it can penalize the lowest-income households and benefit others considered non-vulnerable in terms of income.

This paper seeks to estimate the price and budget elasticities of the household demand for utility services (electricity, natural gas, and water) in Spain between 2009 and 2014. Using data from three different waves of the Spanish Annual Household Budget Survey (HBS), we split the samples based on certain vulnerability conditions and then used an extension of the Quadratic Almost Ideal Demand System (QUAIDS) model based on Banks et al. (1997), to estimate both price and budget elasticities of utility services. Thus, this paper contributes to the literature in several ways. First, an estimation procedure is applied to estimate an aggregate QUAIDS model for utility services and other aggregate categories of goods while simultaneously considering endogeneity and censorship problems. Second, we estimate price and budget elasticities for utility services by considering vulnerable and non-vulnerable households. To our knowledge, our study is the first of its kind in the literature since the QUAIDS approach has not been used before to study the sensitivity of demand for utility services considering the vulnerability situation of households in a developed economy.

We consider Spain to be an interesting case study for the period 2009-2014 since it coincides with the period of the Great Recession. Spain's unemployment rate hit 17.4% at the end of March 2009, and by July 2009, the country had lost 1.2 million jobs in one year and had as many people out of work as France and Italy combined. In March 2012, unemployment in Spain reached 24.4%, twice the average of the Eurozone.

Our findings suggest that the demands of vulnerable households are slightly more price-sensitive for natural gas and water. However, we did not find the same result for electricity demand. We also find some evidence of the substitution between electricity and natural gas. We show elastic demand for electricity for 2009 and 2011, but in 2014, demand became inelastic. Despite differences in household consumption preferences depending on their vulnerability condition, we do not find a clear relationship between household vulnerability and demand sensitivity for utility services.

The remainder of the paper is structured as follows. Section 2.2 introduces the theoretical model for analyzing the consumer demand system and some measures of energy poverty to study the sensitivity of households' demand for utility services. Section 2.3 describes the data and the estimation procedure. Section 2.4 contains the estimated results and discusses the estimates of budget and price elasticity. Section 2.5 presents the conclusions and some policy recommendations.

2.2 Method and vulnerability measures

In this section, we first introduce the QUAIDS model that we propose to model the consumer demand system, which serves as a basis for calculating the budget and uncompensated elasticities of utility services in Spain. Below, we provide several energy poverty measures that enable us to analyze the sensitivity of household electricity demand to its vulnerability.

2.2.1 The Quadratic Almost Ideal Demand System

In analyzing consumer welfare, Banks et al. (1997) state that the minimum level of expenditure needed to reach a given level of utility prices can be obtained by the following indirect utility function:

$$\ln(V) = \left\{ \left[\frac{\ln(m) - \ln(a(\mathbf{p}))}{b(\mathbf{p})} - \lambda(\mathbf{p}) \right] \right\}^{-1}, \tag{2.1}$$

where V denotes the indirect utility function, m denotes (nominal) expenditure, and $\mathbf{p}$ is a n-dimensional price vector of n goods. Assume that $a(\mathbf{p})$, $b(\mathbf{p})$, and $\lambda(\mathbf{p})$ are flexible enough functions of $\mathbf{p}$ such as:

$$\begin{aligned} \ln(a(\mathbf{p})) &= \alpha_0 + \sum_{i=1}^{n} \alpha_i \ln(p_i) + \frac{1}{2}\sum_{i=1}^{n}\sum_{j=1}^{n} \gamma_{ij} \ln(p_i)\ln(p_j) && (2.2) \\ b(\mathbf{p}) &= \prod_{i=1}^{n} p_i^{\beta_i} && (2.3) \\ \lambda(\mathbf{p}) &= \sum_{i=1}^{n} \lambda_i \ln(p_i), \qquad \text{where} \quad \sum_{i=1}^{n} \lambda_i = 0. && (2.4) \end{aligned}$$

Note that in the above expressions, $i = 1, 2, \ldots, n$ represents each good, $\ln(a)$ is a translog specification of prices, $b(\mathbf{p})$ is the Cobb-Douglas price aggregator, and $\lambda(\mathbf{p})$ is a differentiable and homogeneous function of prices of degree zero. Note also that consumer theory implies that demand systems must satisfy the following constraints derived from adjustments to budget constraints and the optimization process of total consumption:

$$\sum_{i=1}^{n}\alpha_i = 1, \quad \sum_{i=1}^{n}\beta_i = 0, \quad \sum_{i=1}^{n}\gamma_{ij} = 0, \quad \text{and} \quad \gamma_{ij} = \gamma_{ji}. \tag{2.5}$$

Empirical studies suggest including linear and higher-order terms associated with demand systems to avoid specification errors in approximating the nonlinear relationships between budget proportions and total expenditure (the well-known *Engel curve*). Therefore, in this paper, we consider the following demand system:

$$w_i = A_i(\mathbf{p}) + B_i(\mathbf{p})\ln(x) + C_i(\mathbf{p})g(x) \quad i = 1, ..., n. \tag{2.6}$$

where w_i is the proportion of household spending on good i and $A_i(\mathbf{p})$, $B_i(\mathbf{p})$, $C_i(\mathbf{p})$ and $g(x)$ are differentiable functions[2]. Denoting q_i as the quantity consumed of each good i and p_i as the price of each good i, w_i can be written as $w_i = p_i q_i/m$. Thus, differentiating Eq.(2.6) with respect to $\ln(p_i)$ and applying Roy's identity, the following demand system in terms of budget shares, w_i, is proposed:

$$w_i = \alpha_i + \sum_{i=1}^{n}\gamma_{ij}\ln(p_j) + \beta_i \ln\left[\frac{m}{a(\mathbf{p})}\right] + \frac{\lambda_i}{b(\mathbf{p})}\left\{\ln\left[\frac{m}{a(\mathbf{p})}\right]\right\}^2, \tag{2.7}$$

where it is assumed that household characteristics are included in the QUAIDS model to account for heterogeneous preferences using the translating approach proposed in Pollak & Wales (1981). We allow household heterogeneity to enter the demand system via the intercepts α_i, which are modeled as the following linear combination of a set of socio-demographic variables (z_j) observed in the households,

[2] $A_i(\mathbf{p})$ corresponds to the *ith* $\ln(p)$ derivative of $\ln(a(p))$, $B_i(\mathbf{p})$ corresponds to the *ith* $\ln(p)$ derivative of $\ln(b(p))$, and $C_i(\mathbf{p})$ correspond to the *ith* $\ln(p)$ derivative of $\ln(c(p))$.

for $j = 1, \ldots, S$, where S is the vector of all such variables:

$$\alpha_i = \rho_{i0} + \sum_{j=1}^{S} \rho_{ij} z_j, \tag{2.8}$$

where ρ_{i0} and ρ_{ij} are unknown parameters to be estimated. We note that modeling household heterogeneity using this approach does not mean that heterogeneity enters the model linearly. As seen in (2.7), heterogeneity appears linearly in the intercepts and nonlinearly in all expenditure terms through the first price aggregator (2.2).

Consequently, the demand estimation model that we propose has the following form:

$$w_i = \rho_{i0} + \sum_{j=1}^{S} \rho_{ij} z_j + \sum_{i=1}^{n} \gamma_{ij} \ln(p_i) + \beta_i \ln\left[\frac{m}{a(\mathbf{p})}\right] + \frac{\lambda_i}{b(\mathbf{p})} \left\{\ln\left[\frac{m}{a(\mathbf{p})}\right]\right\}^2 + \upsilon_i, \tag{2.9}$$

where υ_i is the idiosyncratic error term.

Note that the QUAIDS model that we propose to estimate in (2.9) has several advantages for empirical studies. First, the model satisfies the axioms of choice exactly when all the information on income and substitution effects contained in cross-price elasticities is incorporated and is compatible with microeconomic principles of utility and demand systems (Suárez-Varela 2020). In addition, the homogeneity and symmetry constraints of a linear approach are easily imposed and tested (Deaton & Muellbauer 1980; Banks et al. 1997; Kutortse 2022), and separability is not imposed. Secondly, the curvature of Engel curves is incorporated through the quadratic terms in the logarithm of expenditure (Banks et al. 1997; Suárez-Varela 2020; Díaz & Medlock 2021) so income effects can now vary across the income distribution (Suárez-Varela 2020). Third, this QUAID model is a system of equations designed to analyze budget participation in different goods, and the socioeconomic and demographic characteristics of households can be included in the study (Decoster, Vermeulen, et al. 1998).

Furthermore, the demand system enables us to estimate elasticities consistent with consumer theory (Deaton 1987; Kutortse 2022). More precisely, differentiating (2.9) with respect to $\ln(m)$ and $\ln(p_i)$, the following equations are obtained:

$$\mu_i = \frac{\partial\, w_i}{\partial \ln(m)} = \beta_i + \frac{2\lambda_i}{b(\mathbf{p})} ln\left(\frac{m}{a(\mathbf{p})}\right), \tag{2.10}$$

$$\mu_{ij} = \frac{\partial\, w_i}{\partial \ln(p_i)} = \gamma_{ij} - \mu_i\left(\alpha_j + \sum_l \gamma_{jl} ln(p_l)\right) - \frac{\lambda_i \beta_j}{b(\mathbf{p})}\left[ln\left(\frac{m}{a(\mathbf{p})}\right)\right]^2. \tag{2.11}$$

Subsequently, the budget and uncompensated price elasticities can be calculated as follows:

$$\epsilon_i = \frac{\mu_i}{w_i} + 1 \tag{2.12}$$

$$\epsilon_{ij}^u = \frac{\mu_{ij}}{w_i} - \delta_{ij}, \tag{2.13}$$

where δ_{ij} is the Kronecker delta, 1 if $i = j$ and 0 otherwise.

2.2.2 Vulnerability measures

To analyze households' demand for utilities according to their fuel poverty levels, we need to be able to identify vulnerable consumers in terms of energy poverty. To do this, this section provides several vulnerability measures for households. We propose using budget and price elasticities of demand for different years during the Great Recession in Spain to analyze the sensitivity of households' demand for utility services.

From a theoretical point of view, energy poverty can be said to occur when a household is unable to secure the level and quality of residential energy services (such as air conditioning and heating, cooking, electrical appliances, and information technology) needed to meet its basic needs (Buzar 2007; Bouzarovski 2018). However, this concept refers to the difficulty in obtaining energy services, whatever the cause of the problem (Charlier & Legendre 2021). By contrast, the term "energy vulnerability" identifies a set of conditions that increase the probability that a given household suffering energy poverty (such as social, material, and economic situations) and make some households more sensitive (and less capable of adapting) to difficulties in accessing energy services (Groves et al. 2021).

In this framework, various methodologies have been proposed to identify energy poverty and vulnerable consumers (Romero et al. 2018; Charlier & Legendre 2021), but the definition of fuel poverty is important in policy formulation (Moore 2012). The literature identifies several indicators for measuring energy poverty, split into objective and subjective[3]. The leading objective indicators used in the literature to measure energy poverty are the following:

- 10% *indicator*: when a household cannot obtain adequate energy services for 10 percent of its income (Boardman 1991).
- *2M indicator*: a household is classified as energy-poor when its spending on utility services is more than twice the median for the relevant group of households.
- *Minimum Income Standard (MIS) indicator*: households are considered in fuel poverty if, after deducting their actual housing costs, they do not have sufficient net income to cover their total required fuel costs after all other minimum living costs (defined by MIS) have been met (Moore 2012). The MIS-based indicator of energy poverty is one of the most robust when measuring objective energy poverty, considering income (Romero et al. 2018).

[3]Objective indicators are mainly based on household income and energy expenditure. Subjective indicators use surveys to assess the ability of households to keep homes adequately warm and pay their utility bills on time.

- *Low Income, High Cost (LICH) indicator*: households are defined as fuel-poor when their income is relatively low and the energy spending required to achieve an adequate heat standard is above a specified threshold (Hills 2011).

For the present study, we use the MIS energy poverty indicator to split households into two groups (i.e., vulnerable and non-vulnerable energy households) as proposed Romero et al. (2018) Gómez-Navarro et al. (2021) and Barrella et al. (2022) for Spain. Vulnerable households are assumed to need the electricity social rate due to their energy poverty condition. Non-vulnerable households do not have an energy poverty condition and, therefore, do not have access to electricity at the social rate. Romero et al. (2018) describes an energy-poverty consumer as a household fulfilling the following condition

$$[Nhi - Hc - Ahee] \leq [MISeq - Aee - Ahc], \tag{2.14}$$

where *Nhi* is net household income, *Hc* is housing costs, *Ahee* is household energy spending, *Aee* is average energy expenditure, and *Ahc* is average housing costs. *MISeq* is the minimum income threshold on an objective basis, defined as 1.5 times the Multiplier for the Public Revenue Index (Indicador Público de Renta de Efectos Múltiples (IPREM[4]) in Spanish). Households with income less than 1.5 times the IPREM are considered vulnerable and at risk of social exclusion.

The academic literature on fuel poverty indicators has identified several limitations associated with using expenditure-based indicators as a metric of fuel poverty. In this context, it is pertinent to point out that one of the restrictions inherent to this type of indicator (i.e., MIS) is related to the consideration of the observed

[4]Note that the IPREM indicator is used to determine eligibility in various social programs (including unemployment benefits, social housing subsidies, and minimum wage calculations, among others) and is based on the average household income and number of members.

expenditure compared to the actual or necessary expenditure that households must spend to meet their energy needs.

The indicator may reflect a degree of subjectivity based on energy spending rather than the required expenditure. It has long been contended that since actual spending can be distorted by financial constraints (i.e., some people cut back on heating to make ends meet) – or its reverse, profligacy – measuring fuel poverty on such a basis has limitations (Hills 2011). From this perspective, the observed expenditure on energy could be lower, given the consumption choices that households must make concerning disposable income. In addition, households should spend more on energy products, but do not do so for affordability reasons (Webb et al. 2017). The above could cause households in energy poverty to be many more than those considered.

However, according to Romero et al. (2018), the MIS indicator of energy poverty is undoubtedly one of the most robust when measuring objective, income-based energy poverty because it considers the income available for energy needs after basic needs have been met. The author also mentions the limitations of determining the minimum income standard. The results are sensitive to the value used, so a change in that value would mean a significant change in the indicators obtained.

2.3 Data and methodology

This section presents the dataset used for the study, then points out the main weaknesses that must be dealt with when trying to estimate the QUAIDS model consistently (2.9) with this type of data, and sets out the estimation procedure for solving all these issues simultaneously.

2.3.1 Data and descriptive statistics

Data on household and individual characteristics are taken from the Spanish Annual Household Budget Survey (HBS) for three different years: 2009, 2011, and 2014. This survey is conducted annually by the Spanish National Statistics Institute (INE) and consists of observations on household spending, including energy expenditure, demographic composition, and other socioeconomic characteristics of households. The sample consists of about 24,000 randomly selected households each year, with each household remaining for two consecutive years and half of the sample renewing each year. This approach enables us to establish the expenditure of households in Spain and the distribution of declared expenditure across the different consumer spending categories.

The consumer spending recorded in the HBS refers both to the outlay by households for certain final consumer goods and services and to the value of certain non-monetary household consumer items. Several previous studies have used this survey to explore various issues related to the demand of household utilities (Labandeira, Labeaga, & Rodríguez 2006; Gálvez et al. 2016; Bagnoli & Bertoméu-Sánchez 2022).

The data is corrected for outliers and misreporting by discarding the following: (i) households that do not report income; (ii) households with zero expenditure for the group that represents the consumption of utility services; (iii) households located in the Canary Islands, the Balearic Islands, Ceuta, and Melilla, and those in which there is no record of occupation or gender of the householder; (iv) households whose electricity price is below the 1st percentile or above the 99th; (v) all households that do not report expenditure on at least one of the goods included in the QUAIDS demand system 2.9). Hence, the sample for 2009 contains data from 22,346 households, but only 19,462 are used here due to the data-cleaning process. The sample for 2011 includes 21,680 observations, but the data used in the estimation refer to

18,920. The original sample for 2014 covers 22,146 households, but is reduced to 19,232.

The QUAIDS model does not consider aspects of intertemporal demand decisions. We thus focus on non-durable goods due to data limitations. Commodities are aggregated in an attempt to provide a representative picture of households. We group consumption groups into: (1) electricity, (2) natural gas, (3) water, (4) food and non-alcoholic beverages, (5) housing, (6) transport and communications, and (7) other goods. This aggregation strategy seeks to separate primary household energy and water services while still considering the rest of the goods consumed. Few papers have followed this strategy. For example, Tovar Reaños & Wölfing (2018) differentiates between electricity and heating demand for German households but considers four other types of goods like ours. We also control the size, type, heating system, and region of the home.

One significant drawback of the HBS data is that it does not include prices. To overcome this, in this article we use unit values for disaggregated utility services. Thus, we calculate the ratio of total expenditure of electricity, natural gas, and water for the corresponding levels of consumption as proposed in Gundimeda & Köhlin (2008), Zheng & Henneberry (2012), or Bilgic & Yen (2013), among others. For the rest of the categories aggregated (i.e., from group 4 to group 7), we calculate household-level price indexes (as in Hoderlein & Mihaleva (2008) and García-Enríquez & Echevarría (2018), for example). Thus, we compute a Stone-Lewbel-like price index[5].

The descriptive statistics for the main variables in the analysis are reported in Table 2.1 and 2.2. Compared to previous years, the average expenditures in electricity,

[5] For any group $I \in \{4,5,6,7\}$ which is made up of J_I expenditure sub-groups, we construct a price index at household level $P_{Ih} \equiv (1/K_I)\prod_{j=1}^{J_I}(P_{I,j}/W_{I,j}^h)^{W_{I,j}^h}$, where $K_I \equiv \prod_{j=1}^{J_I} \overline{W}_{I,j}^{-\overline{W}_{I,j}^h}$, $\overline{W}_{I,j}$ is the mean of the proportion of total expenditure sub-group j relative to total expenditure I, $W_{I,j}^h$ and $P_{I,j}$ denotes the aggregate nationwide price index for expenditure sub-group j.

natural gas, and water increased from 2009 to 2011 and 2014. In 2009, the average household spent 588.65€ per year on electricity; in 2014, the equivalent figure was 696.35€. The average energy consumption in kWh per household decreased in 2014, most significantly for electricity, where consumption was 20% lower than in 2014. The total expenditure on utilities (electricity, natural gas, and water) is approximately 66% for electricity, 16% for natural gas, and 18% for water. Finally, the share of total household spending on electricity increased from 3% in 2009 to 4% in 2014, while the figure for natural gas and water was 1% each from 2009 to 2014.

In terms of demographic variables that influence utility demand, we control for numerous household characteristics that have been found to affect consumer behavior. Table 2.1 shows the sociodemographic variables used to estimate the demand system. Factors such as the sex of the primary breadwinner, marital status, employment, and educational level can affect demand. According to the HBS, the main breadwinner in 74% of households is male, although that figure decreased to 69% in 2014. 48% of primary caregivers were employed in 2009; in 2014, the percentage increased to 57%. It should be noted that the level of education of the primary breadwinner also increased in the period under analysis from 26% with higher education in 2011 to 30% in 2014, and the proportion of primary breadwinners without educational qualifications or only primary education decreased from 27% in 2009 to just 16% in 2014. Other variables that play an essential role in demand are the number of members in the household and their ages (Pollak & Wales 1981); a percentage breakdown of household members by age group is shown in Table 2.1.

Geographic location is also used as a control variable because, for example, weather conditions can affect consumption depending on the region. Approximately 19% of all households in the sample are in rural areas. We also use the distribution of households according to the geographic region.

The variables referring to housing type and size are used to estimate the probit model of the first stage of the demand system. In particular, a dummy variable indicates whether a home has natural gas expenses ($Gastnat_g$ is the dependent variable of the probit model). As independent variables, we include a dummy variable that determines whether a home is owned or rented, whether it is a flat or another type of home, and whether it is equipped for heating and water heating with natural gas ($Gastnat_{eq}$). Finally, we also consider the size of homes in square meters.

Table 2.1: Summary statistics for households in HBS

	2009				2011				2014			
	Mean	Std.dev.	Min	Max	Mean	Std.dev.	Min	Max	Mean	Std.dev.	Min	Max
Expenditure on electricity (€ per year)	588.87	499.91	0	10,288.65	770.29	575.27	0	10,800	696.35	433.15	0	8,146.73
Expenditure on natural gas (€ per year)	207.08	416.58	0	5,448.72	214.29	413.24	0	9,864.54	242.29	434.78	0	7,200
Expenditure on water (€ per year)	138.96	115.60	0	2,400.13	148.98	124.02	0	4,380.57	177.88	147.61	0	6,600.27
Consumption of electricity (kWh/year)	3,572.65	3,316.66	0	69,415.20	3,943.82	3,255.72	0	58,524	2,832.53	2,003.99	0	39,484.80
Consumption of natural gas (kWh/year)	214.58	483.51	0	7,260	229.54	557.02	0	24,180	213.77	439.97	0	5,934
Consumption of water (m3/year)	113.10	90.73	0	1,825.20	136.28	121.93	0	4,536	143.81	123.96	0	3,874.2
Price of electricity (€/kWh)	0.17	0.03	0.08	0.38	0.20	0.03	0.10	0.40	0.25	0.05	0.14	0.52
Price of natural gas (€/kWh)	1.12	0.22	0.55	2.49	1.19	0.29	0.25	2.56	1.26	0.23	0.61	2.67
Price of water (€/year)	1.27	0.41	0.46	2.22	1.16	0.40	0.33	2.43	1.31	0.45	0.45	2.55
Share electricity expenditure group	0.67	0.23	0	1	0.70	0.21	0	1	0.66	0.21	0	1
Share natural gas expenditure group	0.16	0.23	0	1	0.15	0.21	0	1	0.16	0.22	0	1
Share water expenditure group	0.18	0.13	0	1	0.16	0.12	0	1	0.18	0.23	0	1
Annual income (€)	29,305.72	19,220.23	1,120	255,920	28,638.20	18,384.93	98	232,876	27,439.75	17,593.86	560	218,624
Share expenditure on electricity	0.03	0.03	0	0.73	0.04	0.05	0	5.14	0.03	0.03	0	1.12
Share expenditure on natural gas	0.01	0.02	0	0.44	0.01	0.02	0	0.60	0.01	0.02	0	0.49
Share expenditure on water	0.01	0.01	0	0.18	0.01	0.02	0	2.11	0.01	0.01	0	0.25
Group W4	0.18	0.09	0	0.79	0.17	0.09	0	0.81	0.17	0.09	0	0.74
Group W5	0.36	0.15	0	0.92	0.35	0.14	0	0.91	0.35	0.14	0	0.94
Group W6	0.14	0.11	0	0.81	0.13	0.11	0	0.77	0.13	0.11	0	0.84
Group W7	0.27	0.14	0	0.94	0.25	0.13	0	0.87	0.24	0.14	0	0.89
Price index Group W4	69.85	49.20	2.95	3,020.45	61.42	19.39	3.19	118.20	70.94	45.84	2.53	2,453.93
Price index Group W5	99.76	252.23	14.82	24,862.99	282.64	29,020.91	1.07	3,991,873	103.10	151.30	8.38	11,138.16
Price index Group W6	24.91	13.74	3.43	476.39	27.26	11.82	3.06	83.61	26.17	14.44	3.32	244.99
Price index Group W7	9.09	8.23	0.05	107.41	11.31	9.61	0.04	72.20	9.79	9.14	0.05	94.38
Total expenditure	29,193.24	17,116.63	960.69	289,320.50	28,549.23	16,746.98	1,934.71	337,661.70	26,619.70	15,377.63	976	198,450

Note: Group W4: food and non-alcoholic beverages; Group W5: Housing; Group W6: Transport and communications; Group W7: Other goods. Sample 2009: 19,462 households. Sample 2011: 18,920 households. Sample 2014: 19,232 households.

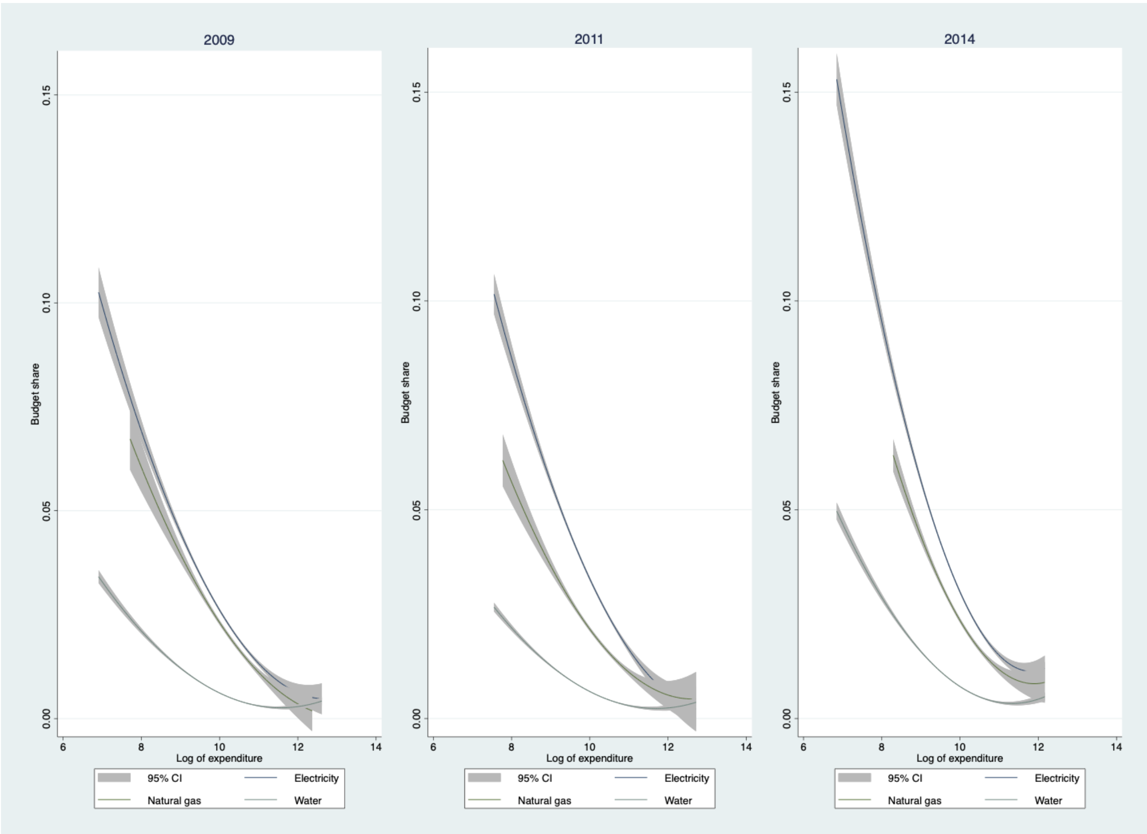
Table 2.2: Summary statistics for households' sociodemographic variables in HBS.

	2009				2011				2014			
	Mean	Std.dev.	Min	Max	Mean	Std.dev.	Min	Max	Mean	Std.dev.	Min	Max
Sex household head:male	0.74	0.44	0	1	0.72	0.45	0	1	0.69	0.46	0	1
Main breadwinner employed	0.48	0.49	0	1	0.58	0.49	0	1	0.57	0.49	0	1
Number of household members												
Household members < 4 years	0.04	0.25	0	6	0.16	0.43	0	3	0.14	0.40	0	4
Household members $5 - 15$ years	0.56	0.87	0	8	0.33	0.65	0	6	0.34	0.67	0	8
Household members $16 - 24$ years	0.14	0.41	0	6	0.28	0.58	0	5	0.26	0.57	0	5
Household members $25 - 34$ years	0.48	0.81	0	7	0.34	0.64	0	5	0.28	0.57	0	4
Household members $35 - 64$ years	1.37	0.99	0	4	1.22	0.86	0	5	1.24	0.85	0	6
Household members $65 - 84$ years	0.20	0.49	0	6	0.42	0.71	0	4	0.42	0.70	0	5
Household members > 85 years	1.13	0.92	0	4	0.05	0.24	0	3	0.06	0.25	0	3
Educational level of main breadwinner												
No qualifications or primary education	0.27	0.44	0	1	0.21	0.40	0	1	0.16	0.37	0	1
Lower secondary education	0.31	0.46	0	1	0.34	0.47	0	1	0.35	0.48	0	1
Upper secondary education	0.16	0.37	0	1	0.17	0.38	0	1	0.18	0.38	0	1
Higher education	0.26	0.44	0	1	0.28	0.45	0	1	0.30	0.46	0	1
Region												
Northwest	0.14	0.34	0	1	0.14	0.35	0	1	0.15	0.35	0	1
Northeast	0.24	0.43	0	1	0.22	0.42	0	1	0.23	0.42	0	1
Central	0.08	0.27	0	1	0.08	0.27	0	1	0.08	0.27	0	1
East	0.17	0.37	0	1	0.17	0.37	0	1	0.17	0.38	0	1
South	0.22	0.41	0	1	0.22	0.42	0	1	0.22	0.41	0	1
Married	0.71	0.41	1	5	0.72	0.45	0	1	0.70	0.46	0	1
Rent	0.11	0.31	0	1	0.11	0.32	0	1	0.12	0.33	0	1
Size	101.80	48.63	-9	300	101.71	49.57	-9	300	101.51	49.89	-9	300
Apartment	0.64	0.48	0	1	0.65	0.48	0	1	0.65	0.47	0	1
Rural	0.20	0.40	0	1	0.19	0.39	0	1	0.19	0.39	0	1
$Gastnat_g$	0.38	0.49	0	1	0.41	0.49	0	1	0.43	0.50	0	1
$Gastnat_{eq}$	0.37	0.48	0	1	0.39	0.49	0	1	0.41	0.49	0	1

Note: Sample 2009: 19,462 households. Sample 2011: 18,920 households. Sample 2014: 19,232 households.

In preliminary data analysis, we assess the shape of the Engel curves in Figure 2.1, which predict electricity, natural gas, and water spending as shares of the log of total household expenditure in 2009, 2011, and 2014. The shapes of these estimates show nonlinear relationships for utility services. Thus, a straightforward specification, such as the translog indirect utility demand system, might be misleading about budget effects. In this sense, the QUAIDS specification appears to be justified, considering that including demographic controls captures household heterogeneity. In this descriptive analysis, we observe different shapes for Engle curves for the case of electricity, comparing the survey of 2014 with the previous years.

Figure 2.1: Engel Curves for utility services.



Note: Author's own elaboration.

2.3.2 Estimation procedure

In order to estimate the QUAIDS system introduced in Eq. (2.9) with the above data, it is necessary to deal with various drawbacks that can lead to inconsistent estimators and misleading inferences. On the one hand, household budget surveys usually record zero consumption of one or more goods and services when they are consumed infrequently, so the dependent variables in (2.9) are censored, and using the standard ordinary least squares (OLS) procedure leads to bias and inconsistent estimators (Keen 1986; Heien & Wessells 1990; Yen & Lin 2006; Meyerhoefer et al. 2005). On the other hand, total spending is usually considered a non-exogenous variable, and using it directly in Eq. (2.9) could cause an endogeneity problem (Attfield 1985).

Given the significant number of households that do not report natural gas consumption, a censorship problem may introduce bias into our estimates and invalidate all our conclusions, as discussed in Heckman (1979) and Denton & Mountain (2016). As noted in Olabisi et al. (2019), for example, when censorship is ignored, preferences for items with observed purchases are expected to be overestimated, while substitution between items is underestimated since the analysis does not control for significant factors (such as access to services) that may prevent households from purchasing specific items. To solve this sample selection problem, we can follow the two-step procedure developed by Heckman (1979). However, this procedure is susceptible to some collinearity problems in the absence of an exclusion restriction[6] as pointed out by Leung & Yu (2006), and the estimates of the covariance matrix of the parameter estimates are inefficient (see Tauchmann (2005) for a deeper explanation).

[6]An exclusion restriction implies that there are variables in the first stage of the estimation procedure that are absent in the output equation. This restriction is very relevant to avoid multicollinearity as a consequence of the linearity of the inverse Mills ratio over a wide range of its support (see Ogundimu (2022) for a more detailed explanation).

To overcome all the above problems simultaneously and increase the asymptotic efficiency of the parameter estimates, we follow the two-step estimation procedure proposed by Shonkwiler & Yen (1999). In the first step, a probit model is estimated based on household socio-demographic characteristics and observed fuel-using equipment to predict the cumulative distribution and probability density functions of making purchases in the category for each household. In the second step, we use the estimated distribution obtained in the previous stage to create a predicted budget share, and the QUAIDS model (eq. (2.9)) is modified to use the predicted budget share in place of the observed budget shares[7]. Therefore, we avoid including the inverse Mills ratio in the QUAIDS model.

An auxiliary regression is used to predict prices for households with natural gas spending of zero in a procedure similar to those in previous studies (see Heien & Wessells (1990), Hoderlein & Mihaleva (2008), Gálvez et al. (2016)). That auxiliary regression uses the implicit price of each utility as the dependent variable, total household spending as independent variables, and the sociodemographic variables included in the demand system (number of household members, sex, and level of education of the primary breadwinner and his or her occupational status).

In the literature on standard demand analysis, total expenditure has long been recognized as a potential endogenous problem because of the possible correlation with unobserved features that affect demand behavior or because of the presence of shocks to total expenditure and expenditure shares (see Blundell & J. M. Robin (1999) or J. Robin & Lecoeq (2006) for further details). Furthermore, the QUAIDS model is a nonlinear demand system that can be computationally intensive, especially when using nonlinear approaches (i.e., nonlinear seemingly unrelated regressions (SUR)

[7]We use the Stata command *aidsills* where standard errors are calculated simultaneously using the asymptotic variance-covariance matrix given in Blundell & J. M. Robin (1999), which uses both the predicted regressors introduced in each equation and the correlation of the error terms across equations.

or nonlinear three-stage least squares, for example) if the dataset is large. Therefore, to account for the endogeneity of total expenditure, we use the instrumental variable and the augmented regression approach of Hausman (1978) and Holly & Sargan (1982). Furthermore, Blundell & J. M. Robin (1999) developed a linear least-squares estimation procedure to simplify and speed linear least-squares estimation by exploiting the conditional linearity of the budget share equation presented in the QUAIDS model on a set of functions of explanatory variables and parameters.

2.4 Results

2.4.1 Main results

As pointed out in the previous section, in the first stage of our estimation procedure, we estimate a probit model to account for those households that do not report any natural gas consumption, with the dependent variable being a dummy for natural gas expenditure. We include as explanatory variables the demographic variables used in the second step of our QUAIDS estimation, such as home characteristics, ages of the household members, education levels of the household members, and location. We also add a dummy variable, which takes a value of one if the home has natural gas equipment for heating or hot water. The results of the probit model are shown in Table 2.3.

The results in Table 2.3 are consistent with other studies that use similar methods. The possession of equipment for natural gas increases the probability of having a positive expenditure on natural gas. The signs in the demographic variables are in line with expectations. Factors such as the type of home (flats), the education levels of household members, the total household income (proxied by spending), and the location of households are relevant in explaining positive expenditures on natural gas.[8]

Table 2.3: Estimated coefficient probit model. 2009, 2011, and 2014.

	2009		2011		2014	
Variables	Coefficient	Std. err.	Coefficient	Std. err.	Coefficient	Std. err.
$Gasnat_{eq}$	3.787***	(0.045)	3.856***	(0.048)	3.820***	(0.046)
Apartment	0.210***	(0.054)	0.189***	(0.055)	0.158***	(0.053)
Rent	-0.082	(0.067)	-0.061	(0.068)	0.021	(0.063)
Household member < 4 years	-0.070	(0.107)	-0.058	(0.050)	-0.005	(0.053)
Household member $5-15$ years	0.075***	(0.029)	-0.057*	(0.034)	-0.067**	(0.032)
Household member $16-24$ years	0.132	(0.100)	-0.041	(0.036)	-0.009	(0.037)
Household member $25-34$ years	-0.049	(0.054)	-0.085**	(0.038)	-0.047	(0.040)
Household member $35-64$ years	-0.105***	(0.043)	-0.017	(0.036)	-0.002	(0.037)
Household member $65-84$ years	-0.002	(0.104)	0.030	(0.044)	0.027	(0.046)
Household member > 85 years	0.013	(0.045)	0.003	(0.084)	-0.044	(0.081)
Sex of household head:male	-0.032	(0.048)	-0.023	(0.051)	-0.033	(0.048)
Married	-0.010	(0.026)	-0.002	(0.061)	0.004	(0.060)
Lower secondary education	0.031	(0.054)	0.102*	(0.061)	0.111*	(0.064)
Upper secondary education	0.224***	(0.064)	0.209***	(0.072)	0.215***	(0.074)
Higher education	0.280***	(0.061)	0.251***	(0.070)	0.214***	(0.072)
Occupation	0.055	(0.058)	-0.039	(0.054)	-0.083	(0.053)
Size	0.000	(0.000)	0.000	(0.000)	-0.001	(0.000)
Log of total expenditure	0.427***	(0.047)	0.508***	(0.049)	0.561***	(0.047)
Rural	0.097	(0.058)	0.025	(0.058)	-0.085	(0.055)
Northeast	0.090*	(0.061)	0.170***	(0.062)	0.150**	(0.062)
Madrid	0.132*	(0.089)	0.000	(0.093)	-0.029	(0.091)
Central	0.005	(0.066)	0.036	(0.066)	0.237***	(0.064)
East	-0.136**	(0.064)	-0.117*	(0.064)	-0.151**	(0.064)
South	-0.512***	(0.079)	-0.620***	(0.080)	-0.627***	(0.079)
Constant	-6.283***	(0.454)	-7.011***	(0.467)	-7.399***	(0.443)

Note: $Gasnat_{eq}$ is a dummy variable with a value of 1 if a household has heating or hot water equipment and 0 otherwise. *Flat* is a dummy variable with a value of 1 if a household is based in an apartment and 0 otherwise. *Rent* is a dummy variable that takes a value of 1 if the household pays rent for the home and 0 otherwise. In addition, significance at the ***1%, **5%, and *10% levels.

The results of our estimation procedure to estimate the demand system in Equation (2.9) are shown in Tables B1-2.3 of the Appendix. Furthermore, the uncompensated demand and budget elasticities computed using the estimators in Tables B1-2.3 are reported in Tables 2.4 and 2.5 for the overall sample. Table 2.4 shows the uncompensated price elasticities of demand for utility services and the rest of the goods categories throughout the period of the Great Recession in Spain. For electricity, the estimated uncompensated own price elasticities decreased (in absolute terms) after 2009. Our estimates show a relatively elastic demand for 2009 and 2011, but

[8]Tables C1-C6 show the results for the price and budget elasticities of demand without censoring correction to point out the relevance of the censorship problem and the misleading conclusions that we would obtain if we ignored it.

2014 demand appears inelastic. Using the overall sample, the uncompensated price elasticity of demand is -1.118 for 2009, -1.037 for 2011, and -0.967 for 2014. The elasticities of the price shown are slightly higher than in previous studies, e.g., those of Labandeira, Labeaga, & Rodríguez (2006) or Gálvez et al. (2016).

The price elasticities for natural gas are greater than one in all cases, so demand for natural gas can be considered elastic during the period analyzed. The same result is obtained by Gálvez et al. (2016). Our results show lower values for the price elasticity of the demand for natural gas (in absolute terms). By contrast, water demand can be considered inelastic, although its value increased (in absolute terms) in 2011 and 2014 compared to the value in 2009. Again, these results are consistent with the estimates of Gálvez et al. (2016).

Table 2.4: Uncompensated price elasticities: overall sample

	2009	2011	2014
Electricity	-1.118***	-1.037***	-0.967***
	(0.030)	(0.025)	(0.022)
Natural Gas	-1.251***	-1.041***	-1.128***
	(0.018)	(0.016)	(0.020)
Water	-0.635***	-0.751***	-0.758***
	(0.018)	(0.017)	(0.016)
Food & Non-alcoholic beverages	-0.740***	-0.541***	-0.693***
	(0.008)	(0.009)	(0.008)
Housing expenses	-1.070***	-1.044***	-1.095***
	(0.006)	(0.005)	(0.006)
Transport & Communications	-0.837***	-0.733***	-0.723***
	(0.015)	(0.015)	(0.014)
Other goods	-1.126***	-1.071***	-1.116***
	(0.003)	(0.003)	(0.003)

Note: The standard errors are within brackets. Significance at the ***1% level.

Table 2.5 presents the budget elasticities of the households for goods included in the demand system in 2009, 2011, and 2014. Analyzing these budget elasticities across different years provides insights into consumer behavior and spending responsiveness to income changes. For 2009, households showed an elasticity of 0.88 for electricity, indicating that a percentage change in income resulted in a significant change in electricity consumption. The other positive estimates range from 0.66 to 0.88 for electricity, 1.1 to 1.18 for natural gas, and 0.38 to 0.52 for water. These elasticities present higher values than those obtained by Gálvez et al. (2016). Thus, natural gas can be considered a more discretionary good. These results may explain the sensitivity of the uncompensated demand for natural gas. However, the stronger response to natural gas demand might be due to higher income rather than the direct price effect. Other more discretionary goods are clustered in Transport and Communications and Other Goods.

Table 2.5: Budget elasticities: overall sample

	2009	2011	2014
Electricity	0.880***	0.659***	0.710***
	(0.035)	(0.030)	(0.027)
Natural Gas	1.187***	1.175***	1.100***
	(0.023)	(0.024)	(0.025)
Water	0.519***	0.384***	0.438***
	(0.035)	(0.032)	(0.031)
Food & Non-alcoholic beverages	0.881***	0.550***	0.727***
	(0.019)	(0.017)	(0.019)
Housing expenses	0.964***	0.902***	0.948***
	(0.014)	(0.013)	(0.013)
Transport & Communications	1.216***	1.121***	1.243***
	(0.034)	(0.030)	(0.031)
Other goods	1.994***	1.385***	1.175***
	(0.018)	(0.018)	(0.020)

Note: The standard errors are within brackets. Significance at the ***1% level.

The results of the uncompensated cross-price elasticity for utility services are presented in Tables 2.6-2.8. For the sake of brevity, we only collect the elasticities for electricity, natural gas, and water. For the rest of the goods, cross-price elasticities are available upon request.

Table 2.6: Uncompensated cross-price elasticity. 2009.

	Electricity price	Natural gas price	Water price
Electricity	-1.118***	0.435***	0.049**
	(0.030)	(0.029)	(0.018)
Natural gas	0.019	-1.251***	0.031**
	(0.019)	(0.018)	(0.012)
Water	0.121***	0.149***	-0.635***
	(0.029)	(0.028)	(0.018)

Note: The standard errors are within brackets. Significance at the ***1% and *10% level.

Table 2.7: Uncompensated cross-price elasticity. 2011.

	Electricity price	Natural gas price	Water price
Electricity	-1.037***	0.265***	0.096***
	(0.025)	(0.020)	(0.015)
Natural gas	-0.082***	-1.041***	-0.011
	(0.020)	(0.016)	(0.012)
Water	0.230***	0.107***	-0.751***
	(0.027)	(0.021)	(0.017)

Note: The standard errors are within brackets. Significance at the ***1% level.

Table 2.8: Uncompensated cross-price elasticity. 2014.

	Electricity price	Natural gas price	Water price
Electricity	-0.967***	0.386***	0.107***
	(0.022)	(0.022)	(0.014)
Natural gas	-0.020	-1.128***	-0.005
	(0.021)	(0.020)	(0.013)
Water	0.213***	0.235***	-0.758***
	(0.026)	(0.025)	(0.016)

Note: The standard errors are within brackets. Significance at the ***1% level.

As shown in Tables 2.6 to 2.8, the positive value of the cross-price of natural gas on the uncompensated demand for electricity is particularly significant. Thus, we have evidence that electricity and natural gas can be seen as gross substitute goods.

2.4.2 Analysis of demand sensitivity based on vulnerability criteria

One of the purposes of this article is to compare the sensitivity of demand for utility services between groups using both criteria defined for allocating the social discount rate (SDR) on electricity and an objective indicator of energy poverty. In the first case, for each year, the sample is divided into vulnerable and non-vulnerable households regarding energy consumption. Then, we consider four different criteria when judging eligibility for the SDR in Spain. We define energy-vulnerable households as those that meet at least one of the following criteria: large families with three or more dependent children; households in which all working-age members are unemployed; households of retirees who receive the minimum pension; and households with a surface area of less than 60 square meters as a proxy variable for consumers with subscribed power demands lower than 3 kW.

In the second case, we employ an indicator of objective energy poverty in the form of the MIS-based energy poverty indicator to define the energy-vulnerable group. More specifically, a household is considered energy-vulnerable if the difference between annual income (minus housing costs) and energy expenditure is greater than the difference between the selected MIS indicator (minus average housing cost) and energy expenditure in the overall sample.

In order to assess the households' demand sensitivity to vulnerability criteria, we first carry out a Chow test with the aim of testing for significant differences in the population parameters of the QUAIDS model (2.9) across vulnerability groups using the above definitions for fuel poverty. The results are collected in Table 2.9.

Table 2.9: Social discount rate and MIS Indicator: Chow test results

	Social discount rate			MIS Indicator		
	2009	**2011**	**2014**	**2009**	**2011**	**2014**
Electricity	1.802***	1.299	3.962***	11.016***	12.351***	16.802***
	(0.004)	(0.123)	(0.000)	(0.000)	(0.000)	(0.000)
Natural Gas	5.365***	7.928***	7.386***	5.541***	6.346***	6.644***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Water	8.674***	3.703***	6.009***	15.453***	11.658***	15.531***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Food	7.406***	2.563***	3.519***	5.859***	3.664***	2.895***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Housing expenditures	17.220***	11.508***	11.090***	2.181***	8.572***	7.011***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)
Transport & communications	9.839***	8.437***	8.680***	1.107	2.403***	2.029***
	(0.000)	(0.000)	(0.000)	(0.312)	(0.000)	(0.001)
Other goods	3.366 ***	4.004***	4.739***	6.113***	7.486***	11.321***
	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)	(0.000)

Note: P-values are within brackets. Significance at the ***1% level.

As seen in Table 2.9, the null hypothesis that demand patterns' households are the same independently of their fuel poverty situation is rejected by more than 90% for the different categories of goods considered in the demand system. Only for electricity in 2011 and for transport & communications in 2009 are the p-values greater than the 10% significance level. Therefore, we have substantial statistical evidence that the demand system estimates are sensitive to the vulnerability status of households.

Taking into account the uncompensated elasticities by households' fuel-poverty status, Table 2.10 reports the uncompensated price elasticities based on the SDR criteria, and Table 2.11 collects the uncompensated own-price elasticities considering energy vulnerability using the MIS indicator. The results in Table 2.10 show that the elasticities of the energy-vulnerable group for electricity in 2009 and 2011 are lower than for the non-vulnerable group. In the case of natural gas, the elasticities for all three years analyzed are slightly higher for vulnerable households. This result indicates a greater sensitivity to changes in natural gas prices for vulnerable households. Water demand is inelastic, but its price sensitivity tends to increase (in absolute terms) during the Great Recession.

Moreover, elasticity levels are higher (in absolute terms) for the group of vulnerable households than for the group of non-vulnerable households. However, the magnitude of these differences is relatively small, so we do not find a clear relationship between household vulnerability and demand sensitivity for utility services. These results align with the results of Ramirez et al. (2021) or Díaz & Medlock (2021) in Mexico. However, other studies, such as Tovar Reaños & Wölfing (2018) in Germany, or Hahn & Metcalfe (2021) in the US, find that vulnerable households present a higher price reaction to energy price changes than non-vulnerable households.

As reported in Table 2.11, the uncompensated own-price elasticities for electricity are slightly higher (in absolute terms) in 2009 and 2011 for the group of non-vulnerable households, while for natural gas, the highest elasticities (in absolute terms) are found in the group of energy-vulnerable households. Similarly, the estimated elasticities in the case of water are higher for vulnerable households. These results show

Table 2.10: Uncompensated price elasticities. Vulnerable and non-vulnerable households based on social discount rate criteria

	Vulnerable households			Non-Vulnerable households		
	2009	**2011**	**2014**	**2009**	**2011**	**2014**
Electricity	-1.098***	-1.031***	-0.970***	-1.132***	-1.042***	-0.965***
	(0.025)	(0.022)	(0.020)	(0.033)	(0.027)	(0.025)
Natural Gas	-1.273***	-1.047***	-1.136***	-1.240***	-1.038***	-1.123***
	(0.020)	(0.016)	(0.021)	(0.018)	(0.015)	(0.020)
Water	-0.699***	-0.788***	-0.792***	-0.585***	-0.722***	-0.725***
	(0.015)	(0.014)	(0.014)	(0.021)	(0.019)	(0.018)

Note: Standard errors are within brackets. Significance at the ***1% level. For the sake of brevity, this figure shows only the elasticities of electricity, natural gas, and water. For the rest of the goods, these elasticities are available upon request.

that households considered to be suffering from energy poverty, according to the MIS or a similar indicator, are less sensitive in general to changes in the price of electricity over time compared to all samples.

A comparison of price elasticities from Table 2.10 and Table 2.11 shows that the estimated values for elasticities are almost identical under the two alternative definitions of energy vulnerability. This finding could be surprising given that the SDR scheme from 2009 to 2016 did not include any income-related criteria, while the MIS-based indicator of energy poverty depends on household income and expenditure.

Table 2.11: Uncompensated own price elasticities. Vulnerable and non-vulnerable households based on MIS indicator

	Vulnerable households			Non-Vulnerable households		
	2009	**2011**	**2014**	**2009**	**2011**	**2014**
Electricity	-1.098***	-1.028***	-0.972***	-1.127***	-1.040***	-0.965***
	(0.025)	(0.021)	(0.019)	(0.032)	(0.027)	(0.024)
Natural Gas	-1.283***	-1.049***	-1.141***	-1.240***	-1.039***	-1.123***
	(0.021)	(0.018)	(0.022)	(0.018)	(0.015)	0.019)
Water	-0.711***	-0.809***	-0.808***	-0.593***	-0.729***	-0.724***
	(0.014)	(0.012)	(0.013)	(0.021)	(0.018)	(0.019)

Note: Standard errors are within brackets. Significance at the ***1% level. For the sake of brevity, this figure shows only the elasticities of electricity, natural gas, and water. For the rest of the goods, these elasticities are available upon request.

Finally, we propose a Chow test that enables us to test whether the preference patterns of Spanish households have changed during the Spanish Great Recession. Furthermore, we have analyzed them for different periods (i.e., 2009-2011, 2009-2014, and 2011-2014). The resulting F statistics are collected in Table 2.12.

Table 2.12: Chow test. Full sample

Variables	2009-2011	2009-2014	2011-2014
Electricity	10.699***	12.450***	5.054***
Natural Gas	12.013***	19.520***	11.687***
Water	7.518***	27.855***	12.968***
Food	47.443***	33.655***	14.079***
Housing expenditures	31.222***	30.261***	5.985***
Transport & communications	20.702***	17.953***	5.026***
Other goods	50.962***	13.265***	26.738***

Note: Significance at the ***1% level.

The figures in Table 2.12 show that the results of the Chow test lead to the rejection of the null hypothesis that each population parameter in the QUAIDS model is the same over two years in all periods considered and for all goods in the demand system at the 1% significance level. Thus, we have strong evidence that the household demand for utility services in Spain shows a structural change over the periods considered in this study.

2.5 Conclusions and policy implications

In recent years, the topics of energy poverty and vulnerability have risen on the policy and research agendas of developed countries. Increases in energy prices, the inability of households to maintain adequate warmth, and problems with paying energy bills on time underscore the importance of this research area. In particular, various initiatives and policies have been implemented in countries of the European Union to protect vulnerable consumers and ensure access to energy at affordable prices.

Energy policies that seek to guarantee access to energy at affordable prices for households, such as discounts or subsidies in utility services, impact the allocation of household expenditure in terms of other goods and utility services and affect household welfare. Estimating the price and budget elasticities of demand is relevant in determining how changes in prices and income can affect households, particularly those in situations of energy vulnerability.

To date, empirical studies and analyses related to the Spanish social discount rate on electricity and its assessment have not considered the sensitivity of electricity demand to price and income or cross-elasticity with other utility services, such as natural gas. Our study enables us to learn how sensitive the electricity demand is for different household groups based on the SDR criteria and indicators related to energy poverty, based on the MIS methodology.

This paper estimates a two-stage QUAIDS to analyze the demand for electricity in Spanish households using the Household Budget Survey for three different years: 2009, 2011, and 2014. The estimated model provides the price and budget elasticities of demand for utility services. We also address problems related to household microdata, such as endogeneity and censorship. Our results show that the price elasticities of the demand for utility services change over the period analyzed and differ between households considered energy-vulnerable and those that are not.

Concerning the price elasticities of demand, we find that electricity demand became inelastic at the end of the Great Recession in Spain. We observe that the response to the electricity demand of the Spanish households decreases in the last year of the analyzed period. This result could be interpreted as being due to a smaller income effect of uncompensated demand. However, we find that the budget for electricity increased in 2014. For the case of natural gas, both the own-price uncompensated and budget elasticities are greater than one in all specifications, so it may be considered a more discretionary good during the Great Recession.

We demonstrate that uncompensated price elasticities are equivalent under two definitions of vulnerable households. Our findings suggest that the demands of vulnerable households are more price-sensitive for natural gas and water. Moreover, we do not find the same result for electricity demand. Comparing the elasticity magnitudes for vulnerable and non-vulnerable households, we can point out that the differences are minimal, despite differences in consumption preferences, according to the Chow test. Therefore, discounts on the price of electricity for vulnerable households, such as the social discount rate for electricity, would not be justified in terms of economic efficiency, but rather for reasons of equity. If the social bonus pursued economic efficiency, the households most sensitive to the price of electricity would be the ones that should have a lower price.

The empirical framework and results of our study could be used as a starting point for future research, for example, to assess energy policies such as the SDR or the heating discount rate through welfare analysis in line with Hahn & Metcalfe (2021), or Tovar Reaños & Wölfing (2018). We could assess the effectiveness of discount rate policies in comparison with targeted compensation schemes. In addition, information on disaggregated price and budget elasticity estimates could be valuable for policymakers in proposing alternative energy policies. In this sense, the evidence of cross-price elasticities between demand for utility services suggests the possibility of a single social discount rate for electricity, natural gas, and water to alleviate energy poverty in Spanish households.

Appendix 2A. Energy poverty policies in Spain

Directive 2009/72/EC of the European Parliament and the Council (2009) concerning common rules for the internal market in electricity defines public service obligations and customer protection in terms of electricity markets. Consequently, it establishes the application of consumer protection measures by Member States, particularly for those in a situation of energy poverty who are considered vulnerable consumers. In Spain, the "social discount rate" for electricity was developed by the Royal Decree-Law (RDL) 6/2009, within the framework of Directive 2009/72/EC. This social discount rate is a government-regulated mechanism that seeks to protect vulnerable low-income consumers through a subsidy or discount on electricity bills.

Table 2.13 shows the regulatory reforms introduced by the social discount rate (SDR) with the main objective of protecting vulnerable consumers. Before 2014, the rate paid by beneficiary consumers was set at 2009 levels, which meant that the amount of savings increased over time. In 2014, it was determined that a discount of 25% on the voluntary price for small consumers (PVPC) should be set (Herrero et al. 2019).

Table 2.13: Regulatory reforms in the social discount rate on electricity in Spain

Royal Decree-Law	Main reforms
RDL 6/2009	This rate is implemented to cover the difference between the voluntary price for small consumers and a base value corresponding to the effective tariff at the time when the tariff of last resort was set. One of the following criteria must be met by the household:1) a large family; 2) a family where all members are unemployed; 3) consumers with subscribed power demand of 3 kW or less; or 4) a pensioner older than 60 with a minimum level pension.
RDL 216/2014	This establishes a fixed discount of 25% on the consumers' regulated tariff.

According to data from the Spanish National Authority for Markets and Competition (CNMC), in 2009, approximately 3 million households signed up for the social discount rate. This figure fell to 1.14 million in 2021, i.e., a 60% drop compared to 2009.

The mechanism for funding the social discount rate for electricity in Spain has also changed over time. The main changes concern which economic agents in the electricity system must provide funding to guarantee the financial sustainability of the SDR and ensure proportionality among those who fund it. The Royal Decree-Law 6/2009 established that a portion of the electricity generation companies in the Spanish electricity system would provide funding. However, the courts considered this funding method discriminatory because the burden of funding the SDR fell only on some agents in the electricity market and excluded others.

In 2013, RDL 9/2013 established that vertically integrated companies in the fields of generation, distribution, and commercialization of electricity must assume the cost of the social discount rate. That cost is established according to the number of supplies connected in the distribution networks and the number of customers supplied by commercial activities.

Appendix 2B. Estimated coefficients of QUAIDS

Table B1: Estimated coefficient QUAIDS model. 2009

	Electricity		Natural gas		Water		Food		Housing		Transport		Other	
Variables	Coefficient	Std. err.	Coefficient	Std. err.	Coefficient	Std. err.	Coefficient	Std. err.	Coefficient	Std. err.	Coefficient	Std. err.	Coefficient	Std. err.
Log of price electricity	-0.003***	(0.066)	0.001**	(0.121)	0.000**	(0.016)	-0.001	(0.265)	0.059***	(0.388)	0.001	(0.353)	-0.058***	(0.385)
Log of price natural gas	0.009***	(0.065)	0.001***	(0.121)	0.000***	(0.016)	0.013***	(0.261)	0.029***	(0.384)	-0.002	(0.355)	-0.035***	(0.378)
Log of price water	0.001***	(0.042)	0.002***	(0.076)	0.002***	(0.010)	-0.004***	(0.002)	0.014***	(0.246)	-0.001	(0.222)	-0.014***	(0.244)
Log of price W4	-0.001***	(0.032)	-0.001	(0.065)	-0.001***	(0.008)	0.042***	(0.129)	-0.048***	(0.226)	-0.024***	(0.293)	0.033***	(0.181)
Log of price W5	-0.006***	(0.043)	0.018***	(0.088)	-0.002***	(0.011)	-0.023***	(0.177)	-0.014***	(0.329)	-0.024***	(0.293)	0.051***	(0.252)
Log of price W6	-0.002***	(0.050)	-0.007***	(0.109)	-0.000***	(0.012)	-0.038***	(0.204)	-0.057***	(0.318)	0.049***	(0.409)	0.055***	(0.306)
Log of price W7	0.001***	(0.018)	0.001	(0.049)	0.000***	(0.004)	0.011***	(0.059)	0.017***	(0.206)	0.002	(0.246)	-0.033***	(0.085)
Log of income	0.006***	(0.181)	-0.023***	(0.375)	0.001**	(0.045)	0.005	(0.738)	-0.100***	(0.928)	0.122***	(0.853)	-0.011	(1.072)
Log of income^2	0.001***	(0.021)	-0.005***	(0.049)	0.001***	(0.006)	0.003***	(0.089)	-0.012***	(0.094)	0.013***	(0.104)	-0.001	(0.130)
Log of total expenditure	-0.014***	(0.090)	0.001	(0.168)	-0.002***	(0.022)	-0.044***	(0.365)	-0.083***	(0.534)	0.076***	(0.472)	0.067***	(0.522)
Household member < 4 years	0.049	(0.078)	-0.001	(0.139)	0.000*	(0.019)	-0.009***	(0.308)	0.013***	(0.445)	0.002	(0.413)	-0.006	(0.452)
Household member $5 - 15$ years	-0.000	(0.025)	0.005***	(0.044)	0.000***	(0.006)	0.018***	(0.098)	-0.018***	(0.140)	-0.003***	(0.131)	-0.001	(0.143)
Household member $16 - 24$ years	-0.002**	(0.073)	0.006***	(0.131)	-0.000	(0.018)	0.008***	(0.289)	0.003	(0.418)	-0.007*	(0.388)	-0.009**	(0.425)
Household member $25 - 34$ years	0.000**	(0.039)	-0.001**	(0.070)	0.000***	(0.009)	0.003*	(0.155)	-0.019***	(0.225)	0.005**	(0.208)	0.011***	(0.228)
Household member $35 - 64$ years	0.000***	(0.030)	-0.004***	(0.054)	0.000***	(0.007)	-0.003**	(0.119)	-0.022***	(0.174)	0.021***	(0.160)	0.006***	(0.175)
Household member $65 - 84$ years	0.001*	(0.077)	-0.004***	(0.137)	0.000	(0.018)	0.003	(0.302)	0.008**	(0.437)	-0.005	(0.405)	-0.003	(0.444)
Household member > 85 years	-0.002***	(0.033)	-0.000	(0.059)	-0.001***	(0.008)	-0.011***	(0.131)	-0.004**	(0.191)	0.002	(0.175)	0.015***	(0.192)
Sex male household head	-0.000	(0.037)	-0.002***	(0.065)	-0.000***	(0.009)	0.011***	(0.144)	-0.031***	(0.212)	0.012***	(0.192)	0.011***	(0.211)
Married	0.000	(0.018)	-0.000	(0.033)	0.000	(0.004)	-0.001	(0.072)	0.000	(0.106)	-0.000	(0.097)	0.001	(0.106)
Secondary education. Lower	-0.001	(0.040)	0.004***	(0.071)	0.000	(0.010)	-0.014***	(0.158)	-0.016***	(0.234)	0.011***	(0.211)	0.015***	(0.232)
Secondary education. Upper	-0.002***	(0.052)	0.011***	(0.092)	-0.000	(0.012)	-0.032***	(0.205)	-0.014***	(0.300)	0.012***	(0.273)	0.025***	(0.300)
Higher education	-0.004***	(0.052)	0.010***	(0.093)	-0.000	(0.012)	-0.038***	(0.206)	-0.008***	(0.301)	0.010***	(0.274)	0.031***	(0.301)
Occupation	-0.001**	(0.045)	0.002***	(0.079)	-0.000***	(0.011)	-0.006***	(0.0176)	0.023***	(0.255)	-0.011***	(0.235)	-0.006**	(0.258)
Rent	0.004***	(0.050)	0.005***	(0.089)	0.003***	(0.012)	0.018***	(0.198)	-0.049***	(0.291)	0.017***	(0.266)	0.003	(0.291)
Size	0.000***	(0.000)	0.000***	(0.000)	0.000	(0.000)	-0.000***	(0.001)	0.000***	(0.002)	-0.000***	(0.002)	-0.000***	(0.002)
Rural	0.003***	(0.041)	0.002***	(0.072)	-0.001***	(0.010)	0.028***	(0.160)	-0.040***	(0.235)	0.019***	(0.213)	-0.011***	(0.235)
Northeast	-0.002***	(0.048)	0.004***	(0.085)	-0.000***	(0.001)	-0.012***	(0.189)	0.037***	(0.275)	-0.017***	(0.251)	-0.011***	(0.276)
Madrid	-0.000	(0.067)	-0.009***	(0.119)	0.002***	(0.016)	-0.021***	(0.264)	0.048***	(0.383)	-0.010***	(0.353)	-0.010**	(0.388)
Central	0.004***	(0.053)	-0.002*	(0.094)	0.001***	(0.013)	-0.007***	(0.209)	0.004	(0.307)	0.006**	(0.279)	-0.007**	(0.307)
East	0.002***	(0.051)	-0.007***	(0.090)	0.002***	(0.012)	-0.012***	(0.199)	0.020***	(0.290)	-0.003	(0.265)	-0.002	(0.292)
South	0.005***	(0.055)	-0.035***	(0.097)	0.002***	(0.013)	0.002	(0.215)	-0.003	(0.315)	0.012***	(0.287)	0.015***	(0.316)
Constant	0.058***	(0.444)	0.002	(0.847)	0.014***	(0.108)	0.206***	(0.018)	0.678***	(2.495)	0.407***	(2.223)	-0.365***	(2.586)

Note: Group W4: food and non-alcoholic beverages; Group W5: Housing; Group W6: Transport and communications; Group W7: Other goods. The standard errors (x100) are within brackets. Significance at the ***1%, **5%, and *10% level.

Table 2.2: Estimated coefficient QUAIDS model. 2011

	Electricity		Natural gas		Water		Food		Housing		Transport		Other	
Variables	Coefficient	Std. err.	Coefficient	Std. err.	Coefficient	Std. err.	Coefficient	Std. err.	Coefficient	Std. err.	Coefficient	Std. err.	Coefficient	Std. err.
Log of price electricity	-0.002**	(0.076)	-0.004***	(0.129)	0.001***	(0.016)	-0.001***	(0.232)	0.051***	(0.366)	-0.013***	(0.330)	-0.023***	(0.349)
Log of price natural gas	0.007***	(0.061)	-0.002*	(0.102)	0.000***	(0.012)	-0.004**	(0.185)	0.018***	(0.294)	-0.003	(0.262)	-0.017***	(0.282)
Log of price water	0.003***	(0.048)	-0.001	(0.081)	0.001***	(0.010)	-0.006***	(0.146)	0.023***	(0.230)	-0.012***	(0.207)	-0.008***	(0.219)
Log of price W4	0.001*	(0.046)	-0.002**	(0.079)	-0.000	(0.010)	0.076***	(0.180)	-0.018***	(0.217)	-0.021***	(0.203)	-0.036***	(0.230)
Log of price W5	-0.004***	(0.040)	0.012***	(0.067)	-0.002***	(0.008)	-0.016***	(0.135)	-0.024***	(0.198)	0.001	(0.171)	0.033***	(0.213)
Log of price W6	-0.003***	(0.043)	-0.004***	(0.073)	-0.000***	(0.009)	-0.021***	(0.142)	-0.039***	(0.209)	0.038***	(0.182)	0.030***	(0.234)
Log of price W7	-0.002***	(0.045)	0.001	(0.078)	-0.001***	(0.009)	-0.018***	(0.155)	-0.010***	(0.234)	0.011***	(0.173)	0.020***	(0.300)
Log of income	-0.004**	(0.153)	-0.014***	(0.298)	-0.001*	(0.034)	-0.044***	(0.487)	-0.076***	(0.643)	0.043***	(0.638)	0.095***	(0.778)
Log of income^2	0.001***	(0.021)	-0.004***	(0.045)	0.000***	(0.005)	0.005***	(0.067)	-0.007***	(0.078)	0.004***	(0.086)	-0.000	(0.106)
Log of total expenditure	-0.012***	(0.102)	0.008***	(0.179)	-0.002***	(0.021)	0.004	(0.324)	-0.069***	(0.512)	0.064***	(0.446)	0.008	(0.508)
Household member < 4 years	0.002***	(0.043)	-0.004***	(0.070)	0.000***	(0.009)	0.006***	(0.126)	-0.002	(0.198)	-0.002	(0.181)	0.000	(0.182)
Household member $5-15$ years	0.002***	(0.029)	-0.003***	(0.048)	0.001***	(0.006)	0.009***	(0.086)	-0.014***	(0.135)	-0.005***	(0.124)	0.010***	(0.124)
Household member $16-24$ years	0.002***	(0.034)	-0.000	(0.056)	0.001***	(0.007)	0.011***	(0.100)	-0.026***	(0.156)	0.011***	(0.144)	0.002	(0.142)
Household member $25-34$ years	0.001**	(0.037)	-0.001**	(0.060)	0.001***	(0.007)	0.012***	(0.108)	-0.036***	(0.170)	0.021***	(0.157)	0.002	(0.156)
Household member $35-64$ years	0.000	(0.035)	0.001	(0.057)	0.001***	(0.007)	0.024***	(0.103)	-0.035***	(0.162)	0.010***	(0.148)	-0.001	(0.149)
Household member $65-84$ years	-0.000	(0.041)	0.004***	(0.067)	0.000***	(0.008)	0.032***	(0.120)	-0.016***	(0.190)	-0.007***	(0.174)	-0.013***	(0.175)
Household member > 85 years	0.000	(0.076)	0.004***	(0.122)	0.000*	(0.015)	0.024***	(0.222)	0.018***	(0.350)	-0.020***	(0.318)	-0.026***	(0.327)
Sex male household head	-0.001**	(0.045)	-0.004***	(0.074)	-0.000	(0.009)	0.002	(0.133)	-0.014***	(0.210)	0.009***	(0.192)	0.008***	(0.192)
Married	0.001*	(0.055)	0.000	(0.089)	-0.000	(0.011)	0.012***	(0.161)	-0.026***	(0.253)	0.009***	(0.232)	0.003	(0.230)
Secondary education. Lower	0.000	(0.054)	0.010***	(0.087)	0.000***	(0.011)	-0.007***	(0.156)	-0.012***	(0.248)	0.006***	(0.226)	0.002	(0.231)
Secondary education. Upper	-0.002***	(0.067)	0.014***	(0.108)	0.000	(0.013)	-0.012***	(0.194)	-0.012***	(0.308)	0.007**	(0.281)	0.005*	(0.285)
Higher education	-0.004***	(0.070)	0.013***	(0.113)	-0.000	(0.014)	-0.018***	(0.204)	-0.007**	(0.324)	0.005*	(0.295)	0.011***	(0.300)
Occupation	-0.001***	(0.049)	-0.002**	(0.080)	-0.000***	(0.010)	0.028	(0.144)	-0.033***	(0.227)	0.017***	(0.208)	0.019***	(0.210)
Rent	0.004***	(0.060)	0.002**	(0.097)	0.002***	(0.012)	0.007***	(0.175)	-0.044***	(0.276)	0.008***	(0.253)	0.021***	(0.251)
Size	0.000	(0.000)	0.000***	(0.000)	0.000	(0.000)	-0.000***	(0.001)	0.001***	(0.002)	-0.000***	(0.002)	-0.000***	(0.002)
Rural	0.004***	(0.051)	-0.000	(0.082)	-0.001***	(0.010)	0.015***	(0.151)	-0.030***	(0.235)	0.019***	(0.215)	-0.007***	(0.216)
Northeast	-0.002***	(0.081)	0.004***	(0.095)	-0.000***	(0.012)	-0.001	(0.172)	0.034***	(0.269)	-0.021***	(0.247)	-0.013***	(0.248)
Madrid	-0.000	(0.081)	-0.011***	(0.133)	0.002***	(0.016)	-0.013***	(0.239)	0.037***	(0.378)	-0.001	(0.346)	-0.014***	(0.348)
Central	0.005***	(0.063)	-0.001	(0.102)	0.000***	(0.013)	-0.005**	(0.186)	-0.006**	(0.290)	0.002	(0.265)	0.004	(0.268)
East	0.004***	(0.061)	-0.007***	(0.100)	0.002***	(0.012)	-0.009***	(0.180)	0.013***	(0.284)	0.002	(0.260)	-0.005**	(0.263)
South	0.008***	(0.066)	-0.037***	(0.106)	.004***	(0.013)	0.001	(0.192)	-0.015***	(0.303)	0.015***	(0.277)	0.024***	(0.280)
Constant	0.031***	(0.424)	0.020***	(0.745)	0.010***	(0.088)	-0.189***	(0.013)	0.680***	(2.007)	0.091***	(1.830)	0.357***	(2.058)

Note: Group W4: food and non-alcoholic beverages; Group W5: Housing; Group W6: Transport and communications; Group W7: Other goods. The standard errors (x100) are within brackets. Significance at the ***1%, **5%, and *10% level.

Table 2.3: Estimated coefficient QUAIDS model. 2014

	Electricity		Natural gas		Water		Food		Housing		Transport		Other	
Variables	Coefficient	Std. err.	Coefficient	Std. err.	Coefficient	Std. err.	Coefficient	Std. err.	Coefficient	Std. err.	Coefficient	Std. err.	Coefficient	Std. err.
Log of price electricity	-0.000	(0.066)	-0.001	(0.138)	0.001***	(0.019)	-0.004*	(0.250)	0.064***	(0.361)	-0.006*	(0.320)	-0.054***	(0.352)
Log of price natural gas	0.011***	(0.066)	-0.007***	(0.141)	0.001***	(0.019)	0.011***	(0.251)	0.035***	(0.368)	-0.003	(0.333)	-0.047***	(0.355)
Log of price water	0.003***	(0.043)	-0.000	(0.089)	0.002***	(0.013)	-0.000	(0.163)	0.018***	(0.233)	-0.007***	(0.207)	-0.015***	(0.229)
Log of price W4	-0.003***	(0.034)	-0.002***	(0.076)	-0.001***	(0.010)	0.050***	(0.157)	-0.030***	(0.241)	-0.036***	(0.237)	0.023***	(0.207)
Log of price W5	-0.008***	(0.054)	0.024***	(0.124)	-0.002***	(0.017)	-0.015***	(0.208)	-0.011***	(0.398)	-0.029***	(0.323)	0.043***	(0.326)
Log of price W6	-0.004***	(0.050)	-0.009***	(0.123)	-0.001***	(0.016)	-0.043***	(0.214)	-0.074***	(0.336)	0.064***	(0.404)	0.068***	(0.253)
Log of price W7	0.002***	(0.031)	-0.003***	(0.084)	0.000	(0.010)	0.002	(0.147)	-0.002	(0.310)	0.018***	(0.194)	-0.017***	(0.279)
Log of income	0.003*	(0.194)	-0.026***	(0.447)	-0.000	(0.060)	-0.033***	(0.781)	-0.144***	(0.896)	0.129***	(0.880)	0.071***	(1.091)
Log of income^2	0.002***	(0.021)	-0.004***	(0.053)	0.000***	(0.007)	0.002*	(0.087)	-0.015***	(0.083)	0.012***	(0.103)	0.004***	(0.116)
Log of total expenditure	-0.015***	(0.091)	0.009***	(0.196)	-0.002***	(0.027)	-0.002	(0.363)	-0.084***	(0.514)	0.052***	(0.437)	0.042***	(0.524)
Household member < 4 years	0.002***	(0.039)	-0.002***	(0.079)	0.000**	(0.011)	0.004***	(0.142)	-0.003*	(0.202)	0.002	(0.184)	-0.002	(0.195)
Household member $5-15$ years	0.002***	(0.024)	-0.003***	(0.049)	0.001***	(0.007)	0.008***	(0.088)	-0.008***	(0.125)	-0.004***	(0.115)	0.003***	(0.121)
Household member $16-24$ years	0.002***	(0.029)	0.001*	(0.059)	0.001***	(0.008)	0.014***	(0.106)	-0.018***	(0.149)	0.006***	(0.138)	-0.005***	(0.144)
Household member $25-34$ years	0.001***	(0.033)	0.001**	(0.068)	0.001***	(0.010)	0.015***	(0.122)	-0.034***	(0.173)	0.017***	(0.157)	-0.001	(0.167)
Household member $35-64$ years	0.001***	(0.032)	0.002***	(0.064)	0.001***	(0.009)	0.027***	(0.116)	-0.034***	(0.167)	0.005***	(0.149)	-0.002	(0.162)
Household member $65-84$ years	-0.001***	(0.038)	0.005***	(0.077)	0.000***	(0.011)	0.032***	(0.140)	-0.019***	(0.201)	-0.008***	(0.180)	-0.009***	(0.195)
Household member > 85 years	0.000	(0.063)	0.002**	(0.126)	0.000	(0.018)	0.020***	(0.230)	0.012***	(0.334)	-0.019***	(0.293)	-0.016***	(0.321)
Sex male household head	-0.001*	(0.037)	-0.003***	(0.075)	-0.000	(0.011)	-0.001	(0.136)	-0.008***	(0.194)	0.008***	(0.175)	0.005***	(0.186)
Married	0.001**	(0.047)	-0.001	(0.095)	-0.000	(0.014)	0.011***	(0.171)	-0.026***	(0.246)	0.015***	(0.221)	0.000	(0.236)
Secondary education. Lower	-0.001*	(0.048)	0.009***	(0.096)	-0.000	(0.014)	-0.009***	(0.175)	-0.010***	(0.256)	0.010***	(0.224)	0.001	(0.245)
Secondary education. Upper	-0.001**	(0.059)	0.015***	(0.119)	-0.000	(0.017)	-0.020***	(0.215)	-0.012***	(0.313)	0.010***	(0.276)	0.008***	(0.302)
Higher education	-0.003***	(0.060)	0.011***	(0.121)	-0.000	(0.018)	-0.025***	(0.220)	-0.004	(0.319)	0.006**	(0.281)	0.016***	(0.308)
Occupation	-0.002***	(0.043)	-0.003***	(0.087)	-0.001***	(0.013)	-0.005***	(0.157)	-0.030***	(0.226)	0.019***	(0.202)	0.022***	(0.218)
Rent	0.004***	(0.050)	0.007***	(0.100)	0.002***	(0.015)	0.016***	(0.181)	-0.038***	(0.262)	0.006***	(0.235)	0.003	(0.250)
Size	-0.000***	(0.000)	0.000***	(0.000)	-0.000	(0.000)	-0.000***	(0.001)	0.000***	(0.002)	-0.000***	(0.002)	-0.000***	(0.002)
Rural	0.002***	(0.041)	-0.005***	(0.082)	-0.001***	(0.012)	0.024***	(0.150)	-0.031***	(0.216)	0.019***	(0.192)	-0.007***	(0.207)
Northeast	-0.002***	(0.050)	0.003***	(0.101)	-0.001***	(0.015)	-0.002	(0.183)	0.028***	(0.262)	-0.025***	(0.236)	-0.002	(0.252)
Madrid	-0.002***	(0.068)	-0.006***	(0.138)	0.002***	(0.020)	-0.013***	(0.250)	0.027***	(0.355)	-0.003	(0.323)	-0.003	(0.344)
Central	0.004***	(0.053)	0.013***	(0.107)	0.001***	(0.016)	-0.001	(0.194)	-0.015***	(0.278)	-0.003	(0.249)	0.001	(0.268)
East	0.002***	(0.051)	-0.005***	(0.103)	0.004***	(0.015)	-0.001	(0.187)	0.003	(0.268)	-0.002	(0.241)	0.000	(0.259)
South	0.004***	(0.055)	-0.033***	(0.112)	0.005***	(0.016)	0.007***	(0.203)	-0.014***	(0.291)	0.011***	(0.261)	0.020***	(0.281)
Constant	0.078***	(0.502)	-0.033***	(1.096)	0.016***	(0.151)	-0.007	(1.969)	0.666***	(0.025)	0.392***	(2.284)	-0.112***	(2.789)

Note: Group W2: food and non-alcoholic beverages; Group W3: Housing; Group W4: Transport and communications; Group W5: Other goods. The standard errors (x100) are within brackets. Significance at the ***1%, **5%, and *10% level.

Appendix 2C. Non-censored corrected elasticities

For brevity, in Tables C2-C3 and C5-C6, we only report electricity, natural gas, and water elasticities. The elasticities for other goods are available upon request.

Table C1: Non-censored corrected uncompensated price elasticities overall sample

	2009	2011	2014
Electricity	-0.925***	-0.848***	-0.613***
	(0.038)	(0.035)	(0.027)
Natural gas	-1.802***	-1.525***	-1.627***
	(0.043)	(0.029)	(0.037)
Water	-0.622***	-0.798***	-0.788***
	(0.028)	(0.025)	(0.022)
Food & Non-alcoholic beverages	-0.684***	-0.505***	-0.651***
	(0.012)	(0.013)	(0.011)
Housing expenses	-0.993***	-0.947***	-1.016***
	((0.011)	(0.009)	(0.010)
Transport & Communications	-0.905***	-0.819***	-0.745***
	(0.024)	(0.023)	(0.021)
Other goods	-1.121***	-1.065***	-1.106***
	(0.005)	(0.004)	(0.005)

Note: Standard errors are within brackets. Significance at the ***1% level.

Table C2: Non-censored corrected uncompensated price elasticities. Vulnerability groups based on energy social rates criteria

	Vulnerable households			Non-Vulnerable households		
	2009	**2011**	**2014**	**2009**	**2011**	**2014**
Electricity	-0.934***	-0.866***	-0.655***	-0.921***	-0.838***	-0.583***
	(0.033)	(0.031)	(0.024)	(0.040)	(0.037)	(0.029)
Natural gas	-1.684***	-1.459***	-1.548***	-1.863***	-1.566***	-1.683***
	(0.037)	(0.026)	(0.033)	(0.046)	(0.032)	(0.041))
Water	-0.682***	-0.825***	-0.816***	-0.590***	-0.781***	-0.767***
	(0.024)	(0.022)	(0.019)	(0.030)	(0.027)	(0.024)

Note: Standard errors are within brackets. Significance at the ***1% level.

Table C3: Non-censored corrected uncompensated price elasticities. Vulnerability groups based on MIS Indicator

	Vulnerable households			Non-Vulnerable households		
	2009	**2011**	**2014**	**2009**	**2011**	**2014**
Electricity	-0.937***	-0.878***	-0.676***	-0.922***	-0.843***	-0.589***
	(0.032)	(0.028)	(0.022)	(0.040)	(0.036)	(0.029)
Natural gas	-1.732***	-1.471***	-1.574***	-1.819***	-1.533***	-1.646***
	(0.041)	(0.028)	(0.035)	(0.043)	(0.030)	(0.038)
Water	-0.709***	-0.846***	-0.833***	-0.596***	-0.789***	-0.769***
	(0.021)	(0.019)	(0.017)	(0.030)	(0.026)	(0.024)

Note: Standard errors are within brackets. Significance at the ***1% level.

Table C4: Non-censored corrected budget elasticities overall sample

	2009	2011	2014
Electricity	0.939***	0.653***	0.635***
	(0.049)	(0.041)	(0.032)
Natural gas	1.366***	0.773***	1.099***
	(0.073)	(0.063)	(0.058)
Water	0.653***	0.488***	0.447***
	(0.052)	(0.049)	(0.042)
Food & Non-alcoholic beverages	0.967***	0.614***	0.754***
	(0.031)	(0.027)	(0.027)
Housing expenses	0.984***	0.871***	0.931***
	(0.022)	(0.020)	(0.018)
Transport & Communications	1.211***	1.173***	1.336***
	(0.058)	(0.049)	(0.046)
Other goods	0.930***	1.358***	1.128***
	(0.028)	(0.026)	(0.027)

Note: Standard errors are within brackets. Significance at the ***1% level.

Table C5: Non-censored corrected budget elasticities overall sample. Vulnerability groups based on energy social rates criteria

	Vulnerable households			Non-Vulnerable households		
	2009	**2011**	**2014**	**2009**	**2011**	**2014**
Electricity	0.935***	0.692***	0.661***	0.941***	0.630***	0.617***
	(0.043)	(0.037)	(0.029)	(0.052)	(0.044)	(0.035)
Natural gas	1.305***	0.806***	1.079***	1.399***	0.752***	1.114***
	(0.062)	(0.055)	(0.051)	(0.080)	(0.068)	(0.064)
Water	0.643***	0.551***	0.504***	0.661***	0.449***	0.406***
	(0.044)	(0.042)	(0.037)	(0.057)	(0.053)	(0.047)

Note: Standard errors are within brackets. Significance at the ***1% level.

Table C6: Non-censored corrected budget elasticities overall sample. Vulnerability groups based on MIS indicator

	Vulnerable households			Non-Vulnerable households		
	2009	**2011**	**2014**	**2009**	**2011**	**2014**
Electricity	0.944***	0.723***	0.687***	0.937***	0.641***	0.616***
	(0.041)	(0.032)	(0.026)	(0.051)	(0.043)	(0.035)
Natural gas	1.331***	0.801***	1.086***	1.375***	0.768***	1.104***
	(0.068)	(0.054)	(0.053)	(0.074)	(0.065)	(0.060)
Water	0.708***	0.605***	0.558***	0.636***	0.467***	0.401***
	(0.039)	(0.034)	(0.031)	(0.056)	(0.051)	(0.047)

Note: Standard errors are within brackets. Significance at the ***1% level.

Bibliography

Addey, K. A., S. Shaik, and K. Sakouvogui (2019). Comparative sectoral price elasticities of U.S. energy demand. *Cogent Economics & Finance* 7 (1), 1682743.

Alvarez, G. G., and R. S. J. Tol (2021). The impact of the Bono Social de Electricidad on energy poverty in Spain. *Energy Economics* 103, 105554.

Attfield, C. L. F. (1985). Homogeneity and endogeneity in systems of demand equations. *Journal of Econometrics* 27 (2), 197–209. ISSN: 0304-4076.

Bagnoli, L., and S. Bertoméu-Sánchez (2022). How effective has the electricity social rate been in reducing energy poverty in Spain? *Energy Economics* 106, 105792.

Banks, J., R. Blundell, and A. Lewbel (1997). Quadratic Engel Curves and Consumer Demand. *Review of Economics and Statistics* 79 (4), 527–539.

Barrella, R., J. C. Romero, and L. Mariño (2022). Proposing a Novel Minimum Income Standard Approach to Energy Poverty Assessment: A European Case Study. *Sustainability* 14 (23), 15526.

Belaïd, F. (2018). Exposure and risk to fuel poverty in France: Examining the extent of the fuel precariousness and its salient determinants. *Energy Policy* 114, 189–200.

Bilgic, A., and S. T. Yen (2013). Household food demand in Turkey: A two-step demand system approach. *Food Policy* 43, 267–277.

Blundell, R., and J. M. Robin (1999). Estimation in large and disaggregated demand systems: An estimator for conditionally linear systems. *Journal of Applied Econometrics* 14 (3), 209–232.

Boardman, B. (1991). *Fuel poverty: from cold homes to affordable warmth.* Vol. 9. Belhaven Press, 427–427.

Bouzarovski, S. (2018). "Understanding Energy Poverty, Vulnerability and Justice". *Energy Poverty: (Dis)Assembling Europe's Infrastructural Divide.* Springer International Publishing, 9–39.

Bradshaw, J., and S. Hutton (1983). Social policy options and fuel poverty. *Journal of Economic Psychology* 3 (3-4), 249–266.

Burlinson, A., M. Giulietti, C. Law, and H.-H. Liu (2021). Fuel poverty and financial distress. *Energy Economics* 102, 105464.

Buzar, S. (2007). When Homes Become Prisons: The Relational Spaces of Postsocialist Energy Poverty. *Environment and Planning A: Economy and Space* 39 (8), 1908–1925.

Cadaval, M., R. M. Regueiro-Ferreira, and S. Calvo (2022). The role of the public sector in the mitigation of fuel poverty in Spain (2008–2019): Modeling the contribution of the Bono Social de Electricidad. *Energy* 258, 124717.

Charlier, D., and B. Legendre (2021). Fuel poverty in industrialized countries: Definition, measures and policy implications a review. *Energy* 236, 121557.

Curtis, J., M. A. Tovar, and G. Grilli (2020). Access to and consumption of natural gas: Spatial and socio-demographic drivers. *Energy Policy* 143, 111614. ISSN: 0301-4215.

Deaton, A. (1987). Estimation of own-and cross-price elasticities from household survey data. *Journal of Econometrics* 36 (1-2), 7–30.

Deaton, A., and J. Muellbauer (1980). *Economics and Consumer Behavior.* Cambridge University Press.

Decoster, A., F. Vermeulen, et al. (1998). *Evaluation of the empirical performance of two-stage budgeting AIDS, QUAIDS and Rotterdam models based on weak separability.* Vol. 23. Kath. Univ., Department Economie, Center for Economic Studies.

Denton, F., and D. Mountain (2016). Biases in consumer elasticities based on micro and aggregate data: an integrated framework and empirical evaluation. *Empirical Economics* 50 (2), 531–560.

Díaz, A. O., and K. B. Medlock (2021). Price elasticity of demand for fuels by income level in Mexican households. *Energy Policy* 151, 112132.

Gálvez, P., P. Mariel, and D. Hoyos (2016). Análisis de la demanda residencial de los servicios básicos en España usando un modelo QUAIDS censurado. *Estudios de economía* 43 (1), 5–28.

García-Enríquez, J., and C. A. Echevarría (2018). Demand for culture in Spain and the 2012 VAT rise. *Journal of Cultural Economics* 42 (3), 469–506.

Gómez-Navarro, T., M. Calero-Pastor, V. Pellicer-Sifres, P. Lillo-Rodrigo, D. Alfonso-Solar, and Á. Pérez-Navarro (2021). Fuel poverty map of Valencia (Spain): Results of a direct survey to citizens and recommendations for policy making. *Energy Policy* 151, 112162.

Groves, C., F. Shirani, and K. Henwood (2021). *Perspectives on energy poverty and energy vulnerability in the United Kingdom.*

Guertler, P. (2012). Can the Green Deal be fair too? Exploring new possibilities for alleviating fuel poverty. *Energy Policy* 49, 91–97.

Gundimeda, H., and G. Köhlin (2008). Fuel demand elasticities for energy and environmental policies: Indian sample survey evidence. *Energy Economics* 30 (2), 517–546.

Hahn, R., and R. Metcalfe (2021). Efficiency and equity impacts of energy subsidies. *American Economic Review* 111 (5), 1658–1688.

Hanemann, M., X. Labandeira, J. M. Labeaga, and X. López-Otero (2013). Energy demand for heating: short run and long run. *Economics for Energy Working Paper* 7, 2013.

Hass, T. (2019). Comparing energy transitions in Germany and Spain using a political economy perspective. *Environmental Innovation and Societal Transitions* 31, 200–2010.

Hausman, J. (1978). Specification tests in econometrics. *Econometrica* 46, 1251–1271.

Heckman, J. (1979). Sample selection bias as a specification error. *Econometrica* (47), 153–161.

Heien, D., and C. R. Wessells (1990). Demand Systems Estimation with Microdata: A Censored Regression Approach. *Journal of Business & Economic Statistics* 8 (3), 365–371.

Herrero, S. T., L. J. Meneses, and J. L. L. Fernández (2019). ¿ Una transición justa? Los bonos sociales a debate desde una perspectiva de pobreza y justicia energética. *Presupuesto y gasto público* 97, 155–176.

Hills, J. (2011). *Fuel poverty: The problem and its measurement.* Tech. rep. Centre for Analysis of Social Exclusion, LSE.

— (2012). *Getting the measure of fuel poverty: Final Report of the Fuel Poverty Review.* Tech. rep. Centre for Analysis of Social Exclusion, London School of Economics & Political Science.

Hoderlein, S., and S. Mihaleva (2008). Increasing the price variation in a repeated cross section. *Journal of Econometrics* 147 (2), 316–325.

Holly, A., and D. Sargan (1982). *Testing for exogeneity in a limited information framework.* Tech. rep. Cahiers de Recherches Ecoomiques 8204, Université de Lausanne.

Isherwood, B., and R. Hancock (1979). *Household expenditure on fuel: Distributional aspects.* Tech. rep. Economic Adviser's Office, DHSS, London.

Keen, M. (1986). Zero expenditures and the estimation of Engel curves. *Journal of Applied Econometrics* 1 (3), 277–286.

Kutortse, D. K. (2022). Residential energy demand elasticity in Ghana: an application of the quadratic almost ideal demand systems (QUAIDS) model. *Cogent Economics & Finance* 10 (1), 2082670.

Labandeira, X., J. M. Labeaga, and X. López-Otero (2017). A meta-analysis on the price elasticity of energy demand. *Energy policy* 102, 549–568.

— (2012). Estimation of elasticity price of electricity with incomplete information. *Energy Economics* 34 (3), 627–633.

Labandeira, X., J. M. Labeaga, and M. Rodríguez (2006). A Residential Energy Demand System for Spain. *The Energy Journal* 27 (2), 87–112.

Leung, S., and S. Yu (2006). Collinearity and two-step estimation of sample selection models: problems, origins and remedies. *Computational Economics* (15), 173–199.

Li, K., B. Lloyd, X.-J. Liang, and Y.-M. Wei (2014). Energy poor or fuel poor: What are the differences? *Energy Policy* 68, 476–481.

Meyerhoefer, C. D., C. K. Ranney, and D. E. Sahn (2005). Consistent Estimation of Censored Demand Systems Using Panel Data. *American Journal of Agricultural Economics* 87 (3), 660–672.

Moore, R. (2012). Definitions of fuel poverty: Implications for policy. *Energy Policy* 49, 19–26.

Ogundimu, E. (2022). Regularization and variable selection in Heckman selection model. *Statistical Papers* (63), 421–439.

Olabisi, M., D. L. Tschirley, D. Nyange, and T. Awokuse (2019). Energy demand substitution from biomass to imported kerosene: Evidence from Tanzania. *Energy Policy* 130, 243–252.

Pollak, R. A., and T. J. Wales (1981). Demographic Variables in Demand Analysis. *Econometrica* 49 (6), 1533.

Ramirez, J., F. Ortiz-Arango, and J. Rosellon (2021). Impact of Mexico's energy reform on consumer welfare. *Utilities Policy* 70, 101191.

Reiss, P. C., and M. W. White (2005). Household Electricity Demand, Revisited. *Review of Economic Studies* 72 (3), 853–883.

Robin, J., and S. Lecoeq (2006). Empirical Economics. *Estimating demand response with panel data* 31, 1043–1060.

Romero, J. C., P. Linares, and X. López (2018). The policy implications of energy poverty indicators. *Energy Policy* 115, 98–108.

Shonkwiler, J. S., and S. T. Yen (1999). Two-Step Estimation of a Censored System of Equations. *American Journal of Agricultural Economics* 81 (4), 972–982.

Suárez-Varela, M. (2020). Modeling residential water demand: An approach based on household demand systems. *Journal of Environmental Management* 261, 109921.

Tauchmann, H. (2005). Efficiency of two-step estimators for censored system of equations. *Applied Economics* (37), 367–374.

Tirado Herrero, S., and L. Jiménez Meneses (2016). Energy poverty, crisis and austerity in Spain. *People Place Policy* 10 (1), 42–56.

Tovar Reaños, M., and N. Wölfing (2018). Household energy prices and inequality: evidence from German microdata based on the EASI demand system. *Energy Economics* 70, 84–97.

Webb, J., G. Bramley, S. Fitzpatrick, and C. Liddell (2017). *A New Definition of Fuel Poverty in Scotland: Review of Evidence*. Scottish Government.

Yen, S. T., and B.-H. Lin (2006). A Sample Selection Approach to Censored Demand Systems. *American Journal of Agricultural Economics* 88 (3), 742–749.

Zheng, Z., and S. R. Henneberry (2012). Estimating the impacts of rising food prices on nutrient intake in urban China. *China Economic Review* 23 (4), 1090–1103.

Chapter 3

Welfare and distributional effects of the 2012 VAT reform on households' demand for utility services

3.1 Introduction

Value-added taxation of utility services is a particularly informative setting for welfare analysis because these services are essential goods. In the short run, households have limited scope to adjust consumption of electricity, natural gas, and water, while these expenditures take up a relatively large share of the budget for low-income households. For these reasons, VAT changes on utilities can translate into sizable welfare losses, with burdens that are likely to differ systematically across the income distribution. Therefore, this context is suitable for the joint analysis of efficiency and equity within the framework of welfare theory.

The empirical context is Spain's 2012 VAT reform, enacted through Royal Decree-Law 20/2012 and implemented in September 2012. The reform increased the standard VAT rate from 18% to 21% and the reduced rate from 8% to 10%. For energy, particularly electricity and natural gas, the policy change implied an increase of 3 percentage points by placing these utilities under the standard rate. However, the reduced rate was applied to water.

To the best of our knowledge, few studies examine the welfare and distributional effects of Spain's 2012 VAT reform. We identify two studies as particularly relevant. García-Enríquez & Echevarría (2016) analyzes the effects of Spain's 2012 VAT reform on household welfare, focusing on a major expenditure group, food and non-alcoholic beverages. A second contribution, García-Enríquez & Echevarría (2018), examines the impact of the reform on household demand for cultural goods and services, with special attention to different values of the pass-through parameter. In both studies, the evidence suggests that the reform is regressive. To date, we are not aware of studies that, for the energy consumption case, specifically assess the magnitude of the reform's effects on household welfare and their distribution across income groups.

From this perspective, welfare analysis provides a framework for assessing how economic policies affect individual and social welfare, as well as the distributional effects across different economic agents. Based on social welfare functions with inequality aversion Atkinson (1970) and monetary measures of welfare change, such as compensatory and equivalent variation Hicks (1941), Muellbauer (1974), and Deaton & Muellbauer (1980), this approach allows us to quantify the effects of tax, regulatory, or tariff reforms. The literature, especially in the field of taxation Mirrlees (1971) and Atkinson & Stiglitz (1980), links efficiency issues with equity, showing that the design of taxes and transfers must consider the responses and behavior of economic agents, as well as the redistributive objectives to be achieved. These tools provide a coherent empirical and theoretical framework for comparing ex-ante and ex-post scenarios and for expressing the results in comparable, distribution-sensitive social welfare metrics.

To assess the welfare consequences of the reform, it is crucial to determine the share of the VAT increase that consumers ultimately bear. Full pass-through occurs when the increase in consumer prices matches the change in the tax rate, whereas underpass-through occurs when ex-post producer prices are lower than ex-ante producer prices (Shiraishi 2022). Understanding the magnitude of tax pass-through is therefore central to evaluating distributional and efficiency effects. Consistent with the incidence literature, the presumption of full pass-through is broadly supported for changes in the standard VAT rate and serves as a reasonable baseline assumption (Benedek et al. 2020; Bird & Gendron 2007; Mooij et al. 2015; Hindriks & Serse 2022).

Empirical evidence on the effects of tax reforms on electricity and gas remains limited. Internationally, studies on the effects of VAT on energy show substantial pass-through and allow inference about distributional impacts. For Belgium, Hindriks & Serse (2022) analyzes the reduction and subsequent reversal of VAT on electricity from 21% to 6% and its reversion to 21%. The authors study the impact on prices and consumption using a difference-in-differences approach and find that the VAT pass-through to residential prices is complete for both the VAT cut and the subsequent VAT hike. Amores et al. (2023) measures the degree of price pass-through of the temporary 2023 VAT cut on basic foodstuffs, assessing whether the tax reduction was effectively passed on to consumers. The results show immediate price declines, suggesting a high pass-through.

On the other hand, García-Muros et al. (2023), using the large amount of household data available in the Household Budget Survey from European Member States, developed a microsimulation model that simulates the distributional and social impacts of the energy price spike at the household level. The results show and confirm the regressive distributional impact of the energy crisis. Additionally, the Bank of Spain (2023) assesses the 2021–2023 measures in response to the energy crisis and rising inflation. This evaluation includes VAT reductions on electricity and gas and assesses the distributional effects of the main fiscal measures aimed at supporting households, as well as their overall budgetary impact (García-Miralles 2023).

The distributive analysis of tax reforms continues to exhibit notable limitations in the applied literature. For certain value-added tax (VAT) reforms, existing evidence is concentrated on selected expenditure groups, resulting in limited welfare-based analysis for utility services. This gap is significant given the essential nature of utilities and their disproportionate budgetary impact on low-income households. In the context of Spain's 2012 VAT reform, prior research has primarily addressed categories such as food, non-alcoholic beverages, and cultural goods, with little direct quantification of the welfare and distributional effects of household consumption of electricity, natural gas, and water.

Second, the results are often sensitive to how statutory tax changes are reflected in consumer prices. Although some studies provide evidence on VAT pass-through, or price transmission, distributive assessments frequently address pass-through only implicitly or fail to examine how alternative assumptions or scenarios may alter incidence conclusions.

Furthermore, many evaluations prioritize changes in spending or affordability over welfare measures that are fully consistent with consumer theory. This gap highlights the need for analytical frameworks that translate tax-induced price changes into money-metric welfare losses and subsequently aggregate these losses for social welfare comparisons.

This chapter evaluates the welfare consequences of the 2012 VAT reform for households' consumption of residential electricity, natural gas, and water services. It is guided by three research questions. First, what were the individual and social welfare effects of the reform on the consumption of these utilities? Second, how were these impacts distributed across the income distribution? Third, to what extent do alternative assumptions regarding tax pass-through affect the resulting welfare estimates?

To address these questions, the chapter builds directly on the demand analysis developed in Chapter 2. Specifically, we combine the price and budget elasticities obtained from the Quadratic Almost Ideal Demand System (QUAIDS) with standard Hicksian welfare measures. The QUAIDS estimates provide the behavioral responses needed to construct utility-consistent changes in welfare attributable to the VAT-induced price variation across electricity, natural gas, and water. On this basis, we compute compensating variation and equivalent variation to quantify the reform's welfare effects at the household level, and we aggregate these measures to characterize impacts on social welfare.

A central objective is to characterize the distributional incidence of the VAT reform. We therefore report welfare changes across the income distribution, highlighting how the policy burden is allocated across households with different income levels. In addition, because welfare estimates depend critically on the extent to which the tax is transmitted to consumer prices, we conduct a sensitivity analysis under alternative pass-through scenarios. This allows us to assess the robustness of the estimated welfare impacts to plausible variation in the tax-to-price mapping. To the best of our knowledge, this represents a significant addition to the existing literature on tax policy and its redistributive consequences.

The remainder of this paper is structured as follows: Section 3.2 discusses the dataset used for the study. Section 3.3 briefly reviews empirical and methodological approaches to measuring individual and social welfare. Section 3.4 summarizes the empirical results of the study. It also quantifies the impact of the VAT reform(s) on individual and social welfare, as well as their distributional incidence across households' consumption of electricity, natural gas, and water. Finally, Section 3.5 presents the conclusions.

3.2 Distributive and welfare analysis

In this section, we combine the price elasticities obtained from the QUAIDS model with Hicksian welfare measures to evaluate how the VAT-induced price changes affect household welfare. We proceed in three steps: (i) we compute tax pass-through; (ii) we derive new consumption levels using Marshallian elasticities; and (iii) we measure the resulting welfare changes through EV and CV.

The concept of pass-through plays a central role in contemporary economic and welfare analysis, as it allows us to understand how changes in taxes or costs are passed on to the final prices faced by consumers. According to Fabinger & Weyl (2012), this parameter synthesizes essential aspects of the market structure and the power of companies to set prices. It directly influences the distribution of the effects of fiscal policies or variations in production costs between producers and consumers. The definition of pass-through is a key tool for analyzing the equity, efficiency, and distributive dynamics underlying markets.

The pass-through parameter γ_i determines how the VAT reform is transmitted to consumer prices. Since utilities are essential goods typically supplied under regulated or semi-regulated conditions, the degree of pass-through is expected to be close to one. Nevertheless, γ_i directly affects the price vector $\boldsymbol{p}_1$, and therefore influences quantities, tax revenues, and welfare measures. We therefore later examine both γ_i = 1 and an empirically estimated γ_i close to 1.

For a commodity i with consumer price p_i, subject to a tax specified, for example, a value-added tax, at an ad valorem tax-exclusive rate τ_i by degree of "pass-through" to the consumer, is meant the proportionate response of the consumer price to an increase in the tax factor $(1 + \tau_i)$ (Mooij et al. 2015). The pass-through can be defined as

$$\gamma_i = \frac{(p_i^1 - p_i^0)/p_i^0}{(\tau_i^1 - \tau_i^0)/(1 + \tau_i^0)}. \tag{3.1}$$

The complete pass-through, with no change in producer price, thus corresponds to $\gamma_i = 1$; and the zero pass-through to $\gamma_i = 0$. In markets that are not perfectly competitive, Stern (1987) demonstrates that the pass-through effect can exceed 1, indicating a more than complete transfer, or fall below 1, signifying a partial transfer. This variation depends on the elasticity of demand and the structure of the market. In other words, pass-through is not fixed or equal to one, but depends on the shape of demand and the degree of competition.

3.2.1 Individual welfare measures

Utility cannot be measured directly in any meaningful way, and must instead be inferred from observed choices made under budget constraints. What we observe are consumer decisions, not utility itself. Adopting a revealed-preference and ordinal approach to preferences allows us to work with monetary measures of welfare rather than attempting to quantify "direct" utility (Araar & Verme 2019; Colander 2007).

Next, we outline the method for estimating equivalent variation (EV) and compensating variation (CV). These are monetary measures of the welfare impact of price changes that quantify how much income a household would need to reach a given level of utility under different price vectors. Their computation requires information on price elasticities of demand, which we obtain from the estimated QUAIDS demand system.

We adopt the methodological approach proposed by García-Enríquez & Echevarría (2018), which is also based on Urzúa (2001) and King (1983). Assuming a Marshallian demand function $q_{ih} = q_{ih}(p_{1h}, p_{2h}, \ldots, p_{nh}, m_h)$, where m_h denotes total expenditure on electricity, natural gas and water, totally differentiating both sides, assuming further m_h to be invariant to the VAT reform, using the hth hosehold quantity demanded q^1_{ih} of the ith good in the new price vector is

$$q^1_{ih} = q^0_{ih}\left[1 + \sum_{j=1}^{n} E^u_{ij}\frac{(\tau^1_j - \tau^0_j) \times \gamma_j}{1 + \tau^0_j}\right], \tag{3.2}$$

for $i = 1, \ldots, n$, let E^u_{ij} denote the uncompensated (Marshallian) cross-price elasticity of the demand for good i with respect to the price of good j. Observe that q^1_{ih} depends on the pass-through parameter γ_j.

Equation (3.2) indicates that the percentage change in quantity demanded is driven by the size of the VAT reform, the relevant uncompensated price elasticities of demand, and the degree of tax pass-through. The direction and magnitude of the adjustment depend on the sign and value of these elasticities.

Accordingly, the expected tax revenues of the hth household post-tax reform R^1_h. Tax revenues of the hth household before and after the reform, respectively, are defined as

$$R^0_h = \sum_{i=1}^{n} \frac{\tau^0_i p^0_{ih} q^0_{ih}}{1 + \tau^0_i} \tag{3.3}$$

and

$$R^1_h = \sum_{i=1}^{n} \frac{\tau^1_i p^1_{ih} q^1_{ih}}{1 + \tau^1_i}. \tag{3.4}$$

This thesis summarizes individual welfare effects using two standard money-metric measures: equivalent variation (EV) and compensating variation (CV). Both express a welfare change in monetary units, but they differ in their reference point and, therefore, in the economic question they answer.

Equivalent variation takes the *post-reform* situation as the benchmark. Intuitively, EV answers the following ex ante question: how much income would a household be willing to give up before the VAT-induced price increase occurs in order to avoid the reform and end up as well off as under the post-reform prices? In this sense, EV is naturally interpreted as a willingness-to-pay (or willingness-to-accept) measure, and it is often used to evaluate hypothetical policy changes.

Compensating variation, in contrast, takes the *pre-reform* situation as the benchmark. It addresses an ex post question that is directly aligned with the evaluation of implemented reforms: once prices have increased, how much income would need to be transferred to the household after the reform so that it can reach its initial (pre-reform) utility level despite facing the new, higher prices? Hence, CV has the natural interpretation of the monetary compensation required to offset the welfare loss generated by the policy in the environment that actually prevails after implementation.

Consider a household affected by a VAT reform that raises the consumer price of a basic utility such as electricity. Under EV, we ask what the household would have been willing to pay before the reform to prevent the price increase from occurring. Under CV, we ask how much the household would need to be compensated after the reform to neutralize the welfare loss caused by the higher electricity price. Because the analysis in this thesis is ex post, CV is the most relevant measure for the core welfare assessment. EV is nevertheless reported as a complementary metric, since both measures are standard in applied welfare analysis and provide a useful check on the magnitude and distribution of welfare impacts.

Once the price effects of the tax-rate change are obtained from (3.3) and (3.4) , the welfare impact for each household can be evaluated using CV and EV. The equivalent variation (EV), the monetary amount which, when assessed in the initial price vector $\mathbf{p}_h^0$, would make the household h achieve the same level of utility under the new price vector $\mathbf{p}_h^1$ while keeping its initial electricity, natural gas, and water expenditure m_h fixed. Formally, if V denotes the indirect utility function of the household, EV_h is implicitly defined by $V(m_h + EV_h, \mathbf{p}_h^0) = V(m_h, \mathbf{p}_h^1)$, implying $EV_h < 0$ whenever $\mathbf{p}_h^1 \geq \mathbf{p}_h^0$ with $\mathbf{p}_h^1 \neq \mathbf{p}_h^0$. If we refer to equations (2.1) through (2.3) from Chapter 2, the EV for the hth household can be expressed as

$$EV_h = a(\mathbf{p}_h^0)\ \exp\left\{\frac{b(\mathbf{p}_h^0)\ \ln\Big[m_h/a(\mathbf{p}_h^1)\Big]}{b(\mathbf{p}_h^1) + \Big[\lambda(\mathbf{p}_h^1) - \lambda(\mathbf{p}_h^0)\Big]\ \ln\Big[m_h/a(\mathbf{p}_h^1)\Big]}\right\} - m_h. \tag{3.5}$$

Analogously, we define the final equivalent expenditure EE_h^F, the amount of expenditure at the initial price vector needed to attain the same utility level as under the post-reform prices, as follows

$$V\Big(EE_h^F, \mathbf{p}_h^0\Big) \equiv V\Big(m_h, \mathbf{p}_h^1\Big). \tag{3.6}$$

Hence, $EE_h^F \equiv m_h + EV_h < m_h$ whenever $\mathbf{p}_h^1 \geq \mathbf{p}_h^0,\ \mathbf{p}_h^1 \neq \mathbf{p}_h^0$.

On its part, CV represents the amount of money that must be taken from the total expenditure of electricity, natural gas, and water of the h-th household, m_h, when facing the new price vector $\mathbf{p}_h^1$, to restore its level of welfare to that obtained under the initial price vector $\mathbf{p}_h^0$. CV_h is implicitly defined by the condition $V(m_h - CV_h, \mathbf{p}_h^1) \equiv V(m_h, \mathbf{p}_h^0)$, which implies that $CV_h < 0$ when $\mathbf{p}_h^1 \geq \mathbf{p}_h^0$ and $\mathbf{p}_h^1 \neq \mathbf{p}_h^0$. Referring to equations (2.1) through (2.3) from Chapter 2, the CV for the hth household can be expressed as

$$CV_h = m_h - a(\mathbf{p}_h^1) \times \exp\left\{\frac{b(\mathbf{p}_h^1) \times \ln[m_h/a(\mathbf{p}_h^0)]}{b(\mathbf{p}_h^0) + [\lambda(\mathbf{p}_h^0) - \lambda(\mathbf{p}_h^1)] \times \ln[m_h/a(\mathbf{p}_h^0)]}\right\}. \qquad (3.7)$$

As was the case with the equivalent variation, the compensating variation allows us to define the initial equivalent expenditure EE_h^I, which represents the amount of income that a household would require after a price change to reach the same level of utility (welfare) it enjoyed before the price change,

$$V(EE_h^I, \mathbf{p}_h^1) \equiv V(m_h, \mathbf{p}_h^0). \qquad (3.8)$$

Note that $EE_h^I \equiv m_h - CV_h$, which implies that $EE_h^I > m_h$ for $\mathbf{p}_h^1 \geq \mathbf{p}_h^0$ and $\mathbf{p}_h^1 \neq \mathbf{p}_h^0$.

3.2.2 Social welfare measures

Individual welfare changes provide a first-order assessment of the impact of the reform. However, given the unequal distribution of utility expenditures and the potentially regressive effects of VAT, it is necessary to evaluate not only the average welfare change but also how these losses are distributed. For this reason, we complement the individual analysis with social welfare measures that incorporate inequality considerations.

To evaluate the tax reform's impact on social welfare, we use the concept of an indirect social welfare function. In the traditional literature on economics, social welfare Atkinson (1970), Sen (1973), Muellbauer (1974), & Cowell (2011); assume the existence of an indirect social welfare function, $W(\cdot)$, defined over the vector of equivalent expenditures across households, $\widehat{\mathbf{EE}} = [EE_1, EE_2, \ldots, EE_H]$. Formally, this can be expressed as

$$W(\cdot) = \begin{cases} \dfrac{1}{H}\displaystyle\sum_{h=1}^{H} \dfrac{EE_h^{1-\varepsilon}}{1-\varepsilon}, & \text{for } \varepsilon \neq 1, \\ \dfrac{1}{H}\displaystyle\sum_{h=1}^{H} \ln(EE_h), & \text{for } \varepsilon = 1, \end{cases} \tag{3.9}$$

where the parameter ε represents the degree of aversion to social inequality (Atkinson 1970; Foster & Székely 2008). This formulation corresponds to the Atkinson (1970) social welfare function, which aggregates household welfare while penalizing inequality in the distribution of expenditures.

From (3.9), we can derive a measure of social welfare value, denoted by the proportional increase in the initial equivalent expenditures, $\widehat{\mathbf{EE}}^I = [EE_1^I, EE_2^I, \ldots, EE_H^I]$, which we represent by λ. The scalar λ is defined as the proportional increase in the initial equivalent expenditure that would make it possible to match the social welfare created by reform García-Enríquez & Echevarría (2018), such that

$$W(\lambda \times EE_1^I, \lambda \times EE_2^I, \ldots, \lambda \times EE_H^I) = W(EE_1^F, EE_2^F, \ldots, EE_H^F), \tag{3.10}$$

where $\widehat{\mathbf{EE}}^F = [EE_1^F, EE_2^F, \ldots, EE_H^F]$ denotes the vector of final equivalent expenditures after the reform. Hence, when $EE_h^I > EE_h^F$ as a consequence of $\mathbf{p}_h^1 \geq \mathbf{p}_h^0$ and $\mathbf{p}_h^1 \neq \mathbf{p}_h^0$, the proportional adjustment satisfies $\lambda < 1$, indicating a social welfare loss induced by the policy reform.

The inequality index for equivalent distribution expenditure can be constructed from the equivalent expenditure function. García-Enríquez & Echevarría (2018) defines the equally distributed equivalent expenditure, G, as the level of equivalent expenditure that, if allocated identically to all households, would provide the same level of social welfare as the actual distribution of equivalent expenditure. Two different expressions of G can be defined based on whether the equivalent initial expenditure or the equivalent final expenditure is utilized,

$$W(G^I, G^I, \dots, G^I) \equiv W(EE_1^I, EE_2^I, \dots, EE_H^I), \tag{3.11}$$

and

$$W(G^F, G^F, \dots, G^F) \equiv W(EE_1^F, EE_2^F, \dots, EE_H^F), \tag{3.12}$$

where $W(\cdot)$ represents the social welfare function defined previously. In this formulation, G serves as a welfare-consistent measure of income or expenditure equality, linking the observed distribution to its socially equivalent uniform counterpart (Atkinson 1970; Cowell 2011).

To quantify inequality, we define the average initial and final equivalent expenditures as $\overline{EE}^I \equiv H^{-1} \sum_{h=1}^{H} EE_h^I$ and $\overline{EE}^F \equiv H^{-1} \sum_{h=1}^{H} EE_h^F$, respectively. Assuming that the social welfare function $W(\cdot)$ is symmetric and concave, reflecting the aversion to inequality, it follows that $G^F \leq \overline{EE}^F$ and $G^I \leq \overline{EE}^I$. Consequently, two inequality indices can be defined, corresponding to the pre- and post-reform situations

$$A^I \equiv 1 - \frac{G^I}{\overline{EE}^I}, \qquad A^F \equiv 1 - \frac{G^F}{\overline{EE}^F}, \tag{3.13}$$

where $A^I, A^F \in [0, 1]$.

From the welfare function in Eq. (3.9), the equally distributed equivalent expenditures are given by

$$G^I(\varepsilon) = \left[\frac{1}{H} \sum_{h=1}^{H} (EE_h^I)^{1-\varepsilon} \right]^{\frac{1}{1-\varepsilon}}, \qquad G^F(\varepsilon) = \left[\frac{1}{H} \sum_{h=1}^{H} (EE_h^F)^{1-\varepsilon} \right]^{\frac{1}{1-\varepsilon}}, \tag{3.14}$$

for $\varepsilon \neq 1$; and in the limiting case $\varepsilon = 1$:

$$G^I(1) = \exp\left(\frac{1}{H}\sum_{h=1}^{H} \ln EE_h^I\right), \qquad G^F(1) = \exp\left(\frac{1}{H}\sum_{h=1}^{H} \ln EE_h^F\right). \tag{3.15}$$

These expressions allow one to compute the proportional social welfare change induced by the reform, expressed as

$$\lambda(\varepsilon) = \frac{G^F(\varepsilon)}{G^I(\varepsilon)} \tag{3.16}$$

which captures the equivalent welfare change in average expenditure for a given level of inequality aversion ε.

Finally, combining Eq. (3.13) and Eq. (3.16), the welfare change can be reformulated in terms of inequality indices as

$$\lambda(\varepsilon) = \frac{[1 - A^F(\varepsilon)] \times \overline{EE}^F}{[1 - A^I(\varepsilon)] \times \overline{EE}^I}. \tag{3.17}$$

This expression indicates that the proportional social gain (or loss) associated with the reform depends jointly on the relative variation in average equivalent expenditures and on the corresponding change in inequality levels between the pre- and post-reform situations.

3.3 Data

We use data from the Spanish Annual Household Budget Survey (HBS) for 2011. The survey reports on household expenditure on goods and services, along with detailed sociodemographic characteristics. We use the 2011 wave of the HBS because it reflects the pre-reform consumption structure and prices. Using a single pre-reform year avoids contamination from expectations or behavioral adjustments related to the 2012 VAT increase.

Following the trimming rules used in 2.3, we correct the microdata for outliers and potential misreporting by excluding (i) households that do not report income; (ii) households with zero expenditure in the aggregate group capturing utility services; (iii) households located in the Canary Islands, the Balearic Islands, Ceuta, and Melilla, as well as those with missing information on the householder's occupation or gender; (iv) households with electricity unit values below the 1st percentile or above the 99th percentile; (v) inconsistent reports such as zero expenditure with positive quantities; and (vi) households that do not report expenditure on at least one of the goods included in the demand system model. Consequently, for 2011 the sample decreases from 21,680 observations to 18,920.

In the HBS, a key empirical limitation is that prices are not directly observed. Chapter 2 addresses this issue by implementing a methodological strategy adapted to the available data. For utility services such as electricity, natural gas, and water, the analysis constructs a household-level implicit price (unit value) as the ratio of the household's reported expenditure on the service to its reported physical consumption. By construction, these implicit prices vary across households, since both the numerator and the denominator are household-specific. The estimated implicit prices are then used as inputs in an auxiliary price regression, where the implicit price for each utility is the dependent variable and total household expenditure, together with the same sociodemographic controls included in the demand system (household size and the primary breadwinner's sex, education, and occupational status), serves as the set of regressors.

The previous process produces predicted prices, which are particularly useful for cases in which a given utility reports zero expenditure and unit values cannot be computed reliably. Overall, the two-step approach retains household-level price variation while enabling consistent price imputation when direct unit-value measures are unavailable or noisy.

Using the HBS microdata, we estimate a Quadratic Almost Ideal Demand System model based on Banks et al. (1997) following the procedure detailed in Section 2.3.2 of Chapter 2. From the QUAIDS model, we compute the elasticities of the price and expenditure for electricity, natural gas, and water. The estimated elasticities, along with household-level information on total expenditure and spending for each of these utilities, are used as inputs for the welfare analysis presented in the following sections.

The table 3.1 reports uncompensated (Marshallian) price elasticities derived from the QUAIDS demand system for three basic utility services: electricity, natural gas, and water, as presented in Chapter 2 of this thesis. The diagonal entries correspond to own-price elasticities, while the off-diagonal entries report cross-price elasticities. Because these elasticities are uncompensated, they reflect both substitution and income effects, and therefore describe the observed consumer response to price changes when nominal expenditure is held constant.

The own-price elasticities are negative and statistically significant for electricity (-1.037) and natural gas (-1.041), indicating that demand for both goods is price elastic. For water, the own-price elasticity is -0.751 and is also statistically significant, suggesting a less elastic demand that is closer to that of a basic necessity. Cross-price elasticities help to characterize substitution or complementarity across goods. For instance, the cross-price elasticity of electricity demand with respect to the price of natural gas is positive (0.265) and highly significant, which is consistent with substitution between these two energy sources.

We use the implied Marshallian (uncompensated) elasticities to approximate post-reform quantity responses Δq_i to the tax-induced price changes. These predicted adjustments are then used to compute VAT revenues before and after the reform, R_0 and R_1, under the maintained pass-through assumption. Finally, combining the household welfare loss (EV or CV) with the change in tax revenue, $\Delta R = R_1 - R_0$, provides an estimate of the excess burden, interpreted as the efficiency cost of the reform over and above the pure fiscal transfer from households to the government.

Table 3.1: Uncompensated cross-price elasticities 2011

	Electricity price	Natural gas price	Water price
Electricity	-1.037***	0.265***	0.096***
	(0.025)	(0.020)	(0.015)
Natural gas	-0.082***	-1.041***	-0.011
	(0.020)	(0.016)	(0.012)
Water	0.230***	0.107***	-0.751***
	(0.027)	(0.021)	(0.017)

Note: Standard errors are within brackets. Significance at the ***1% level.

For welfare evaluation, we exploit the QUAIDS structure in two complementary steps that map directly into the estimated parameters reported in Tables 3.2 and 3.3. First, computes household-level welfare measures from the QUAIDS expenditure function. In practice, this requires constructing the key price components of the expenditure function, the translog price aggregator $a(\mathbf{p})$, which depends on the price-response matrix $\mathbf{\Gamma} = (\gamma_{ij})$ in Table 3.3, the scaling term $b(\mathbf{p}) = \exp(\boldsymbol{\beta}' \ln p)$, and the quadratic term $\lambda(\mathbf{p}) = \lambda' \ln \mathbf{p}$, both governed by the expenditure parameters β_i and λ_i reported in Table 3.2. This approach delivers money metric welfare changes that are fully consistent with consumer theory and computed at the household level under the observed price reform.

Table 3.2: Parameters used in welfare estimations.

	β_i	λ_i
Electricity	-0.00385781	0.00106578
Natural gas	-0.01375731	-0.00413049
Water	-0.00058139	0.00050135

In addition, the parameters in Tables 3.2 and 3.3 should be interpreted jointly with the construction of the price reform in the data. The reform is implemented as a tax-induced change in consumer prices, and the estimated matrix $\mathbf{\Gamma}$ (Table 3.3) determines how changes in each log-price propagate through the translog aggregator $a(\mathbf{p})$, whereas the expenditure parameters (β_i, λ_i) (Table 3.2) control how these price changes translate into welfare via the scaling and quadratic components of the expenditure function. This clarifies the empirical channel through which the observed tax variation in prices is transformed into household-level welfare measures.

Table 3.3: Price parameters (γ_{ij}) used in welfare calculations.

	Electricity price	Natural gas price	Water price
Electricity	-0.00184164	0.00750289	0.00281855
Natural gas	-0.00456821	-0.00174768	-0.00061472
Water	0.00110990	0.00041065	0.00143663

Note: Rows index the demand-share equation (good i) and columns index the log-price regressor (price j).

As with any expenditure survey, reported utility payments may be affected by under-reporting or billing cycles that do not perfectly align with survey reference periods. Although these issues are common, they should be considered when interpreting the magnitude of estimated elasticities and welfare changes.

3.4 Empirical results

We present the results in four steps: (i) absolute and relative individual welfare changes; (ii) distributional patterns across income deciles; (iii) global measures of inequality and social welfare; and (iv) robustness to alternative pass through assumptions.

The VAT reform implemented in Spain in September 2012 raised the tax rate from 18% to 21%. This increase directly affected the group of utilities considered in the analysis: electricity, natural gas, and water. To estimate the VAT-specific pass-through parameter for electricity and natural gas related to the 2012 reform, we approximate γ_i using equation 3.1. This involves replacing the variables with the relevant energy price indices for the month before and the month after the reform, as reported by the Spanish Statistical Office: 87.536 and 89.719, respectively.

We estimate a pass-through parameter of $\hat{\gamma}_i = 97.94\%$, indicating a very high degree of tax transmission to consumer prices and aligning with the evidence discussed at the beginning of this chapter. Full estimation results are reported in the Appendix. Because $\hat{\gamma}_i$ is essentially indistinguishable from full pass-through (100%), we take full pass-through as the baseline scenario for the welfare simulations. That is, the baseline results reported below are obtained by setting the γ parameter in Eq. (3.1) equal to 100%.

Under this baseline assumption, the VAT increase is entirely reflected in final consumer prices for these utility services. Relative to using $\hat{\gamma}_i = 97.94\%$, the qualitative conclusions remain unchanged; differences are confined to minor adjustments in the magnitudes of the individual and social welfare measures.

Table 3.4 reports the estimated values of the equivalent variation (EV) and the compensating variation (CV), both indicators showing negative signs, as expected. CV measures the income change necessary to restore an individual's original utility level after tax reform, resulting in higher utility prices. In other words, it represents the monetary compensation that households would need to maintain the same level of welfare as before the reform. The results show that CV values increase with income, as expected, since higher income households typically have greater levels of utility consumption.

Pre- and post-reform tax revenues are denoted by R^0 and R^1, respectively. R^0 measures the amount of VAT effectively paid by households in the analyzed utilities before the reform, while R^1 reflects the corresponding value after the tax increase.

On average, the VAT burden increased by 20.66€ units, from 134.99€ to 155.62€. Hence, ΔR represents the additional direct cost of the tax for each income decile, that is, the extra monetary expenditure households must incur to purchase the same basket of goods following the price adjustment.

Before the reform, the level of monetary expenditure required by the household to achieve its initial utility level, based on pre-reform prices, is represented by EEi. In contrast, EEf indicates how much the household would have to spend at post-reform prices to maintain its welfare. This amount reflects the level of monetary expenditure necessary after the reform, evaluated at the new prices, to maintain the same initial utility level. The average initial equivalent expenditure is represented as 997.46€, while the average final equivalent expenditure is represented as 930.12€. This shows that the tax reform is not income-neutral. Both the compensating and equivalent variation, as well as the EEf and EEi, demonstrate that all households experience a reduction in their welfare.

Finally, columns EB_{ev} and EB_{cv} report the excess burden or deadweight loss, that is, the net welfare loss associated with the tax calculated using the equivalent and compensating variations, respectively. Higher absolute values indicate greater inefficiency in the tax design.

Estimated welfare measures indicate that welfare losses due to the reform increase in absolute terms as household income increases. This can be explained by the fact that, as household income increases, the consumption of the analyzed utilities also rises; additionally, these households may have greater substitution elasticity as income increases.

Figure 3.1 presents the compensating variation (CV) estimated for each household after the 2012 VAT reform, plotted against annual household income. As discussed above, all households experience a welfare loss, although the magnitude varies sub-

Table 3.4: Distributive analysis of welfare ($\gamma = 100\%$)

Decil	Income	R^0	R^1	ΔR	EV	CV	EE$_i$	EE$_f$	EB$_{ev}$	EB$_{cv}$
1	9,007.39	74.14	85.29	11.22	-15.86	-15.88	556.76	524.54	-3.88	-3.90
2	13,075.55	101.24	116.80	15.29	-21.32	-21.35	751.34	709.70	-5.65	-5.67
3	16,138.83	114.79	131.78	17.34	-24.98	-25.01	845.74	796.25	-7.65	-7.68
4	19,131.64	129.63	149.36	19.61	-28.18	-28.21	954.88	898.92	-8.85	-8.87
5	22,062.38	130.35	150.28	19.66	-31.10	-31.13	964.22	900.08	-11.34	-11.37
6	25,477.54	143.07	164.66	21.80	-34.17	-34.20	1,058.42	990.69	-12.39	-12.42
7	29,361.77	150.57	173.31	22.75	-37.47	-37.49	1,095.88	1,018.53	-14.83	-14.86
8	34,563.60	159.37	183.49	24.26	-41.22	-41.25	1,177.42	1,095.14	-16.97	-17.00
9	41,942.62	172.55	198.65	26.55	-45.80	-45.83	1,267.96	1,178.84	-19.04	-19.07
10	57,495.65	199.04	231.44	31.26	-52.42	-52.44	1,472.08	1,364.66	-21.47	-21.48
Median	23,640.87	134.99	155.62	20.66	-32.54	-32.57	997.46	930.12	-10.53	-10.56

Note: The table reports equivalent (EV) and compensating (CV) variations, initial and final equivalent expenditures (EE_i, EE_f), and welfare balance measures (EB_{ev}, EB_{cv}) by expenditure decile. Monetary values are expressed in consistent units across deciles.

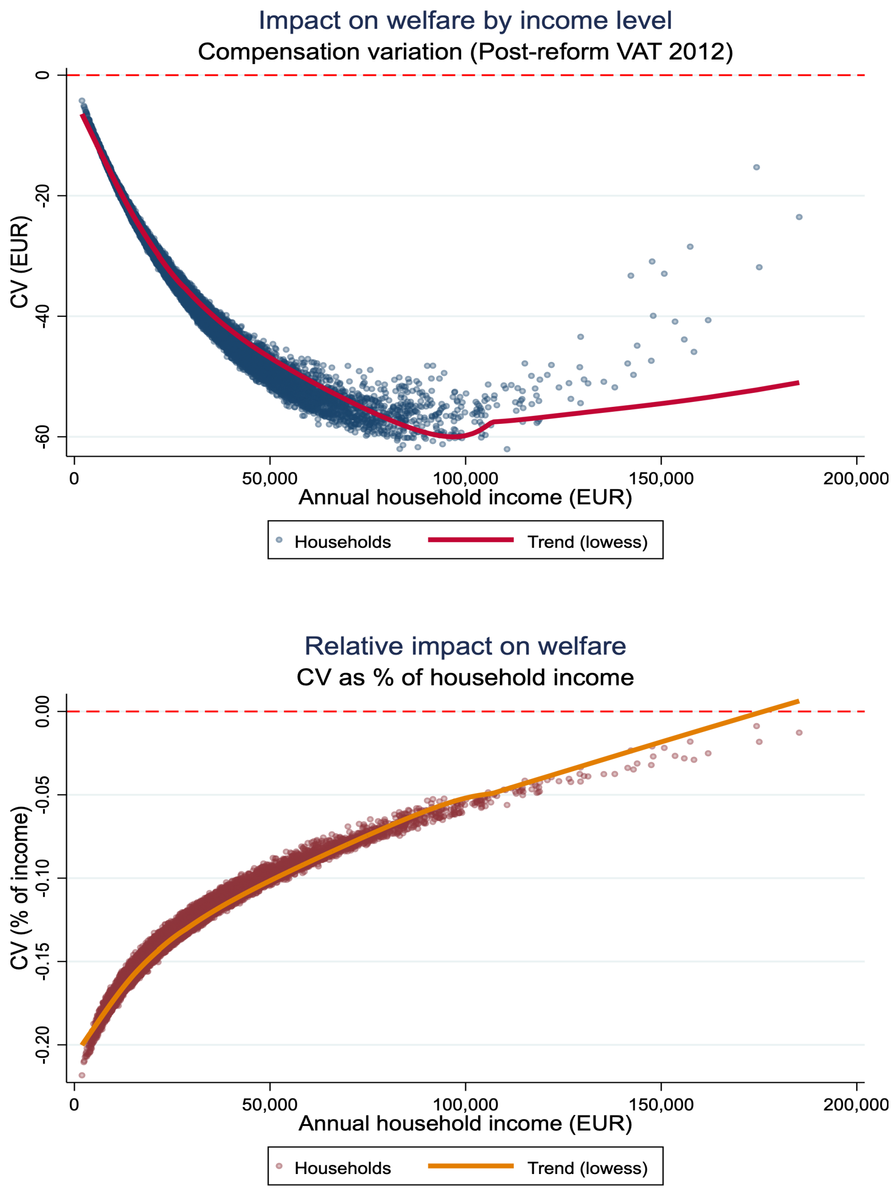
stantially across the income distribution. From a purely monetary point of view, the effect seems proportional or even slightly progressive in absolute terms, as higher-income households would need more compensation to maintain their initial utility levels.

In contrast, the graph in the upper part of of the panel provides a more meaningful perspective on the redistributive implications of the reform. When the CV is expressed as a percentage of household income, the relative welfare impact becomes clearly regressive. Low-income households face welfare losses equivalent to a much larger share of their income (around 15–20%), while for high-income households the loss is minimal. This relative measure accounts for differences in economic capacity, showing that the VAT increase reduces the relative welfare of poor households more severely.

The regressivity in relative terms is driven by the fact that utility services represent a substantially higher budget share for low-income households. Combined with inelastic demand for electricity and gas, this generates disproportionate welfare losses when prices rise.

Figure 3.2 summarizes the distributional effects of the 2012 VAT reform on household

Figure 3.1: Absolute and relative welfare effects of the 2012 VAT reform in Spain.



Note: Author's own elaboration.

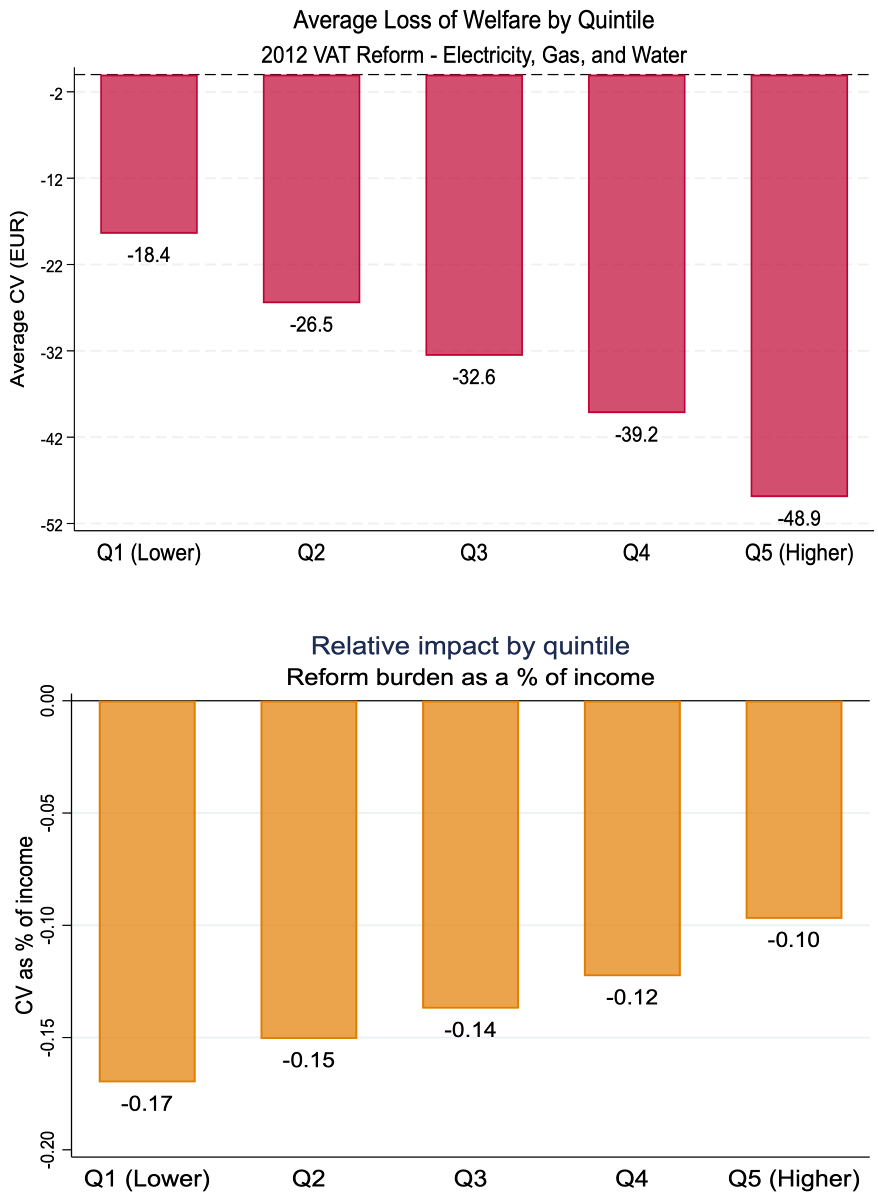
welfare, distinguishing between absolute and relative measures in income quintiles. The upper part of the panel displays the average compensating variation (CV) in euros per household, while the lower graph expresses the same measure as a percentage of household income. In absolute terms, shown on the left, welfare losses increase with income. Higher-income households experience larger monetary losses because they typically consume greater quantities of taxed utilities. However, when welfare losses are measured relative to income, as depicted on the right, the distributional pattern reverses. The share of income required to compensate for welfare loss is considerably higher among the lowest quintile (–0.17) compared with the highest quintile (–0.10). This indicates that poorer households bear a heavier welfare burden relative to their income capacity.

The Lorenz curve illustrated in Figure 3.3 depicts the distribution of losses resulting from the 2012 VAT reform for the set of utilities analyzed. The horizontal axis represents the cumulative households ordered by income level, while the vertical axis displays the cumulative percentage of total welfare loss, measured using the CV. The dashed line represents the perfect equality line, where each percentage of the population would bear an equivalent share of the total losses. The solid line shows the actual distribution of losses resulting from the tax. The fact that the observed curve falls below the equality line indicates that welfare losses are concentrated in lower-income households. In other words, the first deciles of the distribution bear a disproportionate share of the total loss, highlighting the regressive nature of the reform.

In the following, we present the results of the social welfare analysis. The analysis considers different levels of aversion to inequality to estimate the Atkinson and King index. These indices allow us to evaluate how income distribution and welfare losses affect aggregate social welfare, considering different sensitivities to inequality.

The sensitivity to inequality or the degree of aversion to inequality is established by the parameter ε. When $\varepsilon = 0$, society is neutral to inequality; only the aggregate (or average) welfare level matters, not its distribution. As ε increases, the social welfare function becomes more inequality-averse and assigns greater weight to welfare shortfalls among households toward the lower end of the (equivalent) expenditure

Figure 3.2: Absolute and relative welfare losses by income quintile after the 2012 VAT reform.

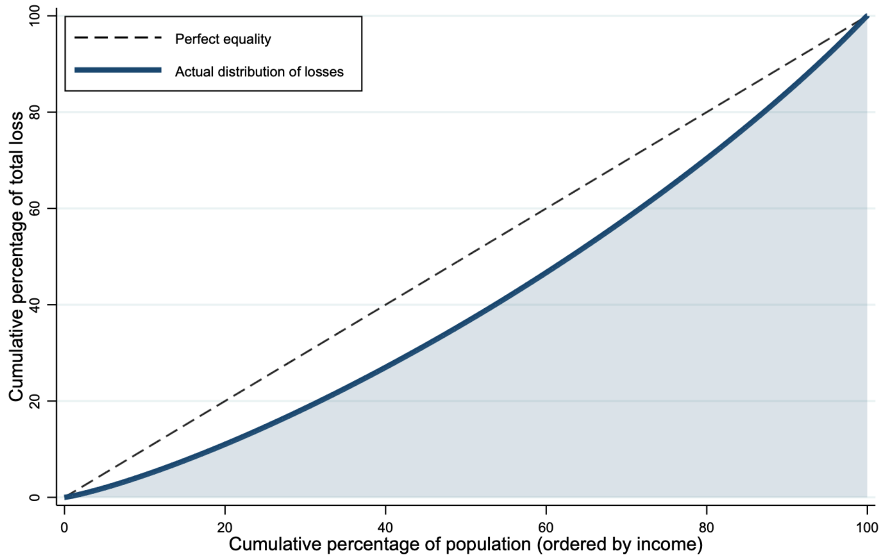


Note: Author's own elaboration.

distribution. Consequently, the same monetary welfare loss can translate into a larger reduction in social welfare when it is concentrated among poorer households.

$A^0(\varepsilon)$ measures baseline inequality in pre-reform expenditure. $A^I(\varepsilon)$ measures inequality in the initial equivalent-expenditure metric (holding the reference utility at

Figure 3.3: Lorenz curve: Concentration of welfare losses.



Note: Author's own elaboration. Area between curves indicates concentation of losses.

pre-reform levels), and $A^F(\varepsilon)$ measures inequality in the corresponding post-reform equivalent-expenditure metric. Differences between $A^I(\varepsilon)$ and $A^F(\varepsilon)$ therefore summarize how the reform changes inequality once expenditures are translated into welfare-consistent monetary equivalents.

Table 3.5 shows that, for all $\varepsilon > 0$, inequality measured on the equivalent-expenditure metric increases after the reform, as reflected by $A^F(\varepsilon) > A^I(\varepsilon)$. Moreover, the gap $A^F(\varepsilon) - A^I(\varepsilon)$ widens as ε rises, indicating that the distributional consequences of the reform are more severe under stronger inequality aversion.

Table 3.5: Social welfare analysis ($\gamma = 100\%$).

Inequality aversion (ε)	Atkinson's $A^0(\varepsilon)$ index	Atkinson's $A^I(\varepsilon)$ index	Atkinson's $A^F(\varepsilon)$ index	King's $\lambda(\varepsilon)$ index	Welfare change (%)
0.0000	0.0000	0.0000	0.0000	0.9424	-5.7643
0.5000	0.0824	0.0786	0.0858	0.9346	-6.5443
1.0000	0.1607	0.1526	0.1681	0.9246	-7.5398
1.5000	0.2413	0.2258	0.2541	0.9075	-9.2518
2.0000	0.3391	0.3036	0.3634	0.8609	-13.9000
2.5000	0.4889	0.3929	0.5423	0.7101	-29.0000
3.0000	0.6893	0.4983	0.7570	0.4561	-54.4000
3.5000	0.8308	0.6096	0.8775	0.2955	-70.4000
4.0000	0.8988	0.7047	0.9285	0.2280	-77.2000

The King index ($\lambda(\varepsilon)$) is introduced as a complementary measure that integrates information on both inequality and aggregate welfare (see Eqs. (3.16) and (3.17)). Unlike the Atkinson index, $\lambda(\varepsilon)$ declines as ε increases, capturing the relative level of effective social welfare once inequality is considered. In other words, $\lambda(\varepsilon)$ represents the proportion of total welfare that remains when differences in household welfare are weighted by social aversion to inequality.

As shown in the last column of the Table 3.5, welfare losses occur for all degrees of inequality aversion, and these losses intensify as ε increases. For example, when $\varepsilon = 0$, the reduction in social welfare is approximately 5.8%, while for $\varepsilon = 4$, the loss reaches approximately 77%. Overall, the VAT reform leads to a decline in inequality-adjusted social welfare, and the impact becomes more pronounced as inequality aversion increases.

To interpret the magnitude of changes in Atkinson's index, recall that $A(\varepsilon)$ admits a direct welfare interpretation through the equally distributed equivalent (EDE). Specifically, $\frac{EDE(\varepsilon)}{\mu} = 1 - A(\varepsilon)$, where μ denotes mean (equivalent) expenditure. Hence, an increase in $A(\varepsilon)$ translates one-for-one into a decline in the EDE-to-mean ratio. For example, at $\varepsilon = 1$, moving from $A^I = 0.1526$ to $A^F = 0.1681$ implies that $(1 - A)$ falls from 0.8474 to 0.8319, i.e., a reduction of 1.55 percentage points in the EDE relative to the mean. At $\varepsilon = 2$, the corresponding decline is 5.98 percentage points (from 0.6964 to 0.6366). Therefore, seemingly modest changes in $A(\varepsilon)$ in levels can imply economically meaningful losses in inequality-adjusted welfare.

The strong responses of welfare losses at higher ε is a mechanical implication of the welfare aggregation behind Atkinson- and King-type measures. A higher ε increases the curvature of the social welfare function and therefore the marginal social weight placed on welfare shortfalls among low-expenditure households. If the reform is regressive, in the sense that the price-induced welfare loss is more burdensome for households toward the bottom of the expenditure distribution, then the same underlying incidence translates into disproportionately larger reductions in inequality-adjusted welfare as ε rises. This mechanism is consistent with the monotonic decline in King's $\lambda(\varepsilon)$ and the increasingly negative welfare change reported in Table 3.5.

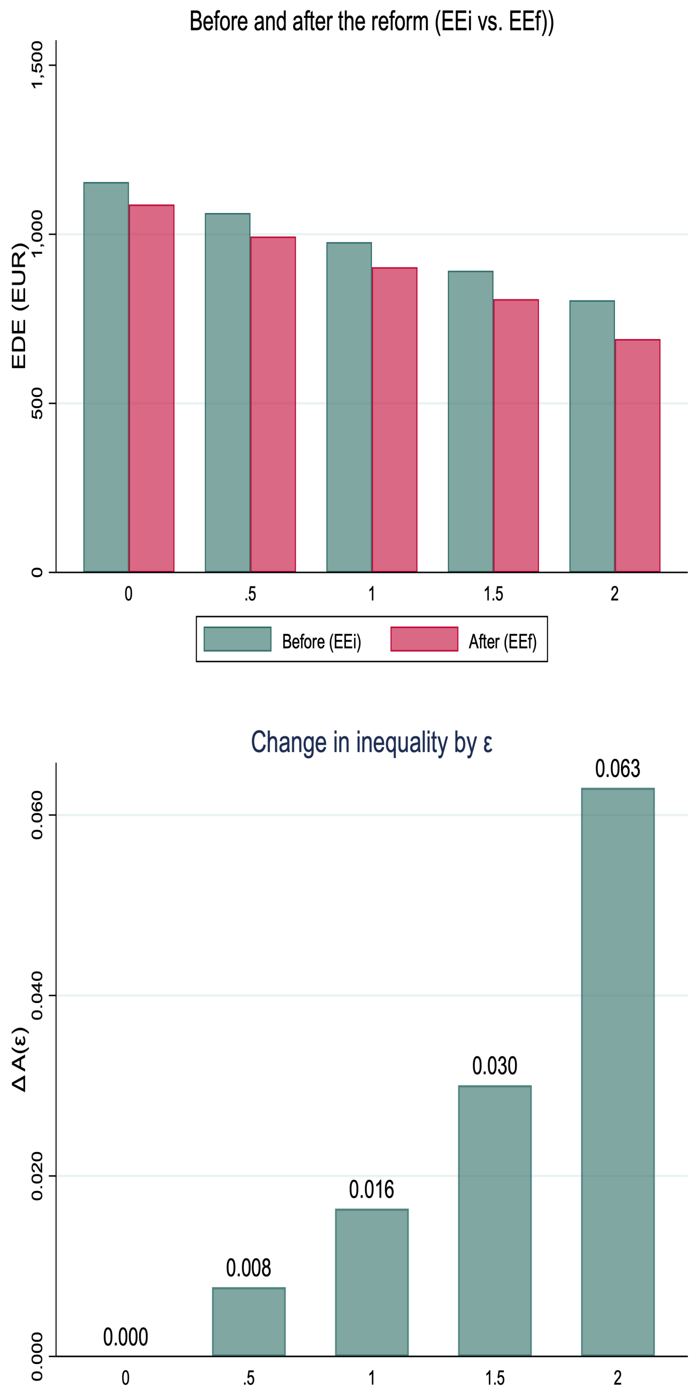
Although the change in the Atkinson index may seem small in absolute value, its systematic increase with ε and the ordering $A^F(\varepsilon) > A^I(\varepsilon)$ indicate that the reform disproportionately worsens welfare for households toward the lower end of the distribution. The King index further shows that the loss in social welfare becomes particularly large for $\varepsilon > 2$, which corresponds to strong aversion to inequality.

The distributional link between welfare losses and inequality is direct in our setup. As shown before, the initial equivalent expenditure under post-reform prices satisfies $EE_h^I = m_h - CV_h$. Therefore, any systematic heterogeneity in CV_h across households maps one-to-one into the distribution of EE_h^I. In particular, when welfare losses represent a larger monetary or proportional burden for low-expenditure households, the transformation $m_h \to EE_h^I$ compresses the lower tail relatively more, increasing dispersion in equivalent expenditure and raising inequality indices computed over EE.

Figure 3.4 presents the results of the welfare and inequality analysis based on the Equally Distributed Equivalent (EDE) and the Atkinson index for different levels of inequality aversion (ε). Panel left shows the EDE before and after the reform, while Panel right reports the corresponding change in the Atkinson inequality index.

The EDE declines systematically after the reform for all values of ε, and the reduction becomes increasingly pronounced as inequality aversion rises. This indicates that the reform led to a net loss in inequality-adjusted social welfare. Consistent with this pattern, the lower panel shows that Atkinson's index increases after the reform, with larger changes observed at higher ε values. While the effect is negligible when $\varepsilon = 0$ (a purely utilitarian perspective), it becomes more substantial as ε increases, revealing that the reform exacerbated inequality in welfare-consistent monetary terms. Taken together, both panels indicate that the policy change was regressive in distributional terms, reducing inequality-adjusted welfare and worsening the relative position of households with lower expenditure levels.

Figure 3.4: Welfare and inequality effects of the VAT reform across inequality aversion levels



Note: Author's own elaboration.

3.5 Conclusions

This chapter examined the welfare and distributional effects of the 2012 VAT reform in Spain on households' consumption of electricity, natural gas, and water services. The reform raised the standard VAT rate from 18% to 21% and applied the standard rate to these utilities, with water remaining subject to a reduced rate, thereby increasing the tax burden on goods that are essential and difficult to substitute in the short run. Although implemented in a broader context of fiscal consolidation, the welfare and inequality implications of taxing basic utilities have received limited attention from a welfare-theoretic perspective.

Using 2011 microdata from the Spanish Household Budget Survey and a QUAIDS demand system estimated in Chapter 2, we derived price and expenditure elasticities for the three utilities and used these estimates to construct standard monetary welfare measures. In particular, we computed compensating variation (CV) and equivalent variation (EV) at the household level and then aggregated these measures to obtain distribution-sensitive indicators of social welfare using Atkinson-type social welfare functions and the King index. Our baseline analysis assumes full pass-through of the VAT increase to final consumer prices, and we subsequently relax this assumption by estimating an empirical pass-through parameter for electricity and natural gas, which remains very close to complete.

The individual-level results indicate that the reform generated welfare losses throughout the distribution. Under the baseline scenario, both EV and CV are negative across expenditure deciles, implying that households require additional monetary resources at post-reform prices to attain their pre-reform utility level. In aggregate terms, the reform increased the average VAT burden on the utilities analyzed by approximately 20.66€ per household (from 134.99€ to 155.62€) and reduced average equivalent expenditure from around 997.46€ to 930.12€. These patterns are consistent with substantial price transmission and underscore that the reform was not welfare-neutral.

Beyond these average effects, the distributional incidence depends critically on the metric used to evaluate losses. In absolute monetary terms, welfare losses increase with income, reflecting higher levels of utility consumption among richer households. However, when welfare losses are expressed relative to household income, a markedly different pattern emerges: lower-income households experience substantially larger proportional losses. This regressive profile reflects two reinforcing mechanisms. First, electricity, natural gas, and water represent a larger share of the budget among households with fewer resources. Second, short-run substitution possibilities are limited, particularly for electricity, which restricts behavioral adjustment and amplifies welfare costs among economically vulnerable households. Distributional diagnostics based on the concentration of welfare losses provide additional evidence that the burden is disproportionately borne by the lower tail of the income distribution.

At the social level, Atkinson's inequality indices and the King index confirm that the VAT reform reduced inequality-adjusted social welfare, and that this reduction becomes more severe as the degree of inequality aversion increases. For all values of the inequality-aversion parameter, the post-reform configuration is associated with higher effective inequality and lower social welfare. When society is nearly inequality-neutral (low ε), the welfare loss is moderate; as ε rises and greater weight is placed on welfare shortfalls among poorer households, the social welfare costs increase sharply. The King index, which jointly reflects changes in mean equivalent expenditure and changes in inequality, shows a substantial proportional reduction in social welfare at high levels of inequality aversion. Taken together, these results indicate that the reform is especially costly from a social welfare perspective precisely in the normatively relevant case where protecting low-income households is assigned greater weight.

The results are robust to relaxing the assumption of full pass-through. Using observed price indices before and after the reform, we estimate a pass-through parameter for electricity and natural gas of approximately 97.94%, implying that most of the VAT increase was transmitted to consumer prices. This finding is consistent with the institutional features of regulated utility markets and helps explain why welfare losses remain sizable across the distribution.

From a policy perspective, the evidence suggests that broad-based VAT increases on essential utility services are a costly instrument in distributional terms. Because lower-income households devote a larger fraction of their budget to electricity, natural gas, and water, and have limited scope to substitute away from these services, uniform VAT increases disproportionately burden those with fewer economic resources. These results therefore support the case for differentiated VAT rates and complementary instruments—such as targeted subsidies, social tariffs, or income-tested rebate schemes—that can protect vulnerable households while still allowing governments to pursue fiscal objectives.

Future research could explore dynamic consumption responses, incorporate more granular billing data, and evaluate alternative targeted policies through microsimulation. Such extensions would deepen our understanding of how tax reforms interact with essential utility consumption and would provide further guidance for designing fiscal policies that balance efficiency, equity, and revenue goals.

Appendix 3A. Individual welfare analysis

Table A1: Distributive analysis of welfare ($\widehat{\gamma} = 97.94\%$)

Decil	Income	R^0	R^1	ΔR	EV	CV	EE$_i$	EE$_f$	EB$_{ev}$	EB$_{cv}$
1	9,007.39	74.14	85.29	11.21	-15.54	-15.56	556.42	524.86	-3.57	-3.59
2	13,075.55	101.24	116.79	15.29	-20.89	-20.91	750.90	710.15	-5.27	-5.29
3	16,138.83	114.79	131.77	17.33	-24.48	-24.50	845.22	796.73	-7.17	-7.19
4	19,131.64	129.63	149.35	19.59	-27.60	-27.63	954.28	899.45	-8.28	-8.31
5	22,062.38	130.35	150.27	19.64	-30.47	-30.50	963.62	900.75	-10.74	-10.77
6	25,477.54	143.07	164.64	21.79	-33.48	-33.51	1,057.73	991.38	-11.68	-11.70
7	29,361.77	150.57	173.29	22.73	-36.70	-36.73	1,095.06	1,019.26	-14.08	-14.11
8	34,563.60	159.37	183.46	24.24	-40.38	-40.41	1,176.53	1,095.96	-16.15	-16.18
9	41,942.62	172.55	198.63	26.52	-44.87	-44.89	1,267.00	1,179.82	-18.14	-18.16
10	57,495.65	199.04	231.25	31.24	-51.35	-51.37	1,470.90	1,365.64	-20.39	-20.40
Median	23,640.87	134.99	155.61	20.63	-31.88	-31.91	996.83	930.78	-9.91	-9.94

Note: The table reports equivalent (EV) and compensating (CV) variations, initial and final equivalent expenditures (EE_i, EE_f), and welfare balance measures (EB_{ev}, EB_{cv}) by expenditure decile. Monetary values are expressed in consistent units across deciles.

Table A2: Social welfare analysis ($\widehat{\gamma} = 97.94\%$).

Inequality aversion (ε)	Atkinson's $A^0(\varepsilon)$ index	Atkinson's $A^I(\varepsilon)$ index	Atkinson's $A^F(\varepsilon)$ index	King's $\lambda(\varepsilon)$ index	Welfare change (%)
0.0	0.0000	0.0000	-0.0005	0.9435	-5.6491
0.5	0.0824	0.0787	0.0857	0.9359	-6.4134
1.0	0.1607	0.1528	0.1679	0.9261	-7.3864
1.5	0.2413	0.2261	0.2535	0.9096	-9.0434
2.0	0.3391	0.3040	0.3611	0.8656	-13.4000
2.5	0.4889	0.3937	0.5329	0.7265	-27.4000
3.0	0.6893	0.4997	0.7430	0.4844	-51.6000
3.5	0.8308	0.6116	0.8676	0.3216	-67.8000
4.0	0.8988	0.7068	0.9220	0.2508	-74.9000

Bibliography

Amores, A. F., S. Barrios, R. Speitmann, and D. Stöhlker (2023). *Price Effects of Temporary VAT Rate Cuts: Evidence from Spanish Supermarkets.* Policy Brief JRC132542. JRC Policy Brief. Joint Research Centre (JRC), European Commission.

Araar, A., and P. Verme (2019). *Prices and Welfare: An Introduction to the Measurement of Well-being when Prices Change.* Springer.

Atkinson, A. B. (1970). On the Measurement of Inequality. *Journal of Economic Theory* 2 (3), 244–263.

Atkinson, A. B., and J. E. Stiglitz (1980). *Lectures on Public Economics.* New York: McGraw-Hill.

Banks, J., R. Blundell, and A. Lewbel (1997). Quadratic Engel Curves and Consumer Demand. *Review of Economics and Statistics* 79 (4), 527–539.

Benedek, D., R. A. de Mooij, M. Keen, and P. Wingender (2020). Varieties of VAT Pass-Through. *International Tax and Public Finance* 27 (4), 890–930.

Bird, R. M., and P.-P. Gendron (2007). *The VAT in developing and transitional countries.* Vol. 207. Cambridge University Press.

Colander, D. (2007). Retrospectives-Edgeworths's Hedonometer and the Quest for Measurable Utility. *Journal of Economic Perspectives* 21 (1).

Cowell, F. A. (2011). *Measuring Inequality.* 3rd. Oxford: Oxford University Press.

Deaton, A., and J. Muellbauer (1980). *Economics and Consumer Behavior.* Cambridge University Press.

Fabinger, M., and E. G. Weyl (2012). Pass-Through and Demand Forms. *American Economic Review* 102 (3), 124–130.

Foster, J. E., and M. Székely (2008). Is Economic Growth Good for the Poor? Tracking Low Incomes Using General Means. *World Bank Economic Review* 22 (3), 413–444.

García-Enríquez, J., and C. A. Echevarría (2016). Consistent Estimation of a Censored Demand System and Welfare Analysis: The 2012 VAT Reform in Spain. *Journal of Agricultural Economics* 67 (2), 324–347.

— (2018). Demand for culture in Spain and the 2012 VAT rise. *Journal of Cultural Economics* 42 (3), 469–506.

García-Miralles, E. (2023). Medidas de apoyo frente a la crisis energética y al repunte de la inflación: un análisis del coste y de los efectos distribucionales de algunas de las actuaciones desplegadas según su grado de focalización. *Boletín Económico - Banco de España* T1. Artículo 15.

García-Muros, X., C. Dias Soares, J. Urios, and E. Alonso-Epelde (2023). *Who took the burden of the energy crisis? A distributional analysis of energy prices shocks.* Tech. rep. Institute for European Environmental Policy (IEEP).

Hicks, J. R. (1941). The Rehabilitation of Consumers' Surplus. *Economica* 8 (31), 174–187.

Hindriks, J., and V. Serse (2022). The incidence of VAT reforms in electricity markets: Evidence from Belgium. *International Journal of Industrial Organization* 80, 102809.

King, M. A. (1983). "The distribution of gains and losses from changes in the tax treatment of housing". *Behavioral simulation methods in tax policy analysis.* University of Chicago Press, 109–138.

Mirrlees, J. A. (1971). An Exploration in the Theory of Optimum Income Taxation. *Review of Economic Studies* 38 (2), 175–208.

Mooij, R. A., D. Benedek, and P. Wingender (Sept. 2015). Estimating VAT Pass Through. *IMF Working Papers* 2015 (214), 1.

Muellbauer, J. (1974). Inequality Measures, Prices and Household Composition. *The Review of Economic Studies* 41 (4), 493–504.

Sen, A. (1973). *On Economic Inequality*. Oxford: Oxford University Press.

Shiraishi, K. (2022). Determinants of VAT pass-through under imperfect competition: Evidence from Japan. *Japan and the World Economy* 61, 101120.

Stern, N. (1987). The effects of taxation, price control and government contracts in oligopoly and monopolistic competition. *Journal of Public Economics* 32 (2), 133–158.

Urzúa, C. M. (2001). Welfare consequences of a recent tax reform in Mexico. *Estudios Económicos*, 57–72.

Chapter 4

Estimation of markups and dynamic productivity decomposition using a production control function approach: The case of Spanish electricity retailers

4.1 Introduction

The analysis of the effects of liberalization and competition in the electricity markets remains a relevant topic in academic and public policy discussions. In particular, few studies analyze how reforms to the electricity market affect and impact prices, the productive structure of retailer companies, and consumer behavior. Amenta et al. (2022) argues that the existing literature on competition outcomes in this sector is inconclusive and highlights the need for more evidence on how liberalization and competition policies affect market performance. Concettini & Creti (2014) identifies the existence of different and often contradictory theoretical points of view. Furthermore, Stagnaro et al. (2020) notes that competition in the retail electricity sector is less studied compared to other aspects of power systems.

From an economic perspective, opening the retail electricity market to competition empowers residential consumers to choose their suppliers. This freedom allows them to select the combination of price and service quality that best fits their needs (Defeuilley 2009). Competition is expected to reduce entry barriers, encourage innovation, and improve market efficiency by refining price formation mechanisms. Ultimately, this should lead to reduced prices for consumers (P. L. Joskow 2008; Defeuilley 2009).

However, liberalization of the retail market has also faced significant challenges. New entrants have struggled to compete against incumbent firms, and few notable innovations have emerged in the sector (Defeuilley 2009). In many cases, competitive market prices coexist with regulated tariffs, limiting the full potential of liberalization. In addition, researchers have highlighted concerns about limited consumer engagement and high market concentration (Wilson & Price 2010).

The debate over the benefits of retail competition has persisted since the early 2000s. Two primary perspectives dominate the literature. P. Joskow (2000) argues that liberalizing the retail electricity market for households may not be entirely beneficial, as electricity is a homogeneous product, offering little room for differentiation. He suggests that households could achieve many of the advantages of competition by accessing the wholesale market directly, bypassing the additional costs associated with retail competition, such as marketing and advertising expenses. Additionally, Wilson & Price (2010) demonstrated that even in a relatively simple and transparent market, consumers often struggle to select the best alternative supplier. Their findings indicate that at least one-fifth of consumers experienced a loss in surplus after switching providers and that, in aggregate, consumers captured only half of the potential gains from switching.

In contrast, Littlechild (2000) argues that competition between retailers can drive innovations in processes and product offerings. Competitive pressure can lead to improvements in customer service, better cost transparency, and more efficient market operations, ultimately benefiting consumers through lower prices.

The available literature has analyzed the electricity retail market, focusing primarily on three key areas. First, studies that analyze household behavior and limitations in achieving the benefits of competition. The literature analyzes consumer behavior and consumer search costs in order to rationalize observed pricing patterns, finding that the results of competition in the electricity retail market for consumers can be poor, while switching costs hinder efficient choice (Giulietti et al. 2014; Dressler & Weiergraeber 2023; Gugler et al. 2023). In some cases, consumers rarely seek alternative retailers, and when they do, they attach brand advantage to the incumbent (Hortaçsu et al. 2017).

Second, the literature that focuses on the analysis of prices and pass-through. Empirical studies reveal an incomplete and asymmetric pass-through from wholesale to retail prices. This phenomenon is often characterized by slower pass-through rates for price decreases compared to price increases, along with significant price variations between different suppliers and contract types (Mirza & Bergland 2012). In addition, these studies also examine price formation and price discrimination in these markets (Byrne et al. 2023; Dormady et al. 2025). The pass-through rate differs between firms with a high market concentration and the remaining firms, as well as between urban and non-urban users. Furthermore, studies show that the pass-through rate of integrated power generation firms is lower than that of nonintegrated or independent firms, and differences between small and large retailers (Perez-Arriaga 2013; Duso & Szücs 2016; Correa-Giraldo et al. 2021; Brown et al. 2020)

Third, there is literature that evaluates market performance from the perspective of retailers. These studies analyze the dynamics of firms entering and exiting the market, estimate efficiency and productivity at the company level, and recover markups from a cost-based or flexible input approach. Despite its importance in understanding competitive behavior and informing public policies, research in this area remains limited.

In this last group, the work of (Stiel et al. 2018) stands out. The authors estimate firm-level productivity for German electricity retailers and investigate whether the ownership type has a significant impact on productivity, employing a control function approach to estimate the production function. They found no evidence that ownership affects productivity when comparing publicly owned and privately owned retailers. In contrast, (Di Leo et al. 2024) applies a robust order-m non-parametric frontier to benchmark Italian electricity retailers in a cross-section for 2020. They estimate two models: a cost-efficiency frontier and a commercial efficiency frontier focused on direct margin as a performance metric.

To our knowledge, there is currently no additional literature in the field of energy economics that examines the productivity of electricity retailers considering their dynamic behavior in the market.

Our work contributes to this latter group of studies. This is the first study to analyze the productivity of electricity retailers in Spain, utilizing a panel of time-series data that includes financial and market information on these retailers. Contributions to the literature are made in different ways, first, by incorporating the analysis used in industrial economics to estimate total factor productivity in a service market, such as electricity retail, and second, by employing the control function approach. Third, we employ the approach proposed by (Olley & Pakes 1996) to control for the problems of endogeneity and simultaneity that are typically present in this type of estimation, while considering the dynamics of electrical retailers, including the exit and entry of companies, as well as the presence of independent and vertically integrated retailers. Finally, the analysis enables us to compare the results in terms of productivity and estimate markups between vertically integrated companies and independent retailers.

The remainder of this paper proceeds as follows. Section 4.2 presents the framework for the production function and the methodology strategy. Section 4.3 discusses the data set used for the analysis. Section 4.4 details our results, distinguishing between vertically integrated and independent retailers throughout the analysis. Finally, Section 4.5 presents the main conclusions.

4.2 Production function framework and estimation methodology

Estimation of production functions for retail electricity is crucial to understanding firm performance, efficiency, and productivity in this sector. As highlighted previously, the Spanish electricity retail sector operates within a competitive market structure in which numerous firms compete to supply electricity to consumers. However, large vertically integrated electricity companies still maintain significant market shares, influencing price competition and market dynamics (Fabra & Reguant 2014). Market liberalization has facilitated the entry of new companies, yet it has also led to a substantial number of company exits due to intense competition and regulatory uncertainties (Newbery 2005).

This study focuses exclusively on firms operating within the free market, as their production structures differ significantly from those of Last Resort Retailers (LRRs). The free market retailers compete by offering different pricing schemes, contract structures, and additional services, whereas LRRs are subject to price regulations and act as suppliers of last resort under government-mandated conditions. Since LRRs operate under a cost-based regulatory framework with guaranteed customers, their operational decisions are fundamentally different from those of free-market firms. By isolating free-market firms, we estimate their production function more appropriately, reflecting competitive market dynamics without distortions from regulatory constraints specific to LRRs.

We use a dynamic optimization model with free and state variables to estimate unobservable productivity or technical efficiency. The state variables are typically capital. In our case, we use total assets as a proxy variable. In addition, free variables are typically labor inputs. We use labor measured in the number of workers and the consumption of intermediate materials, which mainly includes purchases of electrical energy.

4.2.1 Theoretical model

In this chapter, we follow Olley & Pakes (1996) and present a methodology based on the fundamental assumption that firms act as strategic agents, continuously evaluating their decision to remain in operation or exit the market. If a firm chooses to exit, it receives a liquidation value, Φ, and does not re-enter the market. Conversely, if it decides to remain, it strategically determines its input levels, including investment, to maximize future profits. Therefore, a firm's expected productivity follows a predictable pattern based on its current productivity, ω_{it}, and capital, k_{it}, that can be written as $E[\omega_{i(t+1)}|\omega_{it}, k_{it}]$, and profit generation is also influenced by these factors.

Company i is assumed to maximize the expected discounted value of its net future profits. Consequently, both its exit and investment decisions depend on its expectations regarding the distribution of future market structures, given the available information. Hence, the firm's strategy for optimizing the net present value of future profits is formally characterized by the Bellman equation

$$\begin{aligned} & V(k_{it}, \omega_{it}) \\ & = Max\left[\Phi,\ \sup_{r_{it}\geq 0} \Pi_{it}(k_{it}, \omega_{it}) - C(r_{it}) + \rho E\{V_{i(t+1)}(k_{i(t+1)}, \omega_{i(t+1)})|J_{it}\}\right], \end{aligned} \tag{4.1}$$

where $\Pi_{it}(\cdot)$ represents the profit function (i.e., current profits as a function of the state variables), r_{it} is the level of investment of the firm, $C(\cdot)$ is the cost of current investment, and ρ is the discount factor. The expected operator $E[\cdot|J_{it}]$ conditions the firm's expectations on available information at time t. The max operator indicates that a firm compares the sell-off value of its plant Φ to the expected discounted returns of staying in business. In particular, companies exit the market if their expected future profits fall below a critical threshold, defined by the liquidation value Φ.

The solution to this equation results in a Markov perfect equilibrium strategy, defining rules for exit and for investment decisions. Specifically, firm i will decide to stay in the market ($\chi_{it} = 1$), or exit the market ($\chi_{it} = 0$) if its productivity is greater than or less than some threshold subject to the firm's current capital stock, k_{it}. This exit rule is written as follows:

$$\chi_{it} = \begin{cases} 1 & \text{if } \omega_{it} > \omega^*_{it}(k_{it}) \\ 0 & \text{otherwise,} \end{cases} \tag{4.2}$$

where $\omega_{it}^{*}(\cdot)$ is the exit threshold and we assume that the state variable, ω_{it}, follows a first-order Markov process.

Furthermore, the firm's decision to invest in more capital, r_{it}, depends on the firm's productivity, ω_{it}, and capital stock, k_{it}:

$$r_{it} = I(\omega_{it}, k_{it}), \tag{4.3}$$

which implies that firms experiencing positive productivity shocks invest more to capitalize on future growth opportunities. In other words, firms that experience a large positive productivity shock in period t will invest more in period $(t + 1)$.

Provided that r_{it} is assumed to be strictly positive, we can write the inverse function for the unobserved shock ω_{it} as

$$\omega_{it} = I^{-1}(r_{it}, k_{it}) = h(r_{it}, k_{it}), \tag{4.4}$$

where $h(\cdot)$ is an unknown function. Since ω_{it} is strictly increasing in r_{it}, one can invert the investment demand function and thus "control for" the unobserved productivity shock by conditioning on a nonparametric representation of that inverse function (i.e., a nonparametric function of capital stock and investment), as is proposed in Olley & Pakes (1996). Appendix 4A presents the empirical specification.

4.2.2 Estimation procedure

Taking into account all these features that enable us to characterize the production function of the Spanish retail electricity sector, we propose an alternative estimation procedure based on the control function approach (Olley & Pakes 1996). More precisely, instead of instrumenting the endogenous regressors, we include additional regressors to capture the endogenous part of the error term of the equation to be estimated. In particular, we propose to address the simultaneity bias by replacing the unobserved productivity shock, ω_{it}, with the proxy function $h(r_{it}, k_{it})$ that produces the following production function after rearranging terms:

$$y_{it} = \beta_0 + k_{it}\beta_K + l_{it}\beta_L + m_{it}\beta_M + \phi(r_{it}, k_{it}) + \varepsilon^*_{it}, \tag{4.5}$$

where $\phi(r_{it}, k_{it}) = k_{it}\beta_K + h(r_{it}, k_{it})$ is an unknown function that accounts for unobserved productivity and enables us to eliminate the simultaneity bias and $\varepsilon^*_{it} = \varepsilon_{it} + [\omega_{it} - \phi(r_{it}, k_{it})]$ is the new error term.

Nevertheless, the above partially linear model allows us to identify the parameters for labor and capital (β_L, β_M), but not the production function coefficient of capital (β_K) since we are unable to separate the effect of capital on the investment decision from their effect on output. To address this issue, a two-step estimation procedure is proposed.

In the first stage, the parameters β_L and β_M and the function $\phi(\cdot)$ can be estimated using semiparametric techniques such as the kernel approach proposed in Robinson (1988). Alternatively, we propose to use a polynomial approximation to $\phi(\cdot)$ as in Olley & Pakes (1996). Hence, β_L and β_M can be consistently estimated as functions of y_{it}, k_{it}, l_{it}, m_{it}, and the polynomial. Note that this control function approach helps address the self-selection bias stemming from endogenous firm exit. Taking into account the unobserved productivity, ω_{it}, this first-stage ensures that the selection effects related to this unobservable factor do not distort the estimation.

The second stage deals with the identification of β_K for which the following assumptions are required:

(A1) The firm's information set at t, that is, r_{it}, includes current and past productivity shocks $\{\omega_{i\tau}\}_{\tau=0}^{t}$ but does not include future productivity shocks $\{\omega_{i\tau}\}_{\tau=t+1}^{\infty}$. The transitory shocks (ε_{it}) satisfy $E[\varepsilon_{it}|r_{it}] = 0$.

(A2) Productivity shocks evolve according to the distribution $p(\omega_{i(t+1)}|r_{it}) = p(\omega_{i(t+1)}|\omega_{it})$. This distribution is known to firms and is increasing stochastically in ω_{it}.

As noted in Ackerberg et al. (2015), these assumptions are straightforward since companies do not observe ω_{it} until time t, but the distribution $p(\omega_{i(t+1)}|\omega_{it})$ defines what the firm knows about the distribution of future productivity shocks. Also, Assumptions (A2) states that ω_{it} is first-order Markov. Hence, it can be decomposed into its conditional expectation at time $(t-1)$ and an innovation term, that is,

$$\omega_{it} = E[\omega_{it}|r_{t-1}] + \xi_{it} = E[\omega_{it}|\omega_{i(t-1)}] + \xi_{it} = g(\omega_{i(t-1)}) + \xi_{it}, \tag{4.6}$$

where ξ_{it} is an innovation term that is the mean independent of any information at $(t-1)$ or before, i.e., $E[\xi_{it}|r_{t-1}] = 0$.

Furthermore, to obtain consistent estimates for β_K the sample selection bias due to firm exit must be addressed. Recall that the exit rule explained above implies that a firm will choose to stay in the market if its productivity is greater than some threshold function $\omega_{it}^{*}(k_{it})$. Hence, the survival probability of the firm i in period t depends on $\omega_{i(t-1)}$ and $k_{i(t-1)}$, and in turn on capital and investment at time $(t-1)$. In our implementation, we estimate the probability of survival by fitting a probit model of χ_{it} to $r_{i(t-1)}$ and $k_{i(t-1)}$, as well as on their squares and cross products, obtaining the predicted probabilities, $\widehat{P}_{it}$.

Taking into account the expectation of $\{y_{it} - l_{it}\beta_L - m_{it}\beta_M\}$ conditional on the information in t and the survival, we can write

$$
\begin{aligned}
E[y_{it} - l_{it}\beta_L - m_{it}\beta_M | k_{i(t+1)}, \chi_{i(t+1)} = 1] &= \beta_0 + k_{i(t+1)}\beta_K + E[\omega_{i(t+1)}|\omega_{it}, \chi_{i(t+1)} = 1] \\
&= \beta_0 + k_{it}\beta_K + g(\omega^*_{i(t+1)}, \omega_{it}). \qquad (4.7)
\end{aligned}
$$

Substituting the predicted probabilities, $\widehat{P}_{it}$, and the nonparametric estimator obtained in the first-stage, $\widehat{\phi} = \hat{\phi}(r_{it}, k_{it})$, into $g(\cdot, \cdot)$ we obtain

$$
y_{it} - l_{it}\widehat{\beta}_L - m_{it}\widehat{\beta}_M = k_{it}\beta_K + g\left(\widehat{P}_{it}, \widehat{\phi}_{i(t-1)} - k_{it-1}\beta_K\right) + \xi_{it} + \varepsilon^*_{it}, \qquad (4.8)
$$

where $\xi_{it} = \omega_{it} - E[\omega_{it}|\omega_{i(t-1)}, \chi_{it} = 1]$ and $\widehat{\phi}_{i(t-1)} = \widehat{\phi}(r_{i(t-1)}, k_{i(t-1)})$. In this context, the unknown function $g(\cdot)$ is approximated by a second-order polynomial in $\{\widehat{\phi}_{i(t-1)} - k_{i(t-1)}\beta_K\}$ and $\widehat{P}_{it}$. Alternatively, we could use a kernel estimator for $g(\cdot)$, but that is beyond the scope of this paper. Note that the function $g(\cdot)$ is similar in spirit to the inverse of Mills' ratio that is included in two-step sample selection models, but it is complicated by the fact that in this framework the sample selection bias depends on two unknown variables (ω_{it} and ω^*_{it}), rather than just one (the probability of being in the selected subsample).

Finally, note that the estimation procedure involves three stages, and deriving the appropriate analytic standard errors is nontrivial. The command proposed in Yasar et al. (2008) uses the clustered bootstrap, treating all observations for a single firm as one cluster. Alternatively, Wooldridge (2009) shows how to obtain standard errors for the two-step Levinsohn & Petrin (2003) method based on the generalized method of moments. A similar argument could be used here, though implementing such an estimator in Stata would be challenging.

4.2.3 Estimation of firm-level markups

To estimate firm-level markups in the Spanish retail electricity market, we follow the approach proposed by De Loecker & Warzynski (2012) and Collard-Wexler & De Loecker (2015). This approach has been adapted to fit the structural production function framework established in this article. Using this methodology, we can recover markups without making assumptions about the specific nature of competition or the behavior of price-setting.

Markup is defined as the ratio between the output elasticity of an intermediate, such as materials and energy, and the corresponding expenditure share of the input. Specifically, for any variable input X_{it}^v, the firm's markup μ_{it} is given by

$$\mu_{it} = \frac{\theta_{it}^v}{\alpha_{it}^v}, \tag{4.9}$$

where θ_{it}^v is the output elasticity of the input v, estimated from the firm's production function, and α_{it}^v is the cost share of that input. In our implementation, this share is not expressed as a fraction of revenues but rather as the ratio between intermediate consumption and total sales in euros S_{it}, consistent with firm's accounting data,

$$\alpha_{it}^M = \frac{M_{it}}{\mathrm{S}_{it}}. \tag{4.10}$$

Given the structure of our model, we employ intermediate inputs M_{it} (mainly electricity procurement costs) as the variable input free of adjustment costs. The production function in simple terms is specified as the Cobb-Douglas form

$$Y_{it} = K_{it}^{\beta_K} L_{it}^{\beta_L} M_{it}^{\beta_M} e^{\omega_{it}+\varepsilon_{it}}, \tag{4.11}$$

where output Y_{it} is proxied by deflated revenues, and ω_{it} captures firm-specific productivity shocks. The parameters of the production function $(\beta_K, \beta_L, \beta_M)$ are estimated using the semi-parametric control function approach of Olley & Pakes (1996), corrected for selection bias due to firm exit, following Ackerberg et al. (2015). The final step consists of computing markups as

$$\mu_{it} = \frac{\hat{\beta}_M}{\alpha_{it}^M}, \tag{4.12}$$

where $\hat{\beta}_M$ is the estimated output elasticity of intermediate inputs. This estimator captures the gap between price and marginal cost and allows us to track heterogeneity in market power between firms and over time.

In line with the theoretical framework presented in Eqs. (4.1) to (4.14), markups are interpreted as endogenous outcomes reflecting both productivity and strategic firm behavior. In our analysis, we use these markups to assess how firm characteristics, such as vertical integration, market share, and sectoral dynamics, affect pricing behavior in the free electricity market.

4.2.4 Static and dynamic productivity decomposition

To complement the firm-level estimation of productivity and markups, we analyze how aggregate productivity in the Spanish electricity retail market is shaped by three related forces: changes in average firm productivity, market-share reallocation across firms, and firm turnover through entry and exit. Our decomposition strategy builds on the static Olley-Pakes decomposition (Olley & Pakes 1996), the dynamic extension proposed by Melitz & Polanec (2015), and the between-group reallocation framework used by Collard-Wexler & De Loecker (2015).

The starting point is aggregate productivity at time t, defined as the market-share-weighted average of firm-level productivity:

$$\Phi_t = \sum_{i=1}^{N_t} s_{it}\varphi_{it}, \tag{4.13}$$

where φ_{it} denotes firm-level productivity and s_{it} is firm i's market share, with $\sum_i s_{it} = 1$.

Following Olley & Pakes (1996), aggregate productivity can be decomposed into an unweighted mean and a covariance term:

$$\Phi_t = \bar{\varphi}_t + \sum_{i=1}^{N_t}(s_{it} - \bar{s}_t)(\varphi_{it} - \bar{\varphi}_t) = \bar{\varphi}_t + \mathrm{Cov}_t(\varphi_{it}, s_{it}), \tag{4.14}$$

where $\bar{\varphi}_t$ is the unweighted mean of firm productivity and $\bar{s}_t = 1/N_t$ is the average market share. The first term captures the average productivity of firms in the industry, while the covariance term captures allocative efficiency, that is, the extent to which firms with higher productivity also command larger market shares.

A positive covariance term indicates that more productive firms hold larger shares of the market, whereas a negative covariance term indicates misallocation, in the sense that relatively less productive firms account for a disproportionate share of output. This static decomposition is useful to describe the cross-sectional structure of productivity in each year, but it does not separately identify the contribution of entrants andfor describing the cross-sectional structure of productivity in each year, but it does not separately identify the contributionss important in settings with substantial firm turnover, because conventional decompositions may bias the measurement of entry and exit contributions.

Because the Spanish electricity retail market exhibits persistent heterogeneity between vertically integrated (VI) retailers and independent retailers (IND), we further decompose aggregate productivity by retailer type. Let $\psi \in \{VI, IND\}$ index the group to which a firm belongs. Aggregate productivity can then be written as:

$$\Phi_t = \sum_{\psi} s_{\psi t}\Phi_{\psi t}, \tag{4.15}$$

where $s_{\psi t}$ is the aggregate market share of group ψ and $\Phi_{\psi t}$ is the aggregate productivity of that group.

Using the logic of Collard-Wexler & De Loecker (2015), aggregate productivity can be decomposed into three components:

$$\Phi_t = \Phi_t^{\text{between}} + \text{Cov}_t^{\text{within}} + \text{Cov}_t^{\text{between}}, \tag{4.16}$$

where Φ_t^{between} denotes the average productivity component across retailer groups, $\text{Cov}_t^{\text{within}}$ captures allocative efficiency within each group, and $\text{Cov}_t^{\text{between}}$ captures allocative efficiency across groups.

The first term reflects differences in average productivity between vertically integrated and independent retailers. The within-group covariance term captures whether more productive firms obtain larger market shares inside each group. The between-group covariance term captures whether the retailer type with higher average productivity also commands a larger share of the market. This decomposition is particularly useful in our setting because it distinguishes reallocation across firms of the same organizational form from reallocation between retailer types.

To study the sources of productivity change over time, we adopt the dynamic Olley-Pakes decomposition proposed by Melitz & Polanec (2015). This approach extends the static OP framework by explicitly accounting for surviving firms, entrants, and exiters, while avoiding the measurement bias that may arise in decompositions that evaluate entry and exit against a single reference productivity level.

Let A denote the set of continuing firms between periods $t-1$ and t, B the set of entrants observed in period t, and C the set of firms that exit after period $t-1$. Aggregate productivity change can be written as:

$$\Delta\Phi_t = (\Phi_t^A - \Phi_{t-1}^A) + s_{Bt}\left(\Phi_t^B - \Phi_t^A\right) + s_{C,t-1}\left(\Phi_{t-1}^A - \Phi_{t-1}^C\right), \tag{4.17}$$

where the first term measures the contribution of continuing firms, the second term measures the contribution of entrants relative to surviving firms in period t, and the third term measures the contribution of exiting firms relative to surviving firms in period $t-1$.

Entrants contribute positively to aggregate productivity growth when they are more productive than the continuing firms they join in period t. Likewise, exit contributes positively when exiting firms are less productive than continuing firms in period $t-1$. By evaluating entrants and exiters relative to survivors in the corresponding period, the decomposition preserves the logic of the OP framework and avoids the bias associated with alternative decompositions based on a single productivity benchmark.

The contribution of continuing firms can then be further decomposed using the static OP logic:

$$\Phi_t^A - \Phi_{t-1}^A = \Delta\bar{\varphi}_t^A + \Delta\mathrm{Cov}_t^A, \tag{4.18}$$

where $\Delta\bar{\varphi}_t^A$ captures average productivity improvements among continuing firms and $\Delta\mathrm{Cov}_t^A$ captures market-share reallocation among them.

For empirical implementation and to facilitate interpretation in the results section, we report the dynamic decomposition in terms of four components:

$$\Delta\Phi_t = \mathrm{Cont}_t + \mathrm{Rel}_t + \mathrm{Cov}_t + \text{Net Entry}_t, \tag{4.19}$$

where Cont_t denotes within-firm productivity improvement among continuing retailers, Rel_t captures reallocation of market shares among continuing firms, Cov_t captures the interaction between productivity changes and changes in market shares, and Net Entry_t captures the net contribution of entry and exit. This empirical decomposition is the basis for Table 4.5.

4.3 Data

This study uses two sources of data: the Iberian Balance Sheet Analysis System (SABI) database and the Spanish National Markets and Competition Commission (CNMC). The SABI database is a comprehensive source that provides detailed financial and business information on companies operating in Spain and Portugal. To identify electricity retailers, we employ the statistical classification of economic activities in the European Community (abbreviated as NACE), specifically using industrial classification code 3514 (electricity retail). From balance sheets and income statements, we extract key financial variables, including operating revenue, material costs, employee costs, fixed assets, and the number of employees. The SABI database records a total of 1,105 observations, including their respective company name and tax identification number (NIF).

The CNMC provides critical information on the performance of electricity retailers in Spain through its electricity retail market monitoring reports. These reports contain annual data on the volume of consumers categorized by tariff type and market segment (residential, small and medium enterprises (SMEs), and industrial). In addition, they include sales figures (measured in kWh) for each market segment and tariff type. Geographical data on companies' marketing activities, such as the provinces and municipalities where they operate, is also available. Furthermore, the

CNMC identifies each firm by name and assigns two unique identifiers: the retailer's code and the NIF identification number (NIF ID). Additional data obtained from the CNMC includes the date of registration and deregistration of firms, as well as indicators related to the type of energy market in terms of CO_2 emission factors and the classification of energy sources as renewable or non-renewable.

Our dataset spans 12 years from 2010 to 2021. To construct our final dataset, we merged the SABI database with the CNMC reports using the unique NIF ID as an identifier. Since the number of companies recorded in SABI varies annually and some firms lack financial data for all relevant variables, we conducted a data-cleaning process. Specifically, we retained only companies that reported both operating revenues and sales in kWh, ensuring that the resulting sample contained firms with financial and market-related information.

Following this data-cleaning procedure, the final sample comprises 290 retailers that operate in the liberalized market, corresponding to 1,694 firm-year observations. The financial variables expressed in thousands of euros were deflated using the Industrial Producer Price Index for Energy (IPPIE) provided by the Spanish National Statistics Institute (INE). Furthermore, we excluded the eight Last Resort Retailers operating under the regulated tariff[1], thus focusing solely on retailers operating in the competitive market.

We focus on analyzing retailers operating in a free market because competitive conditions allow us to evaluate their productivity effectively. The free market provides the necessary diversity, dynamic incentives, and economic variability for a comprehensive empirical investigation. It is important to recognize that this market

[1]The excluded retailers are: Baser Comercializadora De Referencia, S.A. (R2-284), Energía XXI Comercializadora de Referencia S.L.U. (R2-292), Teramelcor S.L. (R2-532), Comercializador de Referencia Energético, S.L.U (R2-540), Régsiti Comercializadora Regulada, S.L.U (R2-290), Comercializadora Regulada, Gas & Power, S.A. (R2-356), Curenergía Comercializador de Último Recurso S.A.U. (R2-329), Energía Ceuta XXI Comercializadora de Referencia S.A. (R2-530). The full list is available at https://sede.cnmc.gob.es/listado/censo/16.

features differences in efficiency, cost structures, and innovation strategies that aim to attract new customers, characteristics that are often lacking in regulated markets.

In free markets, retailers are driven to optimize costs and innovate in areas such as contracting, renewable energy offers, marketing, and operations. In addition, the market is characterized by many entrants and exits, along with active switching among competitors. This dynamic environment is well-suited for productivity analysis.

One of the key contributions of this article is the creation of a unique and original database. This database was developed by combining information about electricity retailers from both the SABI database and the CNMC, as previously discussed. This database is built following a clear and consistent criterion aimed at capturing the behavior of electricity retailers through a productivity analysis.

Integrating two datasets with inherently different purposes (i.e., SABI compiles firms' financial information while CNMC provides data on the electricity market) entails several limitations that must be acknowledged: (i) not all firms listed in the CNMC database can be matched with corresponding financial records in SABI, leading to the exclusion of some electricity retailers due to missing financial information; (ii) this mismatch implies that certain firms exhibit complete coverage of market data over the full sample period while having only partial financial data, or vice versa, generating temporal inconsistencies that reduce representativeness over time and complicate the assessment of their true market presence; and (iii) entry and exit dates are not systematically reported in the CNMC records for all firms, so the duration of each retailer's market activity has been approximated based on the best available evidence.

Table 4.1 presents the descriptive statistics of the primary variables used in this study. Operating revenue, which represents the total income generated by a retailer

Table 4.1: Summary statistics for electricity retailers. 2010-2021.

Variable	N	Mean	Median	Sd.	Min	Max
Operating revenue (Thousand €)	1,441	282,429	8,126	1,572,815	0.01	17,100,000
Number of employees	1,169	33	6	112	1.00	1,114
Total assets (Thousand €)	1,447	90,591	2,951	556,545	0.68	9,791,818
Intermediate inputs (Thousand €)	1,429	258,488	7,223	1,426,323	0.25	15,900,000
Variation in fixed assets	1,088	4,174	16	37,269	0.01	759,077
Total personnel expenses (Thousand €)	1,220	2,674	242	12,340	0.01	143,706
Total power sales (MWh)	1,647	3,960,000	108,000	24,600,000	0	276,000,000
Total of active connections	1,647	256	29	698	1	7,623
Share of energy sales to the domestic sector.	1,645	0.34	0.23	0.30	0	1
Share of energy sales to the SME sector	1,645	0.40	0.35	0.29	0	1
Share of energy sales to the industrial sector	1,645	0.22	0.08	0.29	0	1
Emission factor	791	0.10	0	0.14	0	0.43
Retailers with 100% renewable energy marketed	1,647	0.29	0	0.45	0	1

from its core business activities, serves as the output variable in our analysis. In all models, we treat labor (l), capital (k), and intermediate inputs (m) as inputs to the production process. The OP model treats capital as a state variable, whereas labor and materials are freely chosen inputs. All nominal financial data were deflated using the Industrial Producer Price Index for Energy (IPPIE) to adjust for inflation.

On average, during the period analyzed, electricity retailers allocated approximately 40% of their total energy sales to SMEs, 34% to the residential sector, and 22% to the industrial sector.

We use the investment as a proxy variable, assuming that it is a monotonically increasing function of productivity. Gross investment is the sum of the net change in total assets from the previous year plus annual depreciation. A constant depreciation rate of 20% was applied, consistent with the usual parameters for assets in the electricity sector.

The emission factor of the electricity mix measures the CO_2 emissions (or CO2e) associated with the electricity consumed. This factor serves as an indicator of the energy sources used in electricity generation, where lower values signify a higher share of renewable or low-carbon energy sources. Additionally, we define a binary variable, Retailers with 100% Renewable Energy, which takes a value of 1 if the retailer has a CO_2 emission factor of zero, indicating exclusive reliance on renewable energy sources, and 0 otherwise.

4.4 Empirical results

4.4.1 Production function estimates

Table 4.2 presents the estimation results of four alternative production function specifications using panel data from the retail electricity sector. First, we estimate a baseline Cobb-Douglas linear production function using Ordinary Least Squares, including year dummy variables to capture common temporal variations affecting all retailers. This is extended by including a dummy variable that captures whether firms are vertically integrated while controlling for possible structural differences in productivity (OLS). The second case introduces firm-level fixed effects to control for time-invariant unobserved heterogeneity (FE). Finally, a semiparametric estimator addresses simultaneity and selection bias using the methodology described in Section 4.2.2 and Appendix 4B.

In panel A, we consider all retailers in the retail market, including both vertically integrated and independent retailers. Panel B shows the estimate for independent retailers. The OP1 function uses an estimate based on the (Olley & Pakes 1996) methodology. It addresses simultaneity issues, but does not account for selection bias. As a result, it overlooks the market dynamics of companies that exit during the analysis period. In contrast, the OP2 function provides estimates that address both the problem of simultaneity and selection bias.

The analysis shows that Spanish electricity retailers are intensive in the use of intermediate inputs, reflecting their role as the link between electricity producers and end users. Unlike generation companies, retailers do not produce electricity; instead, they procure it from third parties through several mechanisms, including participation in the day-ahead and intraday wholesale markets, signing of bilateral contracts or Power Purchase Agreements (PPAs) with generators, or through financial hedging instruments in futures markets. Capital is the second most important input, although to a lesser extent, focusing on the use of technological and communication infrastructure, as well as administrative facilities such as offices for operations and customer service.

Table 4.2: Production function coefficients

	Panel A. All Sample				**Panel B. Independent retailers**			
	OLS	FE	OP1	OP2	OLS	FE	OP1	OP2
l	0.0574***	0.0626***	0.0300***	0.0301**	0.0565***	0.0616***	0.0295***	0.0295**
	(0.0103)	(0.0159)	(0.0040)	(0.0129)	(0.0107)	(0.0167)	(0.0045)	(0.0145)
k	0.0563***	0.0669***	0.0770***	0.1063**	0.0562***	0.0674***	0.0796**	0.0639
	(0.0101)	(0.0174)	(0.0161)	(0.0480)	(0.0105)	(0.0182)	(0.0380)	(0.0432)
m	0.8887***	0.8855***	0.8998***	0.8998***	0.8882***	0.8862***	0.8986***	0.8986***
	(0.0080)	(0.0106)	(0.0224)	(0.0286)	(0.0083)	(0.0109)	(0.0223)	(0.0286)
VIn	0.0535	–	0.0302	0.0302	–	–	–	–
	(0.0407)	–	(0.0254)	(0.0598)	–	–	–	–
Years effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	1164	1164	910	1060	1105	1105	863	1005
Firms	–	227	197	226	–	218	189	216
R^2	0.9881	0.9881	–	–	0.9845	0.9845	–	–
F-stat	6371.81	1648.41	–	–	4948.96	1549.61	–	
CRS (p-value)	0.7002	0.2961	0.3100	0.3836	0.8853	0.3061	0.6900	0.8230

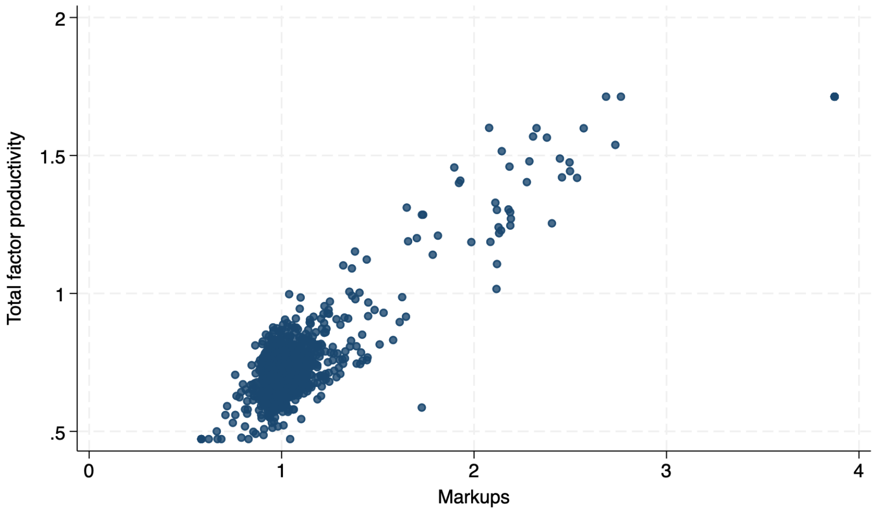
Note: Standard errors in parentheses. *, **, *** indicate significance at the 10%, 5%, and 1% levels, respectively.

The results in Table 4.2 do not reject the null hypothesis of constant returns to scale in any model specifications. This finding aligns with their role as intermediaries, where production technology is essentially linear and the primary input is purchased energy that is resold with a value-added margin.

4.4.2 Total factor productivity and markups

From the OP estimation, we plotted the total factor productivity of each retailer against their respective markups. Figure 4.1 shows a direct relationship between productivity levels and markups, which can be explained by developing competitive advantages that generate productive efficiency.

Figure 4.1: Total factor productivity and markups distributions.



Note: Author's own elaboration.

The scatter plot is denser in the lower markup range (around 1) and TFP values close to 0.7–1, suggesting that most companies operate with moderate margins and average productivity. Toward the right (markups > 2), fewer firms appear, typically with higher TFP levels. This result is consistent with the idea that more productive companies can afford to charge prices with a higher margin over their marginal costs because they enjoy competitive advantages.

The concentration of points near markup 1 suggests that much of the market operates under conditions close to perfect competition or with very low margins, possibly due to competitive pressure or an inability to differentiate themselves. The extreme values (outliers) on the upper right may represent dominant companies or market niches with low levels of direct competition.

Low productivity and markup levels among marketers can be attributed to independent marketers, who face difficulties in managing risk in the context of increasing wholesale electricity prices. As a result, they are exposed to unexpectedly high costs, which reduce their margins and distort their overall productivity.

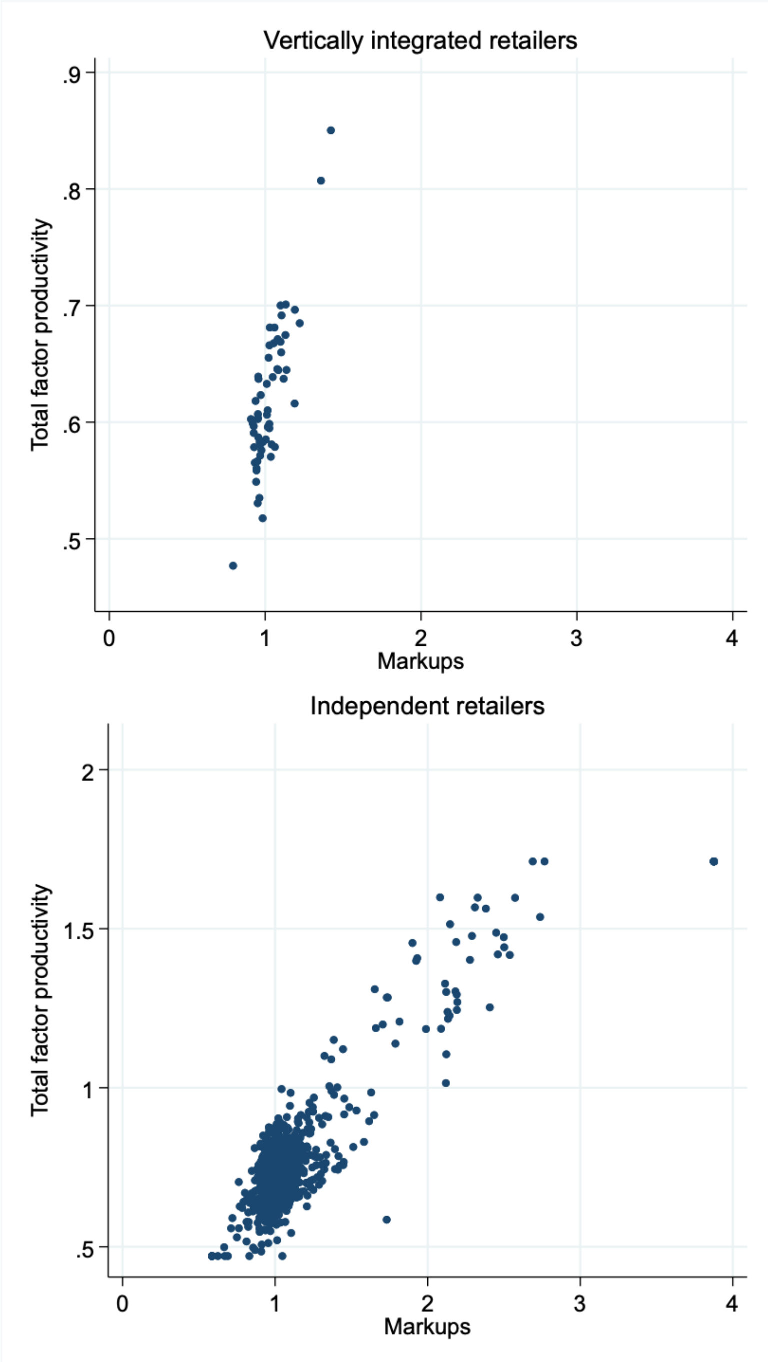
We empirically investigate the relationship between total factor productivity and markup, considering whether retailers are vertically integrated or independent. Vertical integration is a strategic characteristic that can influence both efficiency and market power. Theory suggests that more productive retailers tend to capture higher economic rents through prices above marginal cost.

Despite operating in the deregulated market, vertically integrated electricity retailers show lower and more homogeneous levels of total factor productivity than independent retailers. This situation can be explained by the structural and strategic factors inherent in their belonging to vertical conglomerates. In particular, these retailers probably do not face the same competitive pressure as independent retailers; the decisions of the former may be guided by the broader objectives of the energy group, prioritizing, for example, customer loyalty rather than optimization of operating performance in the retail market.

Figure 4.3 shows the distribution function of the total factor productivity and markup for the electricity retailers, differentiating between independent retailers and vertically integrated. On average, vertically integrated retailers exhibit lower productivity, as measured by the unobserved residual component of the Olley-Pakes model. In addition, the distribution of the integrated ones is sharper and more concentrated, which could indicate less internal heterogeneity in productivity and more uniform pricing structures.

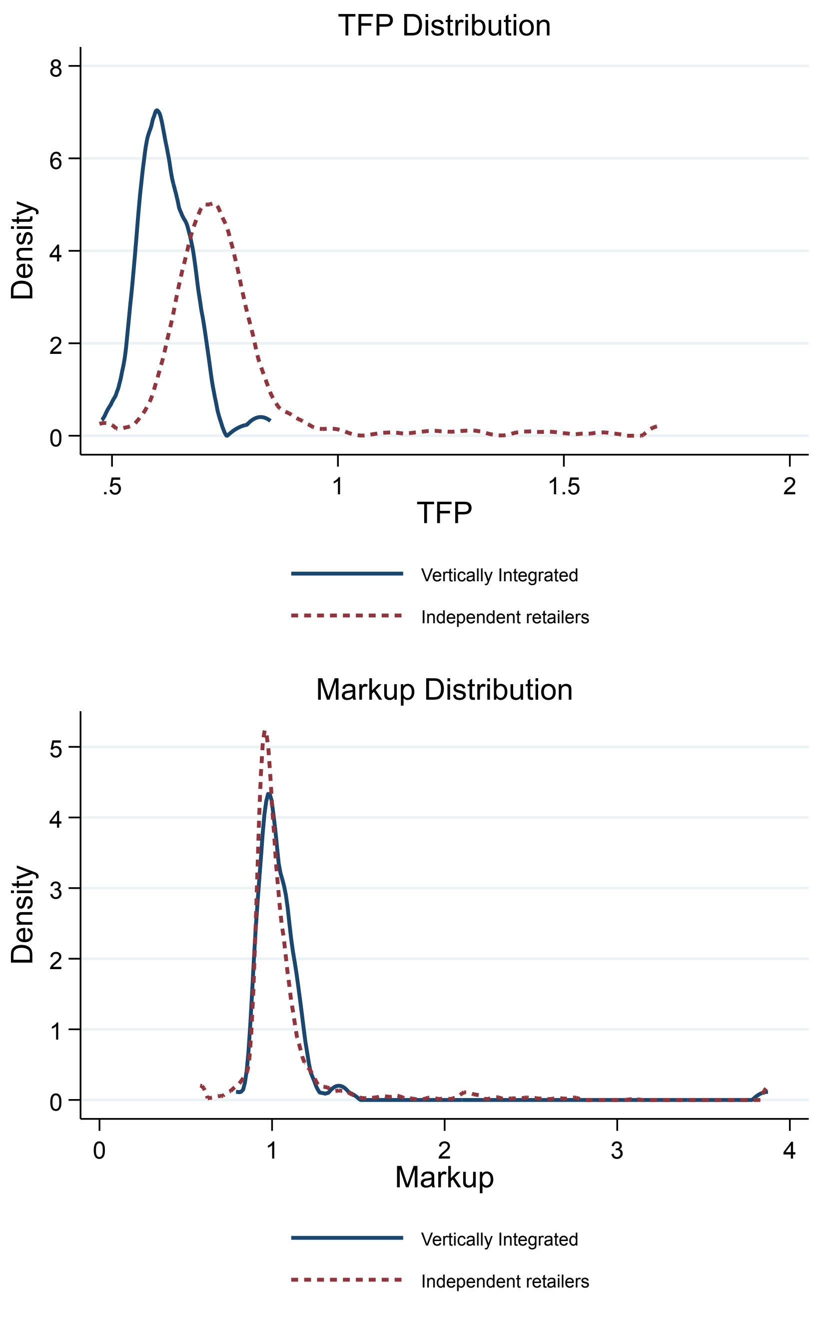
The distribution of markups is primarily clustered around unity, which may suggest prices that are largely aligned with marginal costs. As a result, for most retailers, the margin per kilowatt-hour (kWh) on their variable supply costs is small, meaning they have limited ability to set prices above the cost of purchasing and selling energy.

Figure 4.2: Joint distribution of total factor productivity and markups.



Note: Author's own elaboration.

Figure 4.3: Total factor productivity and markup distributions.

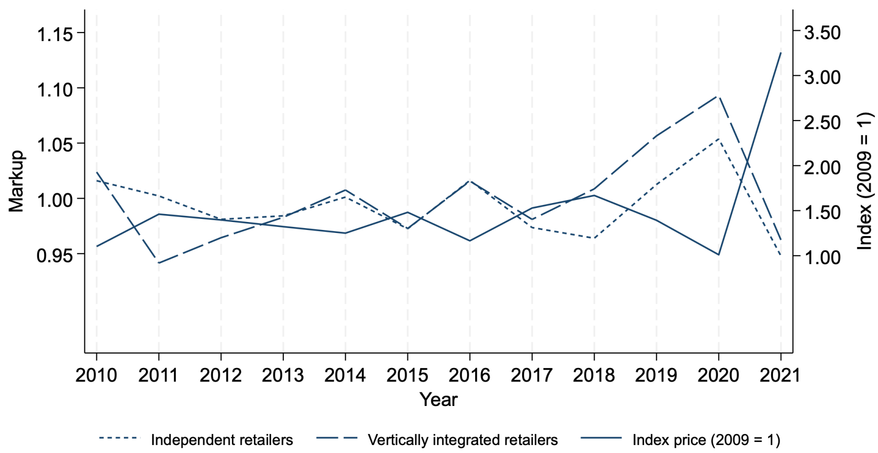


Note: Author's own elaboration.

When comparing groups, both have very similar profiles. However, the independent ones show less dispersion, while the integrated ones exhibit a slightly greater extension to the right. This may be compatible with greater heterogeneity in costs or the possibility of assuming hedging strategies against various specific supply, risk, and contract risks.

The Figure 4.4 shows the evolution of the markup during the analysis period, distinguishing between vertically integrated retailers and independent retailers. An index based on 2009 has been calculated for the average annual wholesale market price in EUR/MWh, using information provided by the electricity market operator. Two relevant findings can be observed, first the difference in markup between vertically integrated and independent retailers widened from 2017 onwards, but this gap narrowed in 2021, a time characterized by high prices. Second, in general, the markup shows an inverse relationship with respect to the calculated price index: when prices increase, the markup decreases, and vice versa. This observation is noteworthy because, when prices rise, retailers may attempt to avoid passing the entire price increase on to their customers, which compels them to reduce their margins.

Figure 4.4: Markup and index of the annual average day-ahead wholesale electricity price (2009 = 1).



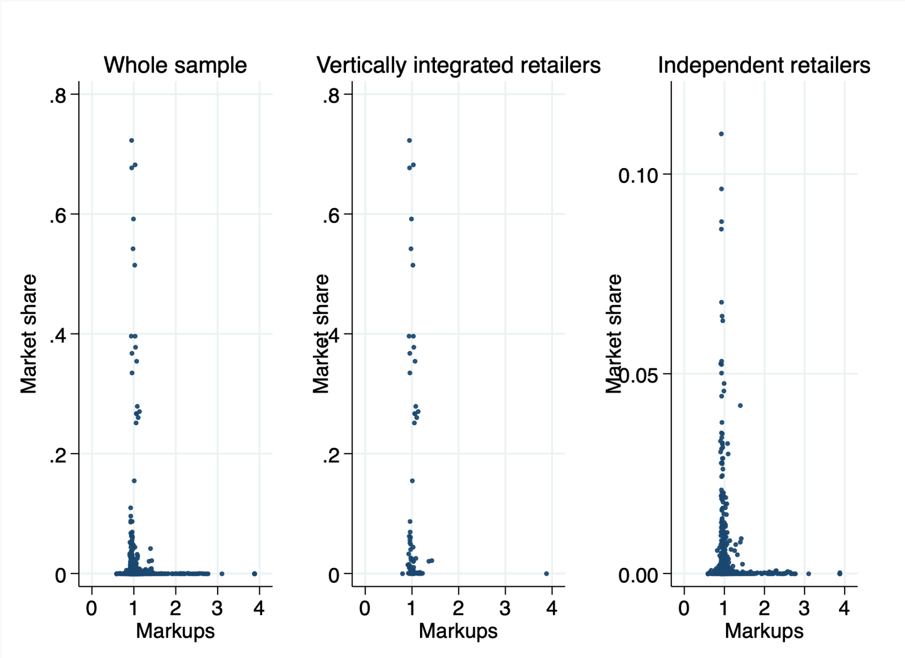
Note: Author's own elaboration.

4.4.3 Aggregate productivity decomposition and resource reallocation

To analyze the aggregate efficiency of the retailer market, we use the static productivity decomposition proposed by Olley and Pakes (1996), which allows us to distinguish between the average level of productivity and the efficiency in the allocation of resources among firms. The methodology assumes that more productive firms should have, in equilibrium, a larger market share. Formally, the total factor productivity (TFP) at the sectoral level can be expressed as the sum of the simple average of productivity between firms and a covariance component between each firm's market share and productivity.

Figure 4.5 presents the static decomposition results for all retailers, vertically integrated firms, and independent retailers. In the full sample, most firms cluster around markups close to one and very low market shares, indicating limited market power for the majority of competitors. Only a few firms achieve either high market shares or markups above two, suggesting a concentrated segment with stronger competitive advantages. Among vertically integrated firms, several companies maintain medium-to-high market shares (0.2–0.7) while maintaining moderate markups, reflecting that their advantage stems more from scale economies and upstream integration than from aggressive pricing. In contrast, independent retailers are concentrated at very low market shares (below 0.05) and markups close to one, highlighting their limited ability to influence prices and their dependence on wholesale markets. From an Olley-Pakes static decomposition perspective, the within-firm component dominates, as most productivity variation occurs inside firms with low market shares, while the between-firm reallocation effect is substantial only among vertically integrated firms.

Figure 4.5: Static decomposition: Market share and markups.



Note: Author's own elaboration.

We apply the static decomposition of aggregate productivity in the Spanish electricity retail sector. The decomposition separates the aggregate productivity observed into two components: (i) the unweighted average firm productivity ($\bar{\varphi}_t$), and (ii) an allocative efficiency component captured by the covariance between firm-level productivity and market share ($\text{Cov}_t(\varphi_{it}, s_{it})$).

Table 4.3 summarizes the results of this decomposition for each year between 2010 and 2021. The columns report $\bar{\varphi}_t$: average total factor productivity between firms; $\text{Cov}_t(\varphi_{it}, s_{it})$: the allocative efficiency term; $\Phi_t^{\text{OP}} = \bar{\varphi}_t + \text{Cov}_t$: aggregate productivity reconstructed by Olley-Pakes decomposition; $\Phi_t^{\text{agg}} = \sum_i s_{it} \cdot \varphi_{it}$: directly computed weighted average productivity.

The term of allocative efficiency is negative every year, indicating that more productive firms tend to have smaller market shares. This suggests a persistent misallocation of market share in the industry. As a consequence, Φ_t^{OP} and Φ_t^{agg} are systematically lower than average productivity $\bar{\varphi}_t$, showing that inefficiency in mar-

Table 4.3: Olley-Pakes static decomposition of aggregate productivity in the Spanish electricity retail market, 2010–2021

Year	$\bar{\varphi}_t$	$\mathrm{Cov}_t(\varphi_{it}, s_{it})$	Φ_t^{OP}	Φ_t^{agg}
2010	0.7903	-0.1637	0.6266	0.6161
2011	0.8191	-0.2176	0.6016	0.5954
2012	0.7204	-0.1484	0.5719	0.5687
2013	0.7557	-0.1302	0.6254	0.5874
2014	0.7460	-0.1312	0.6148	0.6079
2015	0.7153	-0.0825	0.6329	0.5003
2016	0.7555	-0.1270	0.6284	0.6175
2017	0.7481	-0.1223	0.6258	0.6222
2018	0.7500	-0.1045	0.6455	0.5889
2019	0.7468	-0.1177	0.6291	0.6007
2020	0.7438	-0.1097	0.6342	0.6076
2021	0.7442	-0.1167	0.6274	0.5964

ket allocation reduces overall sectoral performance. The close alignment between Φ_t^{OP} and Φ_t^{agg} provides empirical validation of the decomposition, confirming that the theoretical identity holds in practice. Consistent negative covariance suggests the presence of potential barriers, such as vertical integration and market power, which can prevent more productive firms from achieving a larger market share.

To further examine heterogeneity in aggregate productivity, we decompose the market by retailer type, distinguishing between vertically integrated retailers and independent retailers. Following the approach proposed by Collard-Wexler & De Loecker (2015), aggregate productivity is separated into three components: average productivity between retailer types, allocative efficiency within each group, and allocative efficiency across groups. Table 4.4 reports the empirical values of these components for the period 2010–2021.

The results show that the average productivity component of the group ($\Phi_t^{\mathrm{between}}$) remains consistently high and stable throughout the observed period, indicating that the differences in the average total factor productivity (TFP) between vertically integrated and independent retailers are not the main source of variation in aggregate performance. The above suggests that a significant portion of aggregate productivity comes from structural differences between marketers and reallocation toward the

Table 4.4: Between-group and within-group decomposition of aggregate productivity by retailer type, 2010–2021

Year	Φ_t^{between}	$\text{Cov}_t^{\text{within}}$	$\text{Cov}_t^{\text{between}}$	Φ_t^{total}
2010	0.795	-0.132	-0.016	0.647
2011	0.817	-0.141	-0.027	0.650
2012	0.722	-0.099	-0.021	0.602
2013	0.755	-0.082	-0.026	0.646
2014	0.748	-0.107	-0.011	0.630
2015	0.715	-0.040	-0.070	0.606
2016	0.757	-0.140	0.000	0.617
2017	0.749	-0.092	-0.013	0.644
2018	0.750	-0.099	-0.021	0.631
2019	0.747	-0.106	-0.013	0.628
2020	0.743	-0.112	-0.008	0.624
2021	0.744	-0.137	-0.003	0.603

most productive ones.

However, persistent within-group misallocation evidenced by a negative covariance term ($\text{Cov}_t^{\text{within}} < 0$) suggests that more productive firms within each group do not systematically hold larger market shares. On average, companies tend to reduce their productivity compared to their initial position. This inefficiency is further compounded by between-group misallocation ($\text{Cov}_t^{\text{between}} < 0$), implying that the group with higher average productivity does not necessarily dominate the market. As a result, aggregate productivity (Φ_t^{total}) remains consistently below its potential level, represented by Φ_t^{between}, due to the cumulative negative contribution of inefficiencies within and between group allocation.

We implement a dynamic decomposition of the total factor productivity (TFP). This approach separates aggregate productivity change into components attributable to incumbent firm performance, reallocation among incumbents, covariance between market share and productivity changes, and the net effect of firm entry and exit.

Table 4.5 summarizes the evolution of productivity between 2010 and 2021, taking into account the contribution of each dynamic component. The within-firm component (Cont_t) shows minor and oscillating effects, indicating that the improvements within incumbents were not the main driver of aggregate changes. The reallocation

Table 4.5: Dynamic decomposition of aggregate productivity growth into incumbent improvement, reallocation, and net entry, 2011–2021

Year	Cont_t	Rel_t	Cov_t	Net Entry_t	$\Delta\Phi_t$
2011	-0.029	-0.014	0.001	0.019	-0.022
2012	-0.008	0.064	-0.000	0.000	0.055
2013	0.036	-0.079	-0.008	0.004	-0.048
2014	0.001	-0.070	-0.001	0.001	-0.069
2015	-0.004	-0.106	-0.002	0.007	-0.106
2016	0.007	0.040	0.005	0.059	0.112
2017	-0.002	-0.003	0.000	0.000	-0.005
2018	0.008	0.001	-0.000	0.000	0.010
2019	-0.011	0.026	-0.000	0.000	0.015
2020	0.007	-0.029	-0.000	0.000	-0.021
2021	-0.008	-0.029	0.000	0.000	-0.037
Total	0.000	-0.012	-0.000	0.007	-0.005

term (Rel_t) is often negative, revealing that the market share tended to shift to less productive firms. The covariance effects (Cov_t) were minimal, with a negligible interaction between the changes in productivity and the changes in the share. The net entry term was positive, indicating that the entrants contributed more positively than the productivity lost through firm exits. In general, the net change in aggregate productivity ($\Delta\Phi_t$) was slightly negative throughout the period.

The stagnation in aggregate productivity might be due to the poor reallocation of market shares between existing retailers. At the same time, the entry of new firms contributes marginally, and internal improvements in existing retailers are not sufficient to reverse the negative trend.

The comparison between the results of the static decomposition and the dynamic decomposition reveals a persistent pattern of resource misallocation and limited productivity mobility in the Spanish electricity retail market. The most productive retailers neither gain market share nor displace the less efficient ones. In static decomposition, the allocative efficiency component ($\text{Cov}_t(\varphi_{it}, s_{it})$) is negative in all analyzed years, indicating that the most productive companies are not necessarily those with the largest market shares. This finding suggests a weak link between productivity and market participation, possibly associated with structural barriers such as vertical integration and customer lock-in by vertically integrated retailers. Consequently, aggregate productivity (Φ_t^{OP}) remains systematically below its potential level, reflecting a sector-wide loss of efficiency driven by poor resource reallocation.

The dynamic decomposition confirms these findings and further shows that the net entry effect of firms is positive but marginal, suggesting that new entrants are, on average, more productive than exiting firms. However, their limited market weight prevents this positive contribution from reversing the overall stagnation in aggregate productivity.

4.4.4 Markups and vertical integration

In this section, we are interested in empirically analyzing whether vertically integrated electricity retailers have different markups. The analysis of markups provides relevant aspects of firms' market power, cost efficiency, and competitive behavior in the electricity retail market. According to the literature, higher markups may arise from either efficiency advantages or market power, depending on the structure of competition, entry barriers, and cost heterogeneity across firms (De Loecker & Warzynski 2012; Collard-Wexler & De Loecker 2015). In the context of electricity retailing, vertical integration can play a decisive role in shaping these outcomes. Integrated retailers that also participate in generation or distribution may enjoy lower marginal costs, improved risk management, and more stable input prices, leading to higher markups compared to independent retailers.

This empirical exercise is particularly useful not necessarily for identifying causal relationships between markups and specific firm characteristics but for uncovering systematic correlations that reveal underlying patterns of heterogeneity across retailers. To this end, we present the following empirical specification:

$$\ln \mu_{it} = \delta_0 + \delta_1 VIn_{it} + \mathbf{b}'_{it}\theta + \varepsilon_{it}, \tag{4.20}$$

where $\ln \mu_{it}$ denotes the logarithm of the firm level markup, VIn_{it} is a dummy variable equal to one for vertically integrated retailers and zero otherwise, and δ_1 measures the percentage markup premium for vertically integrated retailers. In addition, $\mathbf{b}'_{it}$ is a vector of control variables capturing firm-specific, time-varying characteristics - such as productivity— and an indicator equal to one when the retailer's electricity sales are entirely sourced from renewable generation, and zero otherwise; θ denotes the associated coefficients.

We present the main results of our markup analysis using a variety of estimates. Table 4.6 presents the results of the estimates that analyze the determinants of markup for electricity retailers. The first two columns report individual relationships between the markup and each of the key variables considered: vertical integration and total factor productivity. The third column displays the complete specification.

The vertical integration of an electricity retailer positively influences its markups compared to independent retailers. This advantage arises because integrated retailers, which are part of a group that also generates and distributes electricity, may have structural advantages. An independent retailer purchases all its energy on the wholesale market (pool or bilateral agreements with third parties) and is therefore fully exposed to price volatility. On the other hand, an integrated retailer, although it must also purchase energy on the wholesale electricity market, can cover part of its sales through intra-group forward contracts (internal PPAs)[2], which act as a

[2]For example, the Endesa and Iberdrola groups sold around 60% of their production through this type of contract between 2017 and 2020 (Bank of Spain 2023). In 2023, intragroup bilateral contracts represented 74% of the total bilateral volume, compared to 82% in 2022 (Comisión Nacional de los Mercados y de la Competencia (CNMC) 2024b).

natural hedge, since even if the market price increases, the generation costs of these power plants remain low.

Reports from Comisión Nacional de los Mercados y de la Competencia (CNMC) (2024a) have shown that vertically integrated retailers that use non-fossil fuel generation technologies are not affected by the rising fuel costs. As a result, they can offer lower average electricity prices compared to independent retailers. Similarly, retailers without their own generation facilities were not covered in the forward market and were therefore unable to meet their commitments under fixed-price contracts. This situation has contributed to the tendency for some retailers to exit the market.

Following De Loecker & Warzynski (2012), once we control for productivity and differences in marginal costs, the vertically integrated coefficient detects the variation in average prices between vertically integrated and independent retailers.

$$(lnP_{it} - lnC_{it}) = \delta_0 + \delta_1 VIn_{it} + \delta_2 \omega_{it} + \mathbf{b}'_{it}\theta + \varepsilon_{it}, \tag{4.21}$$

where the coefficient δ_1 measures the average price differences if ω_{it} picks up fully. The positive and highly significant coefficient associated with total factor productivity indicates that more productive electricity retailers achieve higher price-cost margins or markups. In this context, retailers with better operational performance are able to maintain higher markups by lowering their average costs and optimizing their energy procurement strategies.

The results show that retailers selling 100% renewable energy tend to have higher markups than those selling energy from conventional or fossil fuel sources. This result may be attributed to product differentiation, as consumers are willing to pay for green energy and benefit from the cost stability provided by long-term contracts

(PPAs) with renewable generators. The growing demand for 100% renewable electricity, backed by Guarantees of Origin (GOs) managed by the CNMC, can be seen in the increase in the issuance of GOs, which in 2010 was 76,476 GWh, while in 2021 it reached 121,905, a significant growth also reflected in the number of retailers participating in the system, although with significant variations over time.

This suggests that the promotion of renewable energy is a source of additional value, regardless of the corporate structure or degree of integration. Thus, the sale of electricity from renewable sources represents an equally favorable strategy for all participants in the retail market.

Table 4.6: Determinants of electricity retailers' markups

	(1)	(2)	(3)
Vertically Integrated (VIn)	-0.0143	0.1221***	0.1281***
	(0.0260)	(0.0180)	(0.0575)
Log Productivity (ω)		0.8584***	0.8625***
		(0.0567)	(0.0575)
Renewable (Ren)			0.0257**
			(0.0110)
Years effects	Yes	Yes	Yes
Observations	1,429	1,164	1,164
Firms	271	227	227
R^2	0.0250	0.8206	0.8223
F-statistic	2.75	44.49	41.72
Prob > F	0.0015	0.0000	0.0000

Note: Robust standard errors clustered at the firm level (*firmid*). *, **, and *** denote statistical significance at the 10%, 5%, and 1% levels, respectively. Model (4) includes interaction terms between vertical integration and renewable status, as well as total factor productivity (Olley–Pakes) and year fixed effects.

4.5 Conclusions

Our findings indicate that Spanish electricity retailers are highly intensive in intermediate inputs, reflecting their role between electricity generators and end users. Retailers do not generate electricity; instead, they acquire it through wholesale markets, bilateral contracts, and long-term power purchase agreements, and operate with a production technology in which proportional increases in input lead to proportional increases in output.

Even in a liberalized market, vertically integrated electricity retailers exhibit lower and more homogeneous total factor productivity (TFP) than independent retailers. A pattern that may be related to their belonging to an energy conglomerate. In particular, integrated retailers are likely to face weaker competitive pressure and align decisions with group-wide objectives, such as customer retention or market-share preservation, rather than strict optimization of retail-level operating performance. The distribution of markups is similar between vertically integrated and independent retailers, suggesting that prices are primarily aligned with marginal costs. As a result, most independent retailers have limited ability to set prices above the cost of purchasing and selling energy.

Productivity decomposition reveals persistent resource misallocation in the market; more productive firms do not gain market share, and although new entrants are relatively efficient, their limited scale prevents any significant improvement in aggregate productivity. Finally, our results show that vertical integration significantly increases markups for electricity retailers. This reflects the structural advantages of intra-group contracts, which mitigate wholesale price volatility. Retailers selling 100% renewable energy also exhibit higher markups, consistent with product differentiation and cost stability from long-term investments. The value of renewable commercialization benefits both independent and integrated retailers.

Vertically integrated retailers do not, on average, show higher profit margins compared to independent retailers. However, they do have a markup premium when controlled for productivity and 100% renewable supply. This suggests advantages in risk management and hedging, such as the possibility of as intra-group contracts and Power Purchase Agreements (PPAs). Consequently, selling 100% renewable energy is linked to slightly higher markups, which aligns with the notions of product differentiation and reduced vulnerability to fluctuations in fossil fuel prices.

Differences in prices and observed markup heterogeneity may be partially explained by variation in demand elasticities and consumer switching costs. Vertically integrated retailers, which typically have more stable customer bases and access to generation assets, are likely to face less elastic demand, enabling them to have higher markups without substantial customer loss. In addition, consumer stickiness arising from switching costs, contractual inertia, or information frictions tends to reduce competitive pressure and limit the extent of cost pass-through to final prices.

At the same time, productivity improvements and sales guarantees, such as long-term or intragroup contracts, can offset some of the effects of market power by reducing marginal costs and stabilizing revenues. Therefore, the positive and significant association between productivity and markups reflects both efficiency gains and lower exposure to wholesale price volatility, rather than the exercise of pure market power.

Appendix 4A. Empirical specification

To, estimate the production function for the companies in the Spanish retail electricity market we consider the following Cobb-Douglas specification

$$Y_{it} = K_{it}^{\beta_K} L_{it}^{\beta_L} M_{it}^{\beta_M} e^{u_{it}}, \tag{4.22}$$

where Y_{it} represents the output of firm i at time t (e.g., electricity supplied or revenue), K_{it} is the capital stock, L_{it} is labor input, M_{it} represents material inputs, and u_{it} is a composed error term such as $u_{it} = \varepsilon_{it} + \omega_{it}$ where w_{it} represent the firm-specific productivity that is a state variable known by the firm with it makes its capital and labor decisions but unobserved for the researcher, and ε_{it} is an error term capturing unobserved shocks. Taking logs, we obtain the estimable equation:

$$y_{it} = \beta_0 + k_{it}\beta_K + l_{it}\beta_L + m_{it}\beta_M + \omega_{it} + \varepsilon_{it}, \tag{4.23}$$

where lowercase variables denote logarithmic transformations.

The Cobb-Douglas specification comes with the specific restriction that the elasticity of substitution is equal to one and that output elasticities are the same across all firms. This means that it does not account for varying degrees of substitution, such as in situations where the factors act as complements or have greater than one elasticity of substitution.

Estimation of this type of production function encounters several well-documented econometric challenges, including simultaneity bias and sample selection bias. However, traditional methods such as ordinary least squares (OLS) and fixed effects fail to adequately address these issues, leading to biased and inconsistent coefficient estimates. See Mundlak (1961), Mundlak (1963), & Mundlak (1996), Christensen, Jorgenson, et al. (1973), Christensen & Greene (1976), and Panzar (1989), among others.

Simultaneity bias arises because firms determine their input levels (e.g., capital and intermediate inputs) based on their productivity. This often includes unobserved factors known to the firm but not to researchers, resulting in omitted variable bias. When firms adjust their input levels in response to these unobserved productivity shocks, as expected under profit-maximizing or cost-minimizing behavior, the input choices become endogenous (Marschak & Andrews 1944). This issue is particularly relevant in the electricity retail sector, where firms adjust labor, capital, and procurement decisions in response to expected demand and regulatory changes (Fabra & Toro 2005).

Sample selection bias arises in the estimation of production functions because firms that exit the market are not randomly selected from the population. In general, firms decide to remain in the market if their continuation value exceeds their exit value:

$$d_{it} = \mathbb{1}\left\{V^1(k_{it}, \omega_{it}) - V^0(k_{it}, \omega_{it}) > 0\right\}, \tag{4.24}$$

where $\mathbb{1}\{\cdot\}$ is an indicator function such that $\mathbb{1}\{S\} = 1$ if statement (S) is true and $\mathbb{1}\{S\} = 0$ otherwise, $V^1(\cdot)$ is the continuation value which represents the expected present value of future profits, and $V^0(\cdot)$ is the exit value which includes the liquidation value of assets minus exit-related costs such as severance payments and contractual obligations.

The difference inside the indicator function in Eq. (4.24) is increasing in all arguments, implying that all the inputs are more productive in the current firm than in the best alternative use. Therefore, the function is invertible with respect to the productivity shock, ω_{it}, and the optimal exit/stay decision can be written as a single-threshold condition

$$d_{it} = \mathbb{1}\left\{\omega_{it} \geq V(k_{it})\right\}, \tag{4.25}$$

where $V(k_{it})$ is a decreasing function in all its arguments, which means that firms with a lower productivity are more likely to exit (Jovanovic 1982), and $\mathbb{1}\{\cdot\}$ is an indicator function.

In this context, since the estimation of the above production function is based only on firms that survived at the period t (i.e., $d_{it} = 1$), the self-selected productivity shock is not mean-independent of k_{it} since

$$E[\omega_{it}|k_{it}, d_{it} = 1)] = E[\omega_{it}|k_{it}, \omega_{it} \geq V(k_{it})] = \lambda(k_{it}), \tag{4.26}$$

where $\lambda(k_{it})$ is the selection term. Therefore, the production function can be written as

$$y_{it} = \beta_0 + k_{it}\beta_K + l_{it}\beta_L + m_{it}\beta_M + \lambda(k_{it}) + \omega_{it}^* + \varepsilon_{it}, \tag{4.27}$$

where $\omega_{it}^* = \{\omega_{it} - \lambda(k_{it})\}$ is the mean independent of k_{it} by construction. Ignoring the selection term $\lambda(k_{it})$ leads to biased estimates of the parameters of the production function. Specifically, since the selection function is decreasing in both inputs, labor and capital are negatively correlated with the selection bias. However, the correlation with capital stock is typically stronger because firm utility is more sensitive to capital investment than to labor. As a result, the estimated coefficient on capital, β_K, is systematically biased downward, underestimating the true coefficient of capital to production (Ackerberg et al. 2015).

During the last three decades, the methodology developed by Olley & Pakes (1996), and subsequently refined by Levinsohn & Petrin (2003) and Ackerberg et al. (2015), to address these endogeneity issues have been widely applied in empirical research (see Fernandes (2007), Blalock & Gertler (2004), Alvarez & López (2005), Sivadasan

(2009), and Ozler & Yilmaz (2009), among others). In the following, we present a semiparametric approach inspired by Olley & Pakes (1996) to provide a more accurate measure of productivity in the Spanish retail electricity sector, contributing to the literature on firm dynamics in regulated industries. The findings have important policy implications, particularly in evaluating the impact of market liberalization and regulatory interventions on firm performance and industry structure.

Appendix 4B. Appendix probit estimation of firm survival

The first-stage results from the Probit model indicate that higher-order polynomial terms of capital and investment have a statistically significant effect on the probability of firm survival. In particular, the squared term of investment (linv^2) has a negative and significant coefficient at the 5% level, suggesting that higher levels of investment volatility reduce the likelihood of continuation. Furthermore, several interaction terms, such as $k \cdot$ linv^2, $k^2 \cdot$ linv^2, $k^3 \cdot$ linv, and $k \cdot$ linv^3—are also significant, highlighting the complex nonlinear relationship between firm inputs and survival probabilities. Interestingly, the estimated productivity proxy ($\hat{\phi}$) does not significantly affect exit decisions in this specification, potentially indicating that firm continuation is more sensitive to capital and investment dynamics than to short-term productivity fluctuations.

Table 4.7: Probit estimation of firm survival (first stage – Olley-Pakes)

Variable	Coefficient	Std. Err.	z	P> $\|z\|$
k	5.856	11.767	0.50	0.619
linv	-4.760	9.260	-0.51	0.607
k^2	-7.545	4.678	-1.61	0.107
linv^2	-8.516	3.873	-2.20	0.028
k^3	0.662	0.433	1.53	0.126
linv^3	2.065	0.749	2.76	0.006
$k \cdot$ linv	15.754	7.694	2.05	0.041
$k^2 \cdot$ linv	0.096	0.532	0.18	0.857
$k \cdot$ linv^2	-2.760	1.087	-2.54	0.011
$k^2 \cdot$ linv^2	0.339	0.145	2.34	0.019
$k^3 \cdot$ linv	-0.147	0.067	-2.19	0.028
$k \cdot$ linv^3	-0.196	0.080	-2.45	0.014
$\hat{\phi}$ (productivity)	-0.026	0.118	-0.22	0.825
Int_Vert	-0.154	0.642	-0.24	0.810
Constant	-4.275	11.247	-0.38	0.704

Bibliography

Ackerberg, D. A., K. Caves, and G. Frazer (2015). Identification properties of recent production function estimators. *Econometrica* 83 (6), 2411–2451.

Alvarez, R., and R. A. López (2005). Exporting and Performance: Evidence from Chilean Plants. *Canadian Journal of Economics / Revue canadienne déconomique* 38 (4), 1384–1400.

Amenta, C., M. Aronica, and C. Stagnaro (2022). Is more competition better? Retail electricity prices and switching rates in the European Union. *Utilities Policy* 78, 101405.

Bank of Spain (2023). *Vertical integration and competition in the Spanish electricity market.* Tech. rep. Occasional Paper No. 2316. Banco de España.

Blalock, G., and P. J. Gertler (2004). Learning from exporting revisited in a less developed setting. *Journal of Development Economics* 75 (2), 397–416.

Brown, D., C. Tsai, C. Woo, J. Zarnikau, and S. Zhu (2020). Residential electricity pricing in Texas's competitive retail market. *Energy Economics* 92, 104953.

Byrne, D. P., L. A. Martin, and J. S. Nah (2023). Price Discrimination by Negotiation: A Field Experiment in Retail Electricity. *The Quarterly Journal of Economics* 137 (4), 2499–2537.

Christensen, L. R., and W. H. Greene (1976). Economies of Scale in U.S. Electric Power Generation. *Journal of Political Economy* 84 (4), 655–676.

Christensen, L. R., D. W. Jorgenson, and L. J. Lau (1973). Transcendental Logarithmic Production Frontiers. *The Review of Economics and Statistics* 55 (1), 28–45.

Collard-Wexler, A., and J. De Loecker (2015). Reallocation and Technology: Evidence from the U.S. Steel Industry. *American Economic Review* 105 (1), 131–171.

Comisión Nacional de los Mercados y de la Competencia (CNMC) (2024a). *Informe de Supervisión de los Mercados Minoristas de Gas y Electricidad: año 2022 y avance 2023*.

— (2024b). *Reporte de Supervisión del mercado mayorista, 2023*. Informe técnico IS/DE/029/24. CNMC.

Concettini, S., and A. Creti (2014). Liberalization of electricity retailing in Europe: What to do next? *Energy Studies Review* 21, 1–25.

Correa-Giraldo, M., J. J. García-Rendón, and A. Perez (2021). Strategic behaviors and transfer of wholesale costs to retail prices in the electricity market: Evidence from Colombia. *Energy Economics* 99, 105276.

De Loecker, J., and F. Warzynski (2012). Markups and Firm-Level Export Status. *American Economic Review* 102 (6), 2437–2471.

Defeuilley, C. (2009). Retail competition in electricity markets. *Energy Policy* 37 (2), 377–386.

Di Leo, S., M. Chicca, C. Daraio, A. Guerrini, and S. Scarcella (2024). A robust benchmarking of direct margin in Italy's energy retail markets. *Utilities Policy* 86, 101701.

Dormady, N., A. Roa-Henriquez, M. Hoyt, M. Pesavento, G. Koenig, W. Welch, and Z. Li (2025). How are retail prices formed in restructured electricity markets? *Energy Economics* 143, 108243.

Dressler, L., and S. Weiergraeber (2023). Alert the Inert? Switching Costs and Limited Awareness in Retail Electricity Markets. *American Economic Journal: Microeconomics* 15 (1), 74–116.

Duso, T., and F. W. Szücs (2016). Market Power and Heterogeneous Pass-Through in German Electricity Retail. *ERN: Energy (Topic)* 98, 354–372.

Fabra, N., and M. Reguant (2014). Pass-Through of Emissions Costs in Electricity Markets. *American Economic Review* 104 (9), 2872–99.

Fabra, N., and J. Toro (2005). Price wars and collusion in the Spanish electricity market. *International Journal of Industrial Organization* 23 (3), 155–181.

Fernandes, A. M. (2007). Trade policy, trade volumes and plant-level productivity in Colombian manufacturing industries. *Journal of International Economics* 71 (1), 52–71.

Giulietti, M., M. Waterson, and M. Wildenbeest (2014). Estimation of Search Frictions in the British Electricity Market. *The Journal of Industrial Economics* 62 (4), 555–590.

Gugler, K., S. Heim, M. Janssen, and M. Liebensteiner (2023). Incumbency Advantages: Price Dispersion, Price Discrimination, and Consumer Search at Online Platforms. *Journal of Political Economy Microeconomics* 1 (3), 517–556.

Hortaçsu, A., S. A. Madanizadeh, and S. L. Puller (2017). Power to Choose? An Analysis of Consumer Inertia in the Residential Electricity Market. *American Economic Journal: Economic Policy* 9 (4), 192–226.

Joskow, P. (2000). "Deregulation and Regulatory Reform in the U.S. Electric Power Sector". *Deregulation of Network Industries: What's Next?* Ed. by S. Peltzman, and C. Winston. Washington, DC: American Enterprise Inst.–Brookings Joint Center for Regulatory Studies, 113–154.

Joskow, P. L. (2008). Lessons learned from electricity market liberalization. *The Energy Journal* 29 (2_suppl), 9–42.

Jovanovic, B. (1982). Selection and the Evolution of Industry. *Econometrica* 50 (3), 649–670.

Levinsohn, J., and A. Petrin (2003). Estimating production functions using inputs to control for unobservables. *The Review of Economic Studies* 70 (2), 317–341.

Littlechild, S. C. (2000). “Why we need electricity retailers: A reply to Joskow on wholesale spot price pass-through”. Research Paper in Management Studies, Judge Institute of Management Studies Cambridge, University of Cambridge.

Marschak, J., and W. H. Andrews (1944). Random Simultaneous Equations and the Theory of Production. *Econometrica* 12 (3/4), 143–205.

Melitz, M. J., and S. Polanec (2015). Dynamic Olley–Pakes productivity decomposition with entry and exit. *The RAND Journal of Economics* 46 (2), 362–375.

Mirza, F. M., and O. Bergland (2012). Pass-through of wholesale price to the end user retail price in the Norwegian electricity market. *Energy Economics* 34 (6), 2003–2012.

Mundlak, Y. (1961). Empirical Production Function Free of Management Bias. *American Journal of Agricultural Economics* 43 (1), 44–56.

— (1963). Specification and Estimation of Multiproduct Production Functions. *American Journal of Agricultural Economics* 45 (2), 433–443.

— (1996). Production Function Estimation: Reviving the Primal. *Econometrica* 64 (2), 431–438.

Newbery, D. (2005). Electricity liberalization in Britain: The quest for a satisfactory wholesale market design. *The Energy Journal* 26, 43–70.

Olley, G. S., and A. Pakes (1996). The Dynamics of Productivity in the Telecommunications Equipment Industry. *Econometrica* 64 (6), 1263–1297.

Ozler, S., and K. Yilmaz (2009). Productivity response to reduction in trade barriers: evidence from Turkish manufacturing plants. *Review of World Economics* 145, 339–360.

Panzar, J. C. (1989). “Technological determinants of firm and industry structure”. *Handbook of Industrial Organization*. Ed. by R. Schmalensee, and R. D. Willig. Vol. 1. Amsterdam: North-Holland/Elsevier. Chap. 1, 3–59.

Perez-Arriaga, I. (2013). *Regulation of the Power Sector*. Springer.

Robinson, P. M. (1988). Root-N-Consistent Semiparametric Regression. *Econometrica* 56 (4), 931–954.

Sivadasan, J. (2009). Barriers to Competition and Productivity: Evidence from India. *The B.E. Journal of Economic Analysis & Policy* 9 (1).

Stagnaro, C., C. Amenta, G. D. Croce, and L. Lavecchia (2020). Managing the Liberalization of Italy’s Retail Electricity Market: A Policy Proposal. *Energy Policy* 137, 111150.

Stiel, C., A. Cullmann, and M. Nieswand (2018). Do private utilities outperform local government-owned utilities? Evidence from German retail electricity. *German Economic Review* 19 (4), 401–425.

Wilson, C. M., and C. W. Price (2010). Do consumers switch to the best supplier? *Oxford Economic Papers* 62 (4), 647–668.

Wooldridge, J. M. (2009). On estimating firm-level production functions using proxy variables to control for unobservables. *Economics Letters* 104 (3), 112–114.

Yasar, M., R. Raciborski, and B. Poi (2008). Production function estimation in Stata using the Olley and Pakes method. *Stata Journal* 8 (2), 221–231.

Conclusiones

Resultados

Esta tesis doctoral ha examinado la demanda de electricidad, gas natural y agua de los hogares en España, los efectos distributivos y de bienestar producto de la reforma del IVA de 2012; además el desempeño de los comercializadores de electricidad en el mercado minorista liberalizado. El análisis se ha llevado a cabo dentro del marco institucional configurado por la profunda liberalización del sector, caracterizado por una elevada concentración de mercado, la presencia de grupos verticalmente integrados y un notable dinamismo en la entrada y salida de comercializadores independientes. Al combinar enfoques de microeconometría de la demanda, economía del bienestar y organización industrial empírica, el estudio ofrece una perspectiva integrada sobre el funcionamiento del mercado energético tanto desde el lado de los hogares como desde el de las empresas.

Los resultados del análisis de demanda muestran que los hogares presentan una sensibilidad diferenciada ante los cambios de precios entre servicios y según su grado de vulnerabilidad. La electricidad se comporta como un bien cada vez más inelástico, el gas natural presenta elasticidades superiores a uno y el consumo de agua permanece inelástico. Las diferencias observadas entre hogares vulnerables y no vulnerables, particularmente en los casos del gas natural y el agua, sugieren que las políticas diseñadas para aliviar la pobreza energética deben tener en cuenta la heterogeneidad en los patrones de consumo y en la capacidad de los hogares para ajustarse a las variaciones de precios. En el caso de la electricidad, las diferencias son más limitadas, lo que indica que la tarifa social cumple principalmente una función redistributiva basada en criterios de equidad más que en respuestas diferenciadas de demanda. El análisis de la reforma del IVA de 2012 confirma que el aumento del impuesto sobre los servicios energéticos generó pérdidas de bienestar generalizadas y regresivas. Estas pérdidas fueron proporcionalmente mayores para los hogares de menores ingresos debido al mayor peso relativo del gasto energético en sus presupuestos. Las medidas de bienestar basadas en métricas monetarias y funciones de bienestar social, incluidas aquellas construidas a partir del índice de Atkinson, revelan un aumento de la desigualdad asociado con la reforma tributaria. La combinación de elasticidades estimadas y métricas de bienestar permite cuantificar rigurosamente estos impactos, subrayando la importancia de evaluar las consecuencias distributivas de los impuestos aplicados sobre bienes esenciales.

En cuanto al comportamiento de las empresas, la tesis muestra que el mercado minorista de electricidad presenta una estructura heterogénea, compuesta por un gran número de pequeñas comercializadoras que operan con márgenes cercanos a uno, junto con un pequeño grupo de empresas con mayores cuotas de mercado y márgenes más elevados. Los márgenes se ajustan de forma inversa a los precios mayoristas, reflejando la exposición de las comercializadoras a la volatilidad de los costos y la diversidad de estrategias utilizadas para gestionarla. En términos de productividad, la variación agregada se origina principalmente en cambios dentro de la propia empresa, mientras que las dinámicas de reasignación son más pronunciadas entre compañías con estructuras organizativas más complejas. Estos hallazgos contribuyen a caracterizar el entorno competitivo del sector y las diversas posiciones estratégicas de las empresas.

Las contribuciones de la tesis radican en la estimación de elasticidades de demanda mediante un modelo QUAIDS que corrige por endogeneidad y censura, en la evaluación formal de bienestar de una reforma fiscal de gran relevancia, y en la estimación de productividad y márgenes para las comercializadoras eléctricas utilizando un enfoque microeconómico basado en funciones de producción. Integrar estas tres dimensiones dentro de un mismo marco institucional proporciona una comprensión amplia y matizada del sector energético español y ofrece un valor agregado frente a estudios que abordan estos temas por separado.

Como ocurre con cualquier estudio empírico, esta investigación enfrenta limitaciones derivadas de la disponibilidad de datos y de restricciones metodológicas. Los indicadores de vulnerabilidad energética empleados, basados en información de ingresos y gastos, pueden no captar plenamente las restricciones de consumo derivadas de una capacidad de pago limitada. De igual forma, la ausencia de datos detallados sobre precios y condiciones contractuales en el mercado libre obliga a recurrir a medidas implícitas de precios que podrían no reflejar toda la diversidad de ofertas minoristas. La evaluación de la reforma del IVA depende de un supuesto respecto al grado de traslación del impuesto; aunque se utiliza una estimación empírica cercana a una traslación completa, el impacto final podría diferir bajo condiciones de mercado alternativas. La aplicación del método de Olley-Pakes implica supuestos específicos sobre el comportamiento de la inversión que pueden no cumplirse perfectamente en la práctica, y la ausencia de datos más desagregados limita la capacidad de estudiar con mayor detalle los mecanismos de ajuste tanto de los hogares como de las empresas.

Aunque los análisis empíricos desarrollados en los capítulos anteriores se basan en episodios de política y períodos específicos —los años en torno a la Gran Recesión, la reforma del IVA de 2012 y la evolución de las comercializadoras eléctricas entre

2010 y 2021—, los mecanismos analizados siguen siendo directamente relevantes para comprender desarrollos más recientes en el sector energético español. El período posterior a 2021 ha hecho especialmente clara esta conexión. El fuerte incremento de los precios de la electricidad y del gas natural tras la recuperación pospandémica y la invasión de Rusia a Ucrania volvió a ejercer presión sobre la asequibilidad energética de los hogares, los márgenes de las comercializadoras de electricidad y el diseño de la intervención pública. Lejos de debilitar la relevancia de los períodos históricos estudiados en esta tesis, este contexto reciente refuerza el valor del marco analítico desarrollado en la presente investigación.

En primer lugar, la crisis energética posterior a 2021 confirma la importancia de analizar la demanda de los hogares por servicios públicos. En un contexto de aumento de precios, el grado en que los hogares pueden ajustar su gasto en electricidad, gas natural y agua resulta central para evaluar la incidencia de las medidas de política energética. Esto es particularmente relevante para los hogares vulnerables, cuyo gasto energético representa una mayor proporción de la renta disponible y cuya capacidad para sustituir o reducir el consumo puede ser limitada. Por tanto, las elasticidades estimadas en el Capítulo 2 ofrecen más que una descripción retrospectiva del comportamiento de los hogares durante la Gran Recesión en España. En este sentido, constituyen una base metodológica para evaluar cómo distintos tipos de hogares pueden responder a choques recientes en los precios de la energía y a políticas orientadas a reducir los problemas de asequibilidad.

En segundo lugar, la evidencia reciente sobre el bono social refuerza una de las principales implicaciones de política del Capítulo 2: las tarifas sociales deben interpretarse principalmente como instrumentos de equidad, más que como políticas justificadas por una mayor sensibilidad al precio entre los hogares vulnerables. El Capítulo 2 muestra que los hogares vulnerables no son necesariamente más sensibles al precio en la demanda de electricidad que los hogares no vulnerables, aunque las diferencias son más visibles en el caso del gas natural y del agua. Este resultado es coherente con la idea de que la justificación de los descuentos o subsidios eléctricos reside principalmente en la redistribución y en la protección frente a la pobreza energética. En este sentido, la evaluación reciente de Llorca & Rodriguez-Alvarez (2026) resulta particularmente relevante. Utilizando datos de panel de hogares españoles para 2021–2023, los autores encuentran que el bono social contribuye a reducir la pobreza energética entre los hogares beneficiarios, pero que su efectividad se ve limitada por una cobertura insuficiente, una focalización imperfecta y un impacto reducido sobre los hogares más pobres. Sus hallazgos también muestran que las barreras informativas y administrativas son importantes, dado que la educación y el acceso a computadoras se asocian con menores niveles de pobreza energética. Esto sugiere que el diseño de las tarifas sociales no puede evaluarse únicamente en términos de elegibilidad formal o descuentos nominales; también debe considerar si el apoyo llega efectivamente a los hogares que enfrentan las restricciones de asequibilidad más severas.

En tercer lugar, las reducciones temporales de impuestos sobre la electricidad y el gas natural pone de manifiesto la vigencia del análisis de bienestar desarrollado en el Capítulo 3. Aunque dicho capítulo se centra en el aumento del IVA de 2012, el mecanismo económico es el mismo para las reducciones tributarias más recientes: los cambios en la imposición indirecta afectan los precios al consumidor, y sus consecuencias sobre el bienestar dependen del grado de traslación a precios, las participaciones presupuestarias, las elasticidades de la demanda y la distribución del gasto energético entre grupos de ingreso. Por tanto, el marco basado en la variación compensatoria y la variación equivalente, combinado con medidas de bienestar social que incorporan aversión a la desigualdad, puede extenderse para evaluar no solo aumentos tributarios, sino también medidas fiscales de emergencia diseñadas para mitigar choques en los precios de la energía. Esto es importante porque las reducciones tributarias generalizadas pueden proporcionar alivio inmediato, pero no necesariamente constituyen los instrumentos más focalizados si el objetivo de política es proteger a los hogares más pobres o con mayor vulnerabilidad energética.

Finalmente, la crisis posterior a 2021 también refuerza la relevancia del análisis del lado de las empresas comercializadoras de electricidad en el Capítulo 4. El aumento de los precios mayoristas incrementó las necesidades de liquidez, los requerimientos de garantías y los riesgos de aprovisionamiento para las comercializadoras, especialmente para las pequeñas e independientes con capacidad limitada de cobertura. Las comercializadoras de electricidad que abastecían a sus clientes mediante contratos de precio fijo enfrentaron un descalce entre los precios minoristas previamente acordados y los mayores costos de adquisición en el mercado mayorista, lo que comprimió sus márgenes e intensificó las presiones de salida del mercado. En contraste, los grupos verticalmente integrados se encontraban en una mejor posición para gestionar los riesgos de aprovisionamiento y absorber los choques. Estos desarrollos están estrechamente relacionados con el análisis de productividad, márgenes, supervivencia empresarial e integración vertical llevado a cabo en el Capítulo 4.

En conjunto, la evolución reciente del sector energético español confirma la relevancia contemporánea de las tres dimensiones empíricas analizadas en esta tesis doctoral. La estimación de elasticidades de demanda de los hogares es esencial para evaluar políticas de asequibilidad; las medidas de bienestar fundamentadas en la teoría del consumidor son útiles para valorar tanto aumentos como reducciones tributarias; y el análisis de productividad y márgenes entre las comercializadoras eléctricas ayuda a explicar cómo reaccionan las empresas ante choques en los precios mayoristas y presiones regulatorias. Por tanto, los capítulos empíricos examinan episodios históricos identificables, pero los métodos y mecanismos estudiados proporcionan un marco para interpretar los desafíos actuales y futuros de la política energética en España y en otros mercados energéticos liberalizados.

Investigación futura

Los resultados de esta tesis abren varias líneas prometedoras para futuras investigaciones. La estimación de elasticidades cruzadas entre electricidad, gas natural y agua sugiere la posibilidad de evaluar cómo responderían los hogares ante la introducción de un esquema integrado de apoyo energético que abarque estos tres servicios esenciales. Este análisis resulta particularmente relevante dado que la actual tarifa social de electricidad es un descuento regulado sobre el precio financiado por los comercializadores de referencia, la ayuda térmica es una transferencia monetaria financiada con cargo al presupuesto del gobierno central, y las asistencias relacionadas con el agua son desiguales y administradas principalmente por autoridades regionales o locales. Evaluar diseños alternativos e integrados, así como sus implicaciones sobre el consumo, el bienestar y el costo fiscal, constituiría una extensión natural de este trabajo. Además, los márgenes minoristas estimados podrían compararse con los márgenes publicados por la CNMC, que se basan en estándares contables, con el fin de identificar diferencias metodológicas y fortalecer la comprensión del poder de mercado y del desempeño empresarial en el sector.

Investigaciones futuras también podrían explorar respuestas dinámicas del consumo utilizando datos más detallados, o examinar con mayor profundidad la heterogeneidad empresarial incorporando información sobre estrategias de cobertura de riesgo, estructuras tarifarias y ofertas de productos verdes. Una línea relacionada sería analizar el subconjunto de comercializadoras que suministran conjuntamente electricidad y gas natural, evaluando si las empresas de doble suministro difieren sistemáticamente en su comportamiento de precios, estructuras de costos, estrategias de producto o retención de clientes en comparación con las empresas de un solo servicio. Una investigación de este tipo podría profundizar en la comprensión de las prácticas de agrupamiento, las dinámicas competitivas y las posibles implicaciones para el bienestar del consumidor en mercados energéticos multiproducto.

Conclusions

Results

This doctoral dissertation has examined household demand for electricity, natural gas, and water in Spain, the distributional and welfare effects of the 2012 VAT reform, and the performance of electricity retailers in the liberalized retail market. The analysis has been conducted within the institutional framework shaped by the sector's far-reaching liberalization, characterized by high market concentration, the presence of vertically integrated groups, and considerable dynamism in the entry and exit of independent suppliers. By combining approaches from demand microeconometrics, welfare economics, and empirical industrial organization, the study has offered an integrated perspective on the functioning of the energy market from both the household and firm sides.

The results from the demand analysis show that households exhibit differentiated sensitivity to price changes across services and according to their degree of vulnerability. Electricity behaves as an increasingly inelastic good, natural gas displays elasticities above one, and water consumption remains inelastic. The differences observed between vulnerable and non-vulnerable households—particularly in the cases of natural gas and water—suggest that policies designed to alleviate energy poverty must account for heterogeneity in consumption patterns and in households' capacity to adjust to price variations. In the case of electricity, the differences are more limited, indicating that the social tariff primarily serves a redistributive purpose rooted in equity rather than in differential demand responses. The analysis of the 2012 VAT reform confirms that the tax increase on energy services generated generalized and regressive welfare losses. These losses were proportionally larger for lower-income households due to the higher relative weight of energy expenditures in their budgets. The welfare measures based on monetary metrics and social welfare functions, including those built on the Atkinson index, reveal an increase in inequality associated with the tax reform. The combination of estimated elasticities and welfare metrics makes it possible to quantify these impacts rigorously, underscoring the importance of assessing the distributional consequences of taxes on essential goods.

Regarding firm behavior, the thesis shows that the electricity retail market exhibits a heterogeneous structure comprising a large number of small retailers operating with markups close to one, alongside a small group of firms with greater market shares and higher margins. Markups adjust inversely to wholesale prices, reflecting retailers' exposure to cost volatility and the variety of strategies used to manage it. In terms of productivity, aggregate variation originates mainly from within-firm changes, while reallocation dynamics are more pronounced among companies with more complex organizational structures. These findings help characterize the competitive environment of the sector and the diverse strategic positions of firms.

The contributions of the thesis lie in the estimation of demand elasticities using a QUAIDS model that corrects for endogeneity and censoring, in the formal welfare evaluation of a major fiscal reform, and in the estimation of productivity and markups for electricity retailers using a production-function-based microeconomic approach. Integrating these three dimensions within a single institutional framework provides a comprehensive and nuanced understanding of the Spanish energy sector and offers added value compared with studies that address these issues separately. As with any empirical study, this research faces limitations arising from data availability and methodological constraints. The indicators of energy vulnerability employed—based on income and expenditure information—may not fully capture consumption restrictions driven by limited ability to pay. Similarly, the lack of detailed data on prices and contractual conditions in the free market requires reliance on implicit price measures that may not reflect the full diversity of retail offers. The evaluation of the VAT reform depends on an assumption regarding the degree of tax pass-through; although an empirical estimate close to full pass-through is used, the final impact could differ under alternative market conditions. The application of the Olley-Pakes method involves specific assumptions about investment behavior that may not hold perfectly in practice, and the absence of more granular data limits the capacity to study adjustment mechanisms in greater detail for both households and firms.

Although the empirical analyses developed in the previous chapters are based on specific policy episodes and periods, the years surrounding the Great Recession, the 2012 VAT reform, and the evolution of electricity retailers between 2010 and 2021, the mechanisms analyzed remain directly relevant for understanding more recent developments in the Spanish energy sector. The period after 2021 has made this connection especially clear. The sharp increase in electricity and natural gas prices following the post-pandemic recovery and the Russian invasion of Ukraine placed renewed pressure on household energy affordability, retailer margins, and the design of public intervention. Rather than weakening the relevance of the historical periods studied here, this recent context reinforces the value of the analytical framework developed in the thesis.

First, the post-2021 energy crisis confirms the importance of analyzing household demand for essential utility services. In a context of rising prices, the extent to which households can adjust their consumption of electricity, natural gas, and water becomes central for evaluating the incidence of energy-policy measures. This is particularly relevant for vulnerable households, whose energy expenditure represents a larger share of disposable income and whose ability to substitute or reduce consumption may be limited. The elasticities estimated in Chapter 2 therefore provide more than a retrospective description of household behaviour during the Great Recession. They offer a methodological basis for evaluating how different types of households may respond to more recent energy-price shocks and to policies aimed at reducing affordability problems.

Second, recent evidence on the social discount rate reinforces one of the main policy implications of Chapter 2: social tariffs should be interpreted primarily as equity instruments, rather than as policies justified by greater price responsiveness among vulnerable households. Chapter 2 shows that vulnerable households are not necessarily more price-sensitive in electricity demand than non-vulnerable households, even though differences are more visible for natural gas and water. This result is consistent with the idea that the justification for electricity discounts lies mainly in redistribution and protection against energy poverty. In this regard, the recent evaluation by Llorca & Rodriguez-Alvarez (2026) is particularly relevant. Using Spanish household panel data for 2021–2023 and a stochastic frontier approach, the authors find that the social discount rate contributes to reducing energy poverty among recipient households, but that its effectiveness is constrained by insufficient coverage, imperfect targeting, and a limited impact on the poorest households. Their findings also show that information and administrative barriers matter, since education and computer access are associated with lower levels of energy poverty. This suggests that the design of social tariffs cannot be assessed only in terms of formal eligibility or nominal discounts; it must also consider whether support effectively reaches households facing the most severe affordability constraints.

Third, the recent use of temporary tax reductions on electricity and natural gas highlights the continuing relevance of the welfare analysis developed in Chapter 3. Although that chapter focuses on the 2012 VAT increase, the economic mechanism is the same for more recent tax reductions: changes in indirect taxation affect consumer prices, and their welfare consequences depend on pass-through, budget shares, demand elasticities, and the distribution of energy expenditure across income groups. The framework based on compensating and equivalent variation, combined with social welfare measures that incorporate inequality aversion, can therefore be extended to evaluate not only tax increases but also emergency fiscal measures designed to mitigate energy-price shocks. This is important because broad tax reductions may provide immediate relief, but they are not necessarily the most targeted instruments if the policy objective is to protect the poorest or most energy-vulnerable households.

Finally, the post-2021 crisis also strengthens the relevance of the firm-side analysis in Chapter 4. The rise in wholesale prices increased liquidity needs, collateral requirements, and procurement risks for electricity retailers, especially for small and independent firms with limited hedging capacity. Electricity retailers supplying customers under fixed-price contracts faced a mismatch between previously agreed retail prices and higher wholesale procurement costs, which compressed margins and intensified exit pressures. By contrast, vertically integrated groups were better positioned to manage procurement risks and absorb shocks. These developments are closely related to the analysis of productivity, markups, firm survival, and vertical integration carried out in Chapter 4.

Taken together, the recent evolution of the Spanish energy sector confirms the contemporary relevance of the three empirical dimensions analysed in this dissertation. The estimation of household demand elasticities is essential for evaluating affordability policies; welfare measures grounded in consumer theory are useful for assessing both tax increases and tax reductions; and the analysis of productivity and markups among electricity retailers helps explain how firms react to wholesale-price shocks and regulatory stress. The empirical chapters therefore examine identifiable historical episodes, but the methods and mechanisms studied provide a framework for interpreting current and future energy-policy challenges in Spain and in other liberalized energy markets.

Future research

The results of this dissertation open several promising avenues for future research. The estimation of cross-price elasticities between electricity, natural gas, and water suggests the possibility of assessing how households would respond to the introduction of an integrated energy support scheme encompassing all three essential services. Such analysis is particularly relevant given that the current social electricity tariff is a regulated price discount financed by reference retailers, the thermal allowance is a cash transfer funded through the central government budget, and water-related assistance is uneven and mainly administered by regional or local authorities. Evaluating alternative, integrated designs and their implications for consumption, welfare, and fiscal cost would constitute a natural extension of this work. In addition, the estimated retail markups could be compared with the markups published by the CNMC, which are based on accounting standards, in order to identify methodological differences and strengthen the understanding of market power and firm performance in the sector.

Further research could also explore dynamic consumption responses using more detailed data, or examine firm heterogeneity more deeply by incorporating information on risk-hedging strategies, tariff structures, and green product offerings. A related avenue would be to analyze the subset of retailers that jointly supply electricity and natural gas, assessing whether dual-fuel retailers differ systematically in pricing behavior, cost structures, product strategies, or customer retention relative to single-fuel firms. Such an investigation could deepen our understanding of bundling practices, competitive dynamics, and potential implications for consumer welfare in multi-product energy supply markets.