Journal of Business Insight and Innovation
Volume 5 Issue 6, 2026
ISSN-p: 3006-2284, ISSN-e: 3006-0982
https://insightfuljournals.com/

EVALUATING THE NON-LINEAR BEHAVIOUR OF ENERGY CONSUMPTION FOR SELECTED EUROPEAN COUNTRIES

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DOI: https://doi.org/10.63544/jbii.v5i6.172

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Article History:
Received: 10.05.2026
Accepted: 15.06.2026
Published: 25.06.2026

Abstract

Purpose: *The study examines the effects of price changes of energy products and expenditures on energy consumption of electricity and natural gas for two sectors (household and non-household) over the period 2014-2024 in 19 European countries.*

Design/Methodology/Approach. *By employing the Quadratic Almost Ideal Demand System (QUAIDS) model, elasticities of cross-price, own-price and expenditure are estimated to explore the responsiveness of price and income change. The QUAIDS framework captures non-linear Engel curve relationships, allowing for flexible substitution patterns and accurate welfare impact assessment.*

Findings. *The estimated results show that household energy demand of both energy products is more elastic than the non-household sector. The household sector exhibits weak substitutability between electricity and natural gas, and complementarities for non-households. Expenditure elasticities close to unity in both sectors indicate that both energy products are normal goods. The findings indicate that without appropriate steps to compensate economically vulnerable groups, imposing energy taxes raises inequalities. The empirically estimated results provide insights to design equitable efficient energy and climatic policies in Europe.*

Research Limitations. *The study focuses on 19 European countries and two energy products (electricity and natural gas). Future research could expand to include additional energy products, broader geographical coverage, and more granular sectoral disaggregation.*

Practical Implications. *The findings provide policymakers with empirical evidence to design equitable energy taxation policies that minimize welfare losses for vulnerable households while achieving environmental objectives.*

Originality/Value. *The study contributes to the literature by employing QUAIDS model with disaggregated sectoral analysis (household and non-household) for European countries, incorporating climatic, demographic, and environmental control variables.*

Keywords: Energy Demand, Energy Prices, QUAIDS, Own-Price Elasticity, Cross-Price Elasticity, Expenditure Elasticities.

1. Introduction.

Rapidly changes in environment have forced nations to convert their views in 21st century to change the whole structure towards a low carbon-intensive energy system into a more sustainable and energy saving techniques to avoid environmental degradation. Electricity and natural gas usage are the more central driving forces in energy consumption in both household and non-household especially in industry and transportation which cause carbon emissions in both developed nations at a lower rate and in developing countries at a higher rate of carbon emissions. In Europe, different steps have been taken in this aspect to control carbon emissions as EU_ETS is the most important step. Energy taxes have been proved a vital instrument in minimizing environmental degradation and converting towards energy saving techniques (Banks, Blundell and Lewbel, 1997; Brannlund and Nordstrom, 2004; Arze et al., 2012, and Burns and Hotchkiss, 2025).

Elasticities explain the response of consumers as price of the related goods, alternative goods, and income change. In the energy consumption, carbon taxes have been imposed which has changed the pattern of expenditures. Taxes such as carbon taxes or environmental taxes work for a dual purpose: it has increased energy prices which has directly impact household sector especially and on the other side, it generates revenue which can be redistributed for more affected people and for different social objectives. However, it has changed the pattern of energy consumption which is a serious issue in this regard. It has increased many economic and social issues. In both sectors including household and non-household have to use less energy products which have started a debate on imposing tax system (Amell, 1999; Arnell, 2000; Angrist et al., 1999; Arbues et al., 2003; Arbues, Barberan and Villanua, 2004; Andreyeva, Long and Brownell, 2010; Brent and Ward, 2018; Burns and Hotchiss, 2025).

In the case of Mexico, Greenhouse gas emissions have been increased due to economic and population growth. In 2012 climate change law was passed to tackle this issue. In this aspect, energy sector was reformed in 2013 that affected energy prices. There has been build competition in oil and gas industry. The basic purpose of these reforms in the federal electricity commission was to build an environment of competition in the electricity market and for private investors; incentives and subsidies were granted (Komives et al. 2009; Davis et al. 2014; IEA Subsidies Report 2017). These reforms may create a situation of uncertainty in oil sector which will affect energy prices. For the implementation of climatic policy may cause to increase energy price due to cut in energy subsidies for fossil-fuel, and increase in energy prices will cause welfare losses that may rarely compensate. In rich countries, poor household will affect more as a large portion of their expenditures consist on energy products (Speck 1999, and Flues and Thomas 2015).

Most of this growing literature on the welfare effects of energy price changes or subsidy reforms focuses on single fuels, with a strong emphasis on gasoline. As households have to make expenditures on just one or more fuel, it is essential to understand the substitution pattern for fuels and other goods which may disturb welfare due to change in prices. There is no authentic analysis about Mexico which provides clear information about household's reaction against the price increases and welfare of households. More than half population of Mexico lies below national poverty line (Consejo Nacional de Evaluación de la Política de Desarrollo Social, 2014). It is very critical situation for a country with high welfare losses due to increase in prices of energy products which already have to face a high level of carbon emissions, low income, worse situation of prevailing poverty and economically bad infrastructure.

Total expenditures made in the analysis were on (1) motor fuels (2) electricity (3) gas (4) public transport (5) food products excluding alcohol and tobacco, and (6) other goods. The shares of expenditures on four energy products were between 6% and 13% of the total expenditures in household sector, and it showed a U shaped curve. The energy consumption of electricity decreased continuously in Mexico especially for lower-income households. In some other countries like as Mali, Indonesia and Sri Lanka, the share of expenditures on electricity shows increasing trend. Expenditure shares increase for motor fuel which lies from 1.6% to 4.3%. Natural gas and transport show an inverse U shaped curve, and natural gas exhibits less important energy product.

Demand systems play a crucial role in evaluating the impacts of tax policy reforms, especially considering the significant variation in consumer demand across households based on income levels and demographic factors. When analyzing total expenditure shares, expenditures on energy products exhibit linear or non-linear behaviour. Estimating non-linear expenditure patterns using a linear demand system can generate biased results (Banks et al., 1997; West and Williams, 2004; Rosas-Flores et al., 2017; Moshiri, Martinez and Santillan, 2018; Renner et al., 2018).

In analyzing price increase scenarios, progressive effects have been observed for motor fuels only. Taxes on energy products natural gas, electricity and transport are regressive, although in the case of public

Journal of Business Insight and Innovation
Volume 5 Issue 6, 2026
ISSN-p: 3006-2284, ISSN-e: 3006-0982
https://insightfuljournals.com/

transport, the most affected is middle class. Prices are regressive with positive energy demand items. As energy prices change, increase in food prices might show a large welfare effect. Households spend a larger share on food products as in the case of Mexico than on energy products. Due to higher energy prices, middle-income households close to the well-being poverty line are more affected than low-income households. The smaller effect on extreme poverty is given less focused (Feldstein, 1972; Engel, 1985; Dinar and Subramanian, 1997; Epsey et al., 1997; Filippini, Hunt and Zoric, 2014; Escriva et al., 2015).

In private motorized transport, carbon tax affects progressive distribution pattern of welfare. The climatic policy shows more sensitivity for changes in gasoline prices, it shows a smaller monetary loss for households. Carbon tax imposition of $25 per ton CO2 exhibits that welfare effects are progressive and reduction in carbon emission. The prices in agriculture sector will increase as additional taxes will impose, and it will show an inadequate policy to reduce carbon emissions. Furthermore, it will cause increasing poverty. By considering the problematic link between the taxes and prices of food products, the types of emissions as CH4, N2O, only CO2 taxes are enough to handle the issue of poverty and welfare losses by redistributing the tax revenue to poor. Only a small change in price will reduce emissions substantially. It is also necessary to reduce poverty. It can be accounted by redistribution via cash transfer. By redistributing simulated tax, poverty can be reduced. A social welfare programme will reduce poverty and associated emissions.

The novelty of this study by employing QUAIDS model consists in its detailed, expenditure-share-based demand system estimation for energy consumption of electricity and natural gas for two sectors household and non-household in selected European countries. In contrast of traditional single-equation models that impose restrict assumptions on preferences and substitution patterns, the framework of QUAIDS model uses flexible Engel curves and examines non-linear expenditure responses. In the European context, it is crucial especially where a sophisticated model is required to handle the complex behaviour of consumers due to cross sectional variations occur in energy prices, income levels, climatic factors and tax structures (Heckman, 1979; Friedman and Levinsohn, 2002; Gillingham et al., 2006; Labandeira et al., 2006; Komives et al., 2009; Gonzalez, 2012; Flues and Thomas, 2015; IEA, 2016; IEA, 2017; Khosa et al., 2020; Jacksohn et al., 2023; Jamissen et al., 2024). The study estimates by QUAIDS model by including different factors as climate which consists cooling and heating, demographic factors as population at risk of poverty, and environmental factor as GHG emissions to observe energy consumption behaviour. Moreover, disaggregation of sectors in household and non-household, the empirical results will improve robustness of elasticities.

1.2. Research Objectives

The study is guided by the following objectives:

RO1. To estimate own-price elasticities for electricity and natural gas in household and non-household sectors across selected European countries.

RO2. To estimate cross-price elasticities between electricity and natural gas to determine whether these energy products act as substitutes or complements in each sector.

RO3. To estimate expenditure elasticities for electricity and natural gas to determine whether these energy products are normal or inferior goods.

RO4. To examine the non-linear behaviour of energy consumption in response to price changes and expenditures using the QUAIDS framework.

RO5. To analyze the differential responsiveness of household versus non-household sectors to energy price changes.

1.3 Research Questions

Correspondingly, the study poses the following research questions:

RQ1. How do households and non-households respond to changes in electricity and natural gas prices as measured by own-price elasticities?

RQ2. Do electricity and natural gas act as substitutes or complements in household and non-household sectors?

Journal of Business Insight and Innovation
Volume 5 Issue 6, 2026
ISSN-p: 3006-2284, ISSN-e: 3006-0982
https://insightfuljournals.com/

RQ3. Are electricity and natural gas normal goods in both sectors as measured by expenditure elasticities?

RQ4. Does energy consumption exhibit non-linear behaviour in response to price and expenditure changes?

RQ5. Are households more responsive to energy price changes compared to non-households?

1.4 Significance of the Study

The novelty of this study by employing QUAIDS model consists in its detailed, expenditure-share-based demand system estimation for energy consumption of electricity and natural gas for two sectors household and non-household in selected European countries. In contrast of traditional single-equation models that impose restrict assumptions on preferences and substitution patterns, the framework of QUAIDS model uses flexible Engel curves and examines non-linear expenditure responses. In the European context, it is crucial especially where a sophisticated model is required to handle the complex behaviour of consumers due to cross sectional variations occur in energy prices, income levels, climatic factors and tax structures (Heckman, 1979; Friedman and Levinsohn, 2002; Gillingham et al., 2006; Labandeira et al., 2006; Komives et al., 2009; Gonzalez, 2012; Flues and Thomas, 2015; IEA, 2016; IEA, 2017; Khosa et al., 2020; Jacksohn et al., 2023; Jamissen et al., 2024). The study estimates by QUAIDS model by including different factors as climate which consists cooling and heating, demographic factors as population at risk of poverty, and environmental factor as GHG emissions to observe energy consumption behaviour. Moreover, disaggregation of sectors in household and non-household, the empirical results will improve robustness of elasticities.

1.5 Study Arrangement

Next sections of the paper parts coming are as given: Section 2 of this study provides a comprehensive review of the earlier studies in favour of estimating own-price, cross-price and expenditure elasticities for household and non-household sectors of Europe, with special references for consumption of energy products. Section 3 contains discussion about the empirical methodology used and the sample data sources. Section 4 describes a discussion of the estimated results, and a summary with the key points of main conclusions made in Section 5 from the study.

2. Literature Review

The main purpose of conducting this paper is to measure the effects of expenditures on different commodities as prices of commodities change due to imposition of energy taxes for different sectors of consumers. The literature has evidently shown the efficacy of energy taxes for different set of consumers by (1) fuel type and (2) across different groups of commodities (Halvorsen and Larsen, 2001; Berkhout et al., 2004; Barigozzi and Villeneuve, 2004; Agnolucci, 2004, and Ghalwash, 2007). Keeping in view the price and income elasticities measured objective of this dissertation, this objective of our research study aims at estimating consumer responses in the incidence of price changes on different commodities within and across different sectors. It would indeed be a very interesting to see how sensitive the consumer choices are towards price changed. The said practice will be done for sectors including household, industry, commerce and transport across different set of commodities.

Burn et al. (2025) tried to examine the impact of gasoline tax on lower income and higher income households. It focused how mechanism could be replaced by declining gasoline tax revenues which is used for infrastructure maintenance. The findings show that lower income families have to bear more tax than higher income families. It showed three policy alternatives of tax imposition as lump-sum tax is considered as an income-based tax, and (VMT) vehicle mile travelled tax. The study suggests choosing suitable transportation funding to secure and ensure financial sustainability, social equity both in decarbonising transport sector.

Mubiinzi et al. (2024) worked to check the responses of different income groups for different regions of world. Panel data was used from 1980-2023 for research. It indicated that a lot of studies had been done for European and Asian regions, where regions like North Africa, Middle East and sub-saharan African regions were totally neglected. Almost studies showed inelastic behaviour of consumers towards electricity consumption. It means that households spend more share of their budget on electricity product in spite of price changes. It focused especially on vulnerable groups that are more affected than high-income groups. It suggests that policies should be made to compensate low income households.

Mardones and Alvial (2024) worked to evaluate the impact of imposing carbon taxes in Costa Rica for different energy goods. It used Quadratic Almost Ideal Demand System model to estimate elasticities. It employed different carbon tax rates on different products like electricity, food and fuel for household sector and non-household sector including especially transportation sector. Due to imposition of carbon taxes CO2 emissions decreased at a significant level where carbon emissions lie between 89.6% and 91.3% in transport sector. For households, carbon emissions decreased at 20% to 30%. It suggests that climatic policies should be employed in all sectors.

Sachez et al. (2024) tried to examine the utility poverty policies in Spain by estimating price and budget expenditures. It used data from 2009 to 2014 to check the impact of crisis prevailing in Spain on demands of electricity, natural gas and water for households by employing Quadratic Almost ideal Demand System model to estimate elasticities. The results showed that demand of natural gas and water were slightly more elastic about 5% and 7% respectively than the electricity merely 2%. It shows that the demand for electricity remain inelastic during Spain’s crisis. The study suggests that proper steps should be taken to compensate the affected population.

Weibenburger (2024) worked to examine the impact of energy consumption on environment. It used a new framework to estimate long run price elasticity for electricity, hydrogen and its derivates keeping in view the targets set for years from 2025 to 2045. It established 15 wholesale price pathways and estimate final prices in 2045 between 56 euro per megawatt-hour and 182 euro per megawatt-hour. It shows that in household sector, both electricity and hydrogen demand prices are sensitive and its consumption increases more rapidly with lower prices. On the other side; in transportation sector, the demand of road transportation is inelastic or showing very low elasticity. Furthermore, if prices fall, the supply for heating increases more.

Jacksohn et al. (2023) examined to check the changes in greenhouse gasses trend in Germany for household electricity consumption for 20 years. It used time series data using Quadratic Almost Ideal Demand System model for estimation. It showed that greenhouse gasses fell by 21% from 1998 to 2018. The main contribution in greenhouse gasses includes energy products heating, transport, electricity and food during this time period. It shows a stable expenditure elasticity of greenhouse gasses at 92% while own-price elasticity and heating indicate increasing consumption responses.

Liu (2022) worked to find out the impact on residential sector as prices increases due to carbon taxes by using Quaids mode for rural and urban areas. The elasticities showed that the income elasticity for energy demand was (-0.741) for urban area as compared to (0.392) for rural area. The cross-price elasticity showed that China’s household sector moved towards clean and energy saving techniques. Imposition of carbon taxes increases welfare losses, and shows an inverted U-shaped curve. The government should take steps to compensate the affected areas as a priority.

Okonkwo (2021) used Quadratic Almost Ideal Demand System (QUAIDS) model to find the empirical estimation of welfare impacts of carbon taxation on households for South Africa. He used household survey data from 2009 to 2015. The study revealed that imposition of carbon taxes have increased electricity and transport prices regressively which affected lower income households disproportionately. In contrast, a progressive effect was observed due to higher prices of motor fuels showing significant impacts on higher income households. It showed that lower households face more welfare loss than higher income households. It suggests that by redistributing carbon tax revenues through lump-sum transfers to households living below bottom poverty line 40% would compensate. The study further provides valuable information for policy-makers to design equitable tax reforms to minimize the negative effects on lower income households.

Filippin, Hunt and Zoric (2014) examined the impact of energy policies on energy efficiencies in EU household sector. It used panel data from 1996 to 2009 for EU-27 member states. It employed Linear Almost Ideal Demand System model to estimate elasticities for household sector. It showed that household sector confirm the high level of potential for energy saving techniques. It also revealed that the incentives provided to household sector urge them to use more energy saving alternatives.

Journal of Business Insight and Innovation
Volume 5 Issue 6, 2026
ISSN-p: 3006-2284, ISSN-e: 3006-0982
https://insightfuljournals.com/

2.1 Theoretical Framework

Using the consumer demand theory and the Almost Ideal Demand System framework, this research defines energy consumption behaviour as a function of prices, total expenditure, and socio-demographic factors. The Quadratic Almost Ideal Demand System (QUAIDS) extends the standard AIDS model by incorporating a quadratic expenditure term that allows for non-linear Engel curve relationships. The theoretical framework posits that expenditure shares for electricity and natural gas depend on log prices, log real expenditure, and a quadratic expenditure term, enabling the estimation of flexible substitution patterns and non-linear expenditure responses. The study explores how price changes and expenditure variations affect energy consumption patterns in household and non-household sectors.

3. Research Methodology

3.1 Research Design and Philosophical Orientation

This research study is based on the positivist philosophy of research and follows a quantitative approach through the use of econometric modelling. This perspective is suitable for examining the causal relationships between energy prices, expenditures, and energy consumption patterns, yielding statistically robust empirical estimates that can inform policy decisions.

3.2 Population and Sampling

This study includes panel data of 19 European Union selected countries over the period 2014-2024. The sample includes both household and non-household sectors. The selection of countries is based on data availability from Eurostat and other international databases. A balanced panel structure is employed to ensure consistent estimation across time periods and countries.

3.3 Model Specification

To address the non-linear behaviour in energy consumption, the Quadratic Almost Ideal Demand System (QUAIDS) model is employed. The budget share equation is derived from indirect utility function by applying the Roy's identity, given below

$$\omega_{ist} = \acute{\alpha}_i + \sum_{j=1}^{n} \Theta_{ijst} \ln p_{jst} + \beta_{ist} \ln\left[\frac{v}{a(p)}\right] + \frac{\pi_{ist}}{b(p)} \left\{\ln\left[\frac{v}{a(p)}\right]\right\}^2 + \varepsilon_{ist}$$

Where, ω_i is the share of commodity i of total expenditures v, and α_i, γ_{ij} and π_i are parameters of the model to be estimated where i is the commodities, s indicates two sectors, t is the time period, ϴ represents elasticities for two products, π explains as income increases, more expenditures are made on product, the square part is the non-linear portion.

3.4 Data Sources

This study uses panel data of 19 European Union selected countries over the period 2014-2024 to conduct a comprehensive analysis of energy consumption behaviour. The main focus is on two primary energy products electricity and natural gas for two sectors households and non-household examined.

In the QUAIDS model, two dependent variables are expenditure shares of energy products electricity and natural gas, denoted as $w_{elect.}$ and $w_{gas.}$ respectively. Each one is calculated by energy consumption taken in monetary value by the total expenditures on both products in a sector. To get the quantities of energy consumption in euro/kwh, energy consumption is converted into kilowatt-hours (kwh) by multiplying energy consumption in gigawatt-hour (gwh), and then gained values are multiplying by related prices in Euro/kwh. This procedure provides total energy expenditures in euro across countries and time.

The data for both energy products is obtained from Eurostat in disaggregated by sectors (household and non-household). Prices of both energy products electricity and natural gas for both sectors household and non-household are also taken from Eurostat in euro/kwh which is reported on a bi-annual basis, and then average is taken to obtain annual data. Total sectoral expenditures is the main explanatory variable in QUAIDS model, which is used as a proxy for income. It is measured as value added at constant 2015 market prices for both sectors, which represent economic output annually. These data are collected from the United Nations Conference on Trade and Development.

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ISSN-p: 3006-2284, ISSN-e: 3006-0982
https://insightfuljournals.com/

To fix non-linear Engel curve relationship and to ensure pattern of flexible substitution, log and square have been taken for QUAIDS model.

3.5 Estimation Procedure

The demand elasticities are calculated by differentiating the expenditure share with respect to $\ln nm$ and $\ln np_j$:

$$u_i = \frac{\partial \omega_i}{\partial lnx} = \beta_i + \frac{2\pi_i}{b(p)} \left\{ \ln \left(\frac{m}{a(p)} \right) \right\}$$

Budget elasticity can be derived from the budget share equation:

$$e_i = \frac{u_i}{\omega_i} + 1$$

It is income or expenditure elasticity which describes the response of consumers as income increases or if price of product changes, how the consumer spends his income on different commodities.
Uncompensated price elasticity consists of own-price elasticity and cross-price elasticity:

$$\mu_{ij} \equiv \frac{\partial w_i}{\partial lnp_j} = \gamma_{ij} - \beta_i \langle \alpha_j + \sum_k \gamma_{jk} \ln p_k \rangle - \frac{\pi_i \beta_j}{b(P)} \left\{ \ln \left[\frac{m}{a(P)} \right] \right\}^2$$

Formula to calculate uncompensated price elasticity is given by:

$$e_{ij}{}^u = \frac{u_{ij}}{\omega_i} - \delta_{ij}$$

If δ_{ij}=1 it means that own-price elasticity and if not equal to 1, that shows cross-price elasticity.

3.6 Ethical Considerations

The study follows appropriate ethical measures on data confidentiality and proper citation of all data sources. All data used in this study are publicly available from Eurostat, the United Nations Conference on Trade and Development, and other international databases. The study does not involve human subjects, and all data are anonymized and aggregated at the national level. The grouped data set is maintained for study and analysis only.

4. Findings of the Study

Table 1

Household Descriptive Statistics

Household Key Descriptive Statistics			N=209	
Variables	**Mean**	**Std. err.**	**Min**	**Max**
lnecelect	21.664	1.573	18.865	24.519
lnecgas	20.286	2.070	16.937	23.819
lnexpenditures	41.951	3.437	36.208	48.246
W_elect	0.517	0.017	0.486	0.572
W_gas	0.483	0.016	0.428	0.514
P_elect	0.191	0.061	0.086	0.321
P_gas	0.069	0.029	0.030	0.248
lgdp	11.825	1.498	9.253	14.460
Rc	3.915	1.439	1.400	7.200
Cdd	78.445	95.467	0	383.950
Prp	9.412	3.499	3	17.900
Ghg	86.817	9.894	61.800	115.100
Hh1	104.057	60.384	1.000	208.000
Hdd1	105.000	60.477	1.0000	209.000

Table 1 represent descriptive statistics of the data for household and it provides basic understanding of the data. Electricity consumption and natural gas in log form exhibit moderate variability describing the consumption pattern of households. The average of expenditures value (41.95) shows dispersion of income

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Volume 5 Issue 6, 2026
ISSN-p: 3006-2284, ISSN-e: 3006-0982
https://insightfuljournals.com/

heterogeneity amongst households. The values of expenditure shares on electricity and gas are (0.517) and (0.483) are relatively balanced, indicating about equal preference for both energy products. The prices of electricity and natural gas vary clearly with standard deviation mentioned verifying the relation by Quaids model. Other socioeconomic and climatic variables like lgdp, reconstruction, cooling and heating could affect demand pattern. Greenhouse gasses and population at risk are more important for environmental degradation and lower- income groups (Lewbel and Pendakur, 2009; Li et al., 2024; Liu, Gong and Qin, 2022; Mardones and Alvial, 2024; Mubiinzi et al., 2024; Naqvi, 2025; Nikodinoska and Schroder, 2016; Okonkwo, 2021; Ramirez et al., 2021; Renner, Lay and Thiele, 2018; Rivera et al., 2016; Rosas et al., 2017; Shah and Larsen, 1992).

Table 2

Non-Household Key Descriptive Statistics

Non-Household Key Descriptive Statistics				N=209
Variables	**Mean**	**Std. err.**	**Min**	**Max**
lnecelect	26.549	1.426	23.985	29.351
lnecgas	25.288	1.641	22.165	28.229
lnexpenditures	51.838	3.007	46.548	57.579
W_elect	0.512	0.006	0.497	0.529
W_gas	0.488	0.006	0.471	0.503
P_elect	0.144	0.051	0.076	0.381
P_gas	0.059	0.026	0.028	0.225
lgdp	12.895	1.251	10.650	14.896
Rc	3.915	1.439	1.400	7.200
Cdd	78.444	95.467	0	383.95
Prp	9.412	3.490	3	17.900
Ghg	86.817	9.894	61.800	115.1
Hh1	104.057	60.384	1	208
Hdd1	105	60.477	1	209

Table 2 represents describes the descriptive statistics for non-household sector. In this table, electricity consumption and natural gas in log form also exhibit moderate variability almost same as Table A describing the consumption pattern of non-households. The average of expenditures value (51.838) shows dispersion of income heterogeneity amongst households. The values of expenditure shares on electricity and gas are (0.512) and (0.488) are relatively balanced, indicating about equal preference for both energy products. Other socioeconomic and climatic variables like lgdp, reconstruction, cooling and heating could affect demand pattern. Greenhouse gasses and population at risk are more important for environmental degradation and lower- income groups.

Table 3

Expenditure Elasticities calculated at the averages of Prices, expenditure and other variables

	Household		
Expenditure	**Elasticity Coefficient**	**Stand. Error**	**Z-Value**
Elect.	0.987***	0.006	147.140
Gas	1.014***	0.007	141.48
	Non-Household		
Elect.	0.996***	0.003	310.12
Gas	1.004***	0.003	297.83

****, ** and * indicate the statistical significance at 1%, 5% and 10% levels, respectively.*

In this table, the empirical results of expenditure elasticities are estimated by taking the average prices of energy products and the expenditures on electricity and natural gas across two sectors: household and non-

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ISSN-p: 3006-2284, ISSN-e: 3006-0982
https://insightfuljournals.com/

household. The term "average" can refer to different measures, including the arithmetic mean, median, or mode (Shojaeddini et al., 2024; Shonkwiler and Yen, 1999; Speck, 1999; Stern, 1987; Sterner, 2011; Symons, Proops and Gay, 1994; Tiezzi and Verde, 2016; Timmer et al., 2015)

Expenditure elasticity measures the responsiveness of energy consumption (electricity and natural gas) to changes in household expenditures. The elasticity coefficient of 0.987 indicates that for a 1% increase in household expenditures, electricity consumption increases by 98%. Similarly, an elasticity coefficient of 1.014 for natural gas suggests that natural gas consumption increases by slightly more than 100% with the same 1% increase in household expenditures. Both the coefficients are strongly significant at 1% level.

For non-household sector, the elasticity coefficients for both electricity and natural gas are also high and statistically significant; the elasticity coefficient for electricity is 0.99 and 1.004 for natural gas indicating 100% increase in energy consumption indicating a strong response in demand as expenditures change. A high elasticity coefficient reflects a substantial change in demand for these energy products with shifts in expenditure. The low standard deviation values in these calculations suggest a high level of accuracy in the estimated values.

Table 4

Expenditure elasticities calculated at the means of Prices, expenditure and other variables

Household			
Expenditure	**Elasticity Coefficient**	**Stand. Error**	**Z-Value**
Elect.	0.981***	0.008	117.36
Gas	1.019***	0.009	113.98
Non-Household			
Elect.	0.994***	0.002	354.49
Gas	1.007***	0.003	341.36

****, ** and * indicate the statistical significance at 1%, 5% and 10% levels, respectively.*

In Table 4, expenditure elasticities are similarly calculated based on the mean prices of energy products and expenditures for energy products in both household and non-household sectors. Expenditure elasticity measures the responsiveness of energy consumption to changes in expenditures. The elasticity coefficient of 0.981 indicates that for a 1% increase in household expenditures, electricity consumption increases by 98%. Similarly, an elasticity coefficient of 1.019 for natural gas suggests that natural gas consumption increases by slightly more than 100% with the same 1% increase in household expenditures. Both the coefficients are strongly significant at 1% level (Yen, Kan and Su, 2002; West and Williams, 2004; Vance, 2012; Zhang et al., 2023; Zhang, 2024; Weibenburger et al., 2024).

For the non-household sector, the elasticity coefficients for both electricity and natural gas are also high and statistically significant; the elasticity coefficient for electricity is 0.994 and 1.007 for natural gas indicating 100% increase in energy consumption indicating a strong response in demand as expenditures change. A high elasticity coefficient reflects a substantial change in demand for these energy products with shifts in expenditure. The low standard deviation values in these calculations suggest a high level of accuracy in the estimated values.

Table 5

Uncompensated (Marshallian) Price Elasticities

HOUSEHOLD SECTOR			
Prices	**Elasticity**	**Std.Err.**	**Z-value**
Good_Elect			
Elect	-1.017***	0.007	-128.880
Gas	0.018**	0.008	2.19
Good _Gas			
Elect	0.029***	0.006	4.53

Journal of Business Insight and Innovation
Volume 5 Issue 6, 2026
ISSN-p: 3006-2284, ISSN-e: 3006-0982
https://insightfuljournals.com/

Gas	-1.033***	0.007	-150.20
	Non-Household Sector		
Prices	**Elasticity**	**Std.Err.**	**Z-value**
Good_Elect			
Elect	-0.988***	0.003	-345.64
Gas	-0.013***	0.003	-4.210
Good _Gas Elect	-0.008***	0.002	-3.490
Gas	-0.992***	0.002	-407.74

****, ** and * indicate the statistical significance at 1%, 5% and 10% levels, respectively.*

The table above presents the own price elasticity and cross price elasticity for energy products. Own-price elasticity for electricity has a negative sign, indicating that as the price of a electricity increases, the demand for electricity decreases.

For households, the coefficient value for own price elasticity for is (-1.017), means that a 1% increase in the price of electricity decreases the demand to a 101.7%. Cross-price elasticity has a positive sign indicating that as the price of one product increases, consumers tend to substitute it with another product, thereby increasing its demand. For the household sector, the cross price elasticity of natural gas coefficient value is 0.018 indicating that a 1% increase in the price of electricity leads to a 1.8% increase in the demand for natural gas. Although this positive value shows that natural gas product is a substitute for electricity product, the substitution effect is weak, implying limited interchange ability between the two energy products. Both elasticities are highly significant, confirming that these products act as substitutes in the household sector (Banks et al., 1997; West and Williams, 2004; Rosas-Flores et al., 2017; Moshiri and Martinez Santillan, 2018; Renner et al., 2018).

In the lower part of the table, both own-price elasticity and cross-price elasticity are negative for the non-household sector. For electricity, the own-price elasticity coefficient value is -0.988, and the cross- price elasticity is -0.013. The own-price elasticity for natural gas is -0.992, and the cross-price elasticity is -0.008. These negative sign of cross-price elasticities indicate that electricity good and natural gas good are complementary goods in the non-household sector, meaning that as the price of any one product tends to increase, the demand for both products decreases. In is especially in industries, when the price of electricity or energy products raises, the overall demand for these energy products tends to decrease. This results in negative cross-price elasticity. This occurs because the structure of industries is complex, making it difficult to substitute one energy product with another. This estimated relationship is proved with imperial results by the earlier studies (Lewbel et al., 1997; Popkin et al., 2017; Marta, 2020; Richard et al., 2021).

5. Conclusion and Recommendations

The study explains the energy consumption pattern in selected European countries by employing Quaids model to capture the complex responses of household and non-household due to changes in prices of energy products including electricity and natural gas and expenditures. The estimated results show that own-price elasticities of electricity and natural gas are significantly negative in both sectors which confirm the theoretical expected relationship that energy consumption decreases as the prices of related energy product increases. The important thing is that the household sector is relatively elastic than the non-household sector indicating that the energy taxes have a strong impact on household welfare. Cross-price elasticities in household sector are positive but having a small magnitude which indicates that there is a limit of substitution between electricity and natural gas. In the non-household sector, cross-price elasticity is negative which show that both goods are complementary, and it is might due to the rigid structures in industries and services.

Expenditure elasticities close to unity in both sectors indicate that electricity and natural gas are normal goods. Expenditure elasticity measures the responsiveness of energy consumption (electricity and natural gas) to changes in household expenditures. The elasticity coefficient of 0.987 indicates that for a 1% increase in household expenditures, electricity consumption increases by 98%. Similarly, the elasticity coefficient of 1.014 for natural gas suggests that natural gas consumption increases by slightly more than 100% with the same 1% increase in household expenditures. In the non-household sector, the elasticity coefficient for electricity is 0.99 and 1.004 for natural gas indicating 100% increase in energy consumption. The results reveal the importance of elasticities.

For non-households, the coefficient value for own price elasticity for is (-1.017), means that a 1% increase in the price of electricity decreases the demand to a 101.7%. The cross price elasticity of natural gas coefficient value is 0.018 indicating that a 1% increase in the price of electricity leads to a 1.8% increase in the demand for natural gas. For electricity, the own-price elasticity coefficient value is -0.988, and the cross-price elasticity is -0.013. The own-price elasticity for natural gas is -0.992, and the cross-price elasticity is -0.008. These negative sign of cross-price elasticities indicate that electricity good and natural gas good are complementary goods in the non-household sector, meaning that as the price of any one product tends to increase, the demand for both products decreases.

Author Contributions

All authors participated in ideation, development, and writing the manuscript. All authors read and approved the final manuscript.

Conflict of Interest Statement

The authors declare that there is no conflict of interest regarding the publication of this article.

Funding Statement

The authors did not receive financial support from any funding agency or external organization for the research, authorship, or publication of this article.

Informed Consent

Informed consent was obtained from all participants.

Data Availability

The datasets generated during and analysed during the current study are available from the corresponding author on reasonable request.

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