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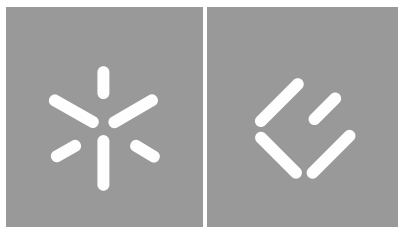
Estimating Energy Demand Elasticities in the European Union: A Panel Data Analysis of gasoline prices, income and inflation (2001-2019)



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A panel data analysis of gasoline prices, income, and inflation.**

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Resumo

Esta tese analisa como o consumo de energia na União Europeia responde, no curto prazo, a variações em variáveis económicas chave. Utilizando dados em painel de 22 países da UE entre 2001 e 2019, foi aplicado um modelo de efeitos aleatórios para estimar os efeitos dos preços da gasolina, do rendimento nacional e da inflação, na procura de energia primária. O objetivo é compreender as elasticidades a curto prazo e fornecer informações úteis para a elaboração de políticas.

Os resultados mostram que a procura de energia diminui quando os preços da gasolina aumentam, sendo o efeito modesto. Isto significa que medidas baseadas apenas nos preços, como os impostos sobre os combustíveis, podem não reduzir rapidamente o consumo de energia, especialmente em setores como os transportes, onde as alternativas são limitadas. A elasticidade do rendimento também é baixa, sugerindo que o crescimento económico tem um efeito limitado sobre a procura de energia a curto prazo, o que apoia os objetivos da UE de dissociar o consumo de energia do crescimento do PIB.

As conclusões sugerem que a política energética da UE deve combinar instrumentos de fixação de preços com outras medidas, tais como o investimento em infraestruturas, o apoio à inovação e a proteção específica dos grupos vulneráveis. Uma combinação de instrumentos é mais eficaz do que depender apenas de sinais de preços.

Embora este estudo seja limitado pela utilização de dados a nível nacional e de um modelo estático, contribui para a nossa compreensão da forma como a procura de energia reage às condições económicas. Futuras investigações poderão basear-se neste estudo, utilizando dados mais detalhados e modelos dinâmicos.

Palavras-chave: consumo de energia, elasticidade dos preços, União Europeia, preço da gasolina, fatores macroeconómicos, política energética.

Abstract

This thesis explores how energy consumption in the European Union responds in the short term to changes in key economic variables. Using panel data from 22 EU countries between 2001 and 2019, a random effects model was applied to estimate the effects of gasoline prices, national income, and inflation on primary energy demand. The goal is to understand short-run elasticities and provide insights for policy.

The results show that energy demand decreases when gasoline prices rise, but the effect is modest. This means that price-based measures alone, like fuel taxes, may not quickly reduce energy use, especially in sectors like transport where alternatives are limited. Income elasticity is also low, suggesting that economic growth has a limited effect on short-term energy demand, which supports EU goals for decoupling energy use from GDP growth.

The findings suggest that EU energy policy should combine pricing instruments with other measures, such as investment in infrastructure, support for innovation, and targeted protection for vulnerable groups. A mix of tools is more effective than relying only on price signals.

Although this study is limited by its use of national-level data and a static model, it adds to our understanding of how energy demand reacts to economic conditions. Future research could build on this by using more detailed data and dynamic models.

Keywords: energy consumption, price elasticity, European Union, gasoline price, macroeconomic factors, energy policy.

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LIST OF ABBREVIATIONS

EU - European Union

ETS - Emission Trading system

GDP - Gross Domestic Product

GJ - Gigajoule

HICP - Harmonized Index of Consumer Prices

OECD - Organization for Economic Cooperation and Development

USD - United States Dollar

1 Introduction

The European Union faces growing pressure to balance energy security, climate commitments, and economic resilience (European commission, 2019). However, the energy transition in the EU is far from just a responsive approach to global crises, it represents a long-term development plan that goes beyond decades of economic and environmental planning (European Parliament, 2019). Starting in the early 2000s, particularly following the Kyoto Protocol (European commission, 2004) and the introduction of the 2004 Climate and Energy Package (European Parliament, 2019), the EU has positioned itself at the centre of global efforts to reduce the carbon intensity of the EU's economy and promote sustainable development.

In order to understand the best way to achieve the success and the challenges of these development in the long term, it is important to analyse the economic effects that could influence changes in the energy consumption. To interpret these relationships between energy demand and development, it is necessary to take into account key concepts of analysis that describe the relationship between energy demand and variation in the world economy. Energy consumption plays a significant role in defining economic performance, environmental impacts and social conditions (International Energy Agency, 2021). In the context of the European Union's decarbonisation strategy, particularly its efforts to achieve climate neutrality by 2050 and its goal of reducing greenhouse gas emissions by 55% by 2030 (European commission, 2020). it is important to understand the factors of energy demand that allow policies to be formulated based on these factors.

However, despite the EU's efforts to promote the energy transition, reducing energy demand remains a constant challenge. The main issue to consider is the diversity of consumer responses to changing economic conditions, particularly with fluctuations in energy prices and incomes.

Although policy instruments such as carbon taxes or subsidies depend on predicted behavioural changes, demand responses are often heterogeneous, influenced by sector conditions, household income levels and infrastructure use. In addition, constant concerns about energy poverty and inflation increase the problems of defining interventions that are not only functional but also balanced. These problems demonstrate a constant gap between theory and practice in the creation and implementation of policies. Thus, there is a growing

demand for data to guide policymakers on better understanding how different economic variations affect energy consumption in EU Member States.

The energy demand is not static, as it can change based on economic factors, such as price changes, which have an impact on consumer behaviour across all sectors (Labandeira et al., 2017). Analysing these responses allows policymakers to better predict the impact of measures such as carbon taxes, fuel taxes and subsidies, ensuring that consumption and emission reduction goals are achieved without harming the economy (Gillingham & Palmer, 2014). It also helps identify sectors that may be most significantly affected by the energy transition, such as the transport sector (Díaz, Pérez, & Sánchez, 2019).

The transport sector plays a key role in this context, as the sector remains highly dependent on fossil fuels, contributing to almost 30% of total final energy consumption in the EU and more than a 25% share of total greenhouse gas emissions (Ajayi & Reiner, 2020; Berry & Börjesson, 2024). Research shows that gasoline and diesel consumption in the EU has significant price elasticity, meaning that changes in fuel prices can have immediate and significant effects on consumer behaviour (Aklilu, 2020). An increase in fuel prices tend to reduce vehicle use, increase demand for public transport and increase the switch to low-emission vehicles (Fridstrøm and Østli, 2021). However, the behavioural responses are different across countries, showing differences in income levels and road infrastructure (Wohlgemuth, 1997; Dahl, 2012). Understanding these dynamics is important for the definition of policies to reduce carbon emissions in transport without affecting economic activity. Moreover, in the context of the EU's 2050 climate neutrality goals, the acceleration of the transport transition to low-carbon options, such as electric mobility and sustainable biofuels, has a significant effect on reducing gas emissions and energy consumption.

In addition, changes in energy consumption and mobility behaviour, as well as growing dependence on transport, represent a challenge for the transition to a low-carbon economy. In contrast to other sectors, where electricity and energy efficiency can be introduced more easily, the transport sector shows a higher carbon intensity and is therefore more difficult to transform. Given these challenges, the importance of a decarbonisation policy for the transport sector, including sustainable mobility and the transition to electric mobility, is important in order to reduce gas emissions and dependence on fossil fuels.

On the other hand, studying the price elasticity of energy demand and energy consumption patterns also show how vulnerable different economies to energy price shocks

(Burke & Csereklyei, 2016). These types of analyses allow for a better understanding of the differences between EU countries and the adaptation of better policies considering national specifications, rather than the application of more general measures (Roupas et., 2011).

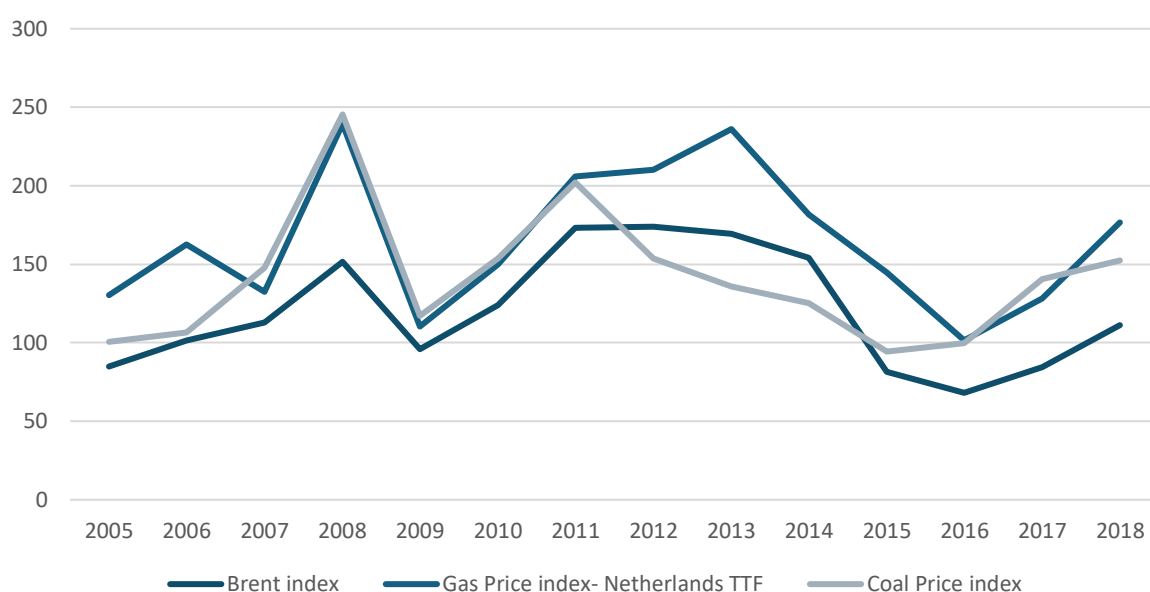
Evolution of energy consumption in Europe.

Understanding the evolution of energy consumption in the European Union (EU) is necessary to analyse the impact of recent economic crises. Events such as the 2008 financial crisis, the COVID-19 pandemic and the war in Ukraine have not only damage economic activity but also directly influenced energy consumption patterns (Ajayi & Reiner, 2020). These events have shown the vulnerability of energy systems to external shocks (Shevchenko, 2023).

The 2008 crisis, for example, caused a significant reduction in industrial activity and energy consumption, especially in countries most exposed to financial shocks (Burke & Csereklyei, 2016). Similarly, the pandemic restrictions had a negative impact on mobility and energy consumption in the transport and services sectors (Gao et al., 2021). The war in Ukraine has caused instability in energy markets, increasing fossil fuel prices and reopening the discussion about energy security and import dependence in the EU (Tesfu, 2024).

The impact of these crises can also be seen in the volatility of fossil fuel prices.

Figure 1 – Evolution of Fossil Fuels Prices (2001-2018)

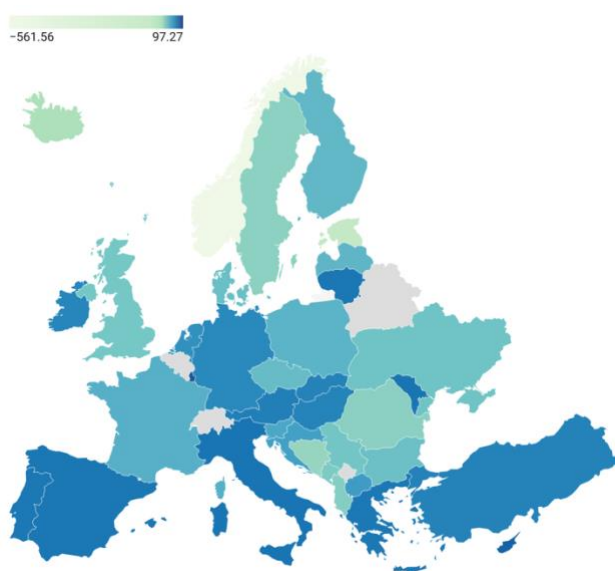


Source: Prepared by the author with data from Our World in Data, retrieved from <https://ourworldindata.org/grapher/fossil-fuel-price-index>

Figure 1, above, shows the price index of Brent crude oil, Dutch TTF gas and coal in Europe between 2005 and 2018. This shows significant price fluctuations, particularly around the 2008 financial crisis, after a period of recovery and a second significant drop between 2014 and 2015, caused by a shock in global oil and gas supplies, which led prices to their lowest levels in more than a decade, showing even more the dependence of European markets on fossil fuels.

These events show that we need energy policies that can adapt and are based on real evidence. It's important to understand how energy demand responds to changes in variables like price, income, and unemployment to make effective ways to reduce the negative effects of future crises. Also, how countries respond to the same crisis shows how important it is to compare and consider each country's economic and social context.

Figure 2 – Energy dependence in Europe (2019)



Source: Prepared by the author with data from Eurostat (2024) retrieved from https://ec.europa.eu/eurostat/databrowser/view/sdq_07_50/default/table

Figure 2, above, presents the variation in energy dependence between European Union countries in 2019. This demonstrates that there are significant differences in energy

dependence across Europe. Eastern and southern countries such as Malta, Cyprus, Greece and Hungary are more dependent on energy imports, while northern countries such as Sweden, Finland and Estonia are less dependent due to more developed energy infrastructure and domestic resources. Norway is an exception, since it is a large energy exporter. This shows that European countries are exposed to different levels of risk when energy prices rise, or when supplies are affected. It also shows that energy policies should be adapted to the situation of each country, instead of using the same approach for all countries.

Although the concepts of energy price elasticity and energy intensity are well established in the literature, there are still some gaps in understanding how to best respond to how energy demand reacts to macroeconomic shocks in the short term, particularly during periods of economic transition. Most existing studies focus on long-term estimates, which tend to obscure behavioural changes that may occur more rapidly during crises or periods of instability (Labandeira et al., 2017). Understanding short-term elasticities is important to make better policy responses during economic crises, when consumer behaviour tends to change more in the short term than the long term. In addition, the impact of variables such as fuel prices, income, inflation or unemployment on energy consumption is still unclear. The results obtained are often inconclusive across countries and methodologies, and short-term elasticity estimates for European economies continued to be understudied (Gao et al., 2021). Furthermore, many empirical models use annual data, which makes it hard to see how energy demand change over time and how policies implemented over time impact it (Ajayi & Reiner, 2020). So, there is a need for a more detail and over time studies that can give more information about how energy demand changes in response to variation in economic conditions in the European Union.

In the context of constant economic policy changes, it is becoming more important to understand how energy demand reacts to shocks in the economic sector. Energy consumption patterns in the EU are defined by a combination of structural situations and short-term effects, such as fluctuations in fuel prices and changes in income. Analysing the elasticities of energy demand in relation to these variations provides important information about the behavioural, economic and social dynamics that have an impact on consumption.

The European Union is a case study in how to respond to demand in times of economic and geopolitical instability, as recent events such as the 2008 financial crisis, the COVID-19 pandemic and the war in Ukraine have caused significant changes in economies and the

energy sector. In addition, the internal diversity of the EU, where countries show significant differences in terms of fossil fuel dependence, energy efficiency and fiscal performance, highlights the need for comparative analyses that can control for these structural differences (Roupas et al., 2011). This study aims to complement the literature on energy demand by presenting recent and focused estimates of short-run price in the European Union. Moreover, while many previous studies emphasize long-term trends (Labandeira et al., 2017), this research attempts to offer a more context sensitive analysis of the EU during a period of energy and economic transition. The analysis allows for a better understanding of how energy demand responds to economic indicators during periods of structural change, a topic that remains understudied. From a policy perspective, the results contribute to the formulation of appropriate and flexible instruments, such as fuel taxes or energy subsidies, at national and European levels. Furthermore, by demonstrating how energy consumption responds to income, price, and inflation changes, this study can improve the accuracy and balance of energy and climate policies, particularly in times of present and future energy crises.

The objective of this study is to estimate the short-run economic determinants of energy demand in the European Union member states during the period 2001-2019. Using a panel dataset from 22 countries, the study focuses on the response of primary energy consumption to fluctuations in fuel prices, national income, inflation, and unemployment. Fixed-effects and random-effects models are used, complemented by year dummies to control for time-specific shocks.

The empirical analysis allows to estimate the short-term elasticities of primary energy consumption, meaning, it allows us to estimate how energy demand responds to price changes in different regions and over time.

After the introduction, the thesis is divided into four main parts. The first part presents a review of the literature on energy demand, focusing on elasticity, macroeconomic influences and the political context of the EU. The second part describes the data sources, variables and panel data methodology used to estimate short-term elasticities. The third part presents the empirical analysis, which studies the impact of fuel prices, income, inflation and macroeconomic shocks on energy consumption. The final section summarizes the main conclusions, discusses their policy implications and presents suggestions for future research.

2 Literature review

In the current context of a rapidly changing global energy landscape, the European Union (EU) is striving to balance environmental sustainability with economic resilience. The EU has set an ambitious target of achieving climate neutrality by 2050, alongside an interim goal of reducing greenhouse gas emissions by 55% by 2030 (European commission, 2020). These commitments have drawn increased attention to the structural and behavioral dimensions of energy consumption.

At the same time, energy prices have become increasingly volatile (Shevchenko, 2023) due to various geopolitical factors, particularly the Russian invasion of Ukraine, alongside systemic disruptions stemming from the COVID-19 pandemic. These events have highlighted the EU's vulnerability to outside energy dependencies and have emphasized the urgent need to transition to more secure and sustainable energy sources (Tesfu, 2024). This transition is crucial not only for environmental goals but also for ensuring long-term energy security and stability.

Energy price elasticity and energy intensity are important concepts that help us understand how energy markets work and how consumers respond to changes in energy prices and policies. Price elasticity refers to how much energy demand changes in response to shifts in cost, which is useful for evaluating the effectiveness of fiscal policies like carbon taxes or fuel subsidies (Labandeira et al., 2017). Meanwhile, energy intensity looks at the amount of energy consumed for each unit of economic output, giving us insight into economic efficiency and the potential for reducing carbon emissions in industrial sectors (Díaz et al., 2019). Considering these concepts is crucial, not just for their technical aspects but also because they have significant implications for policy-making, investment decisions, and the socioeconomic conditions within EU member states. Understanding these metrics can provide valuable guidance for developing effective strategies moving forward.

This literature review looks at a wide range of studies to explore how energy price elasticity and energy intensity have changed in the EU over time. It is organized into three main parts. The first part presents topics on how energy price elasticity and energy intensity have shifted across the EU in the last ten years. The second part looks into the energy market instability and context, considering its impact in energy price elasticity. Finally, the third part looks at the various factors of the energy transition that also impact energy price elasticity.

2.1 Energy price elasticity and energy intensity

Energy price elasticity has been a subject of significant development over recent decades, a large amount of empirical literature focusing on the European context. The work on energy demand responsiveness starts with Houthakker's (1951) study, which laid the foundation for the subsequent theoretical models in the analysis of energy demand elasticities, focusing on price elasticity. Subsequent contributions by Taylor (1975) and Espey & Espey (2004) refined these findings, with a focus on the price elasticity of residential electricity demand.

The concept of price elasticity varies significantly depending on many factors, including energy type, consumption sector, time horizon, and geographical region. Labandeira et al. (2017) examined the elasticities of energy demand. They found that average short-run price elasticities tend to be inelastic (i.e., less than one in absolute value). In the European context, short-run elasticities for petrol and diesel are proposed to be between -0.1 and -0.3, while long-run elasticities tend to be larger, suggesting greater consumer adaptability over time (Dahl, 2012).

Research on long-run price elasticities in the transport sector demonstrates a higher capacity for behaviour and structure to change over time. As Small and Van Dender (2007) demonstrate, although short-term responses to fuel price changes tend to be limited, long-term effects are more significant due to improvements in fuel efficiency and shifts in behavioral patterns when it comes to travel, driven by long-term policy. In addition, Donna (2018) developed a theoretical model of urban travel demand, finding that long-run elasticities for automobile use and public transport are significantly higher than their short-run elasticities. This finding suggests that consumers may be able to adapt more significantly to price variations over time, as long as they are supported by appropriate policy interventions, such as investments in public transit and technological alternatives.

In a consistent estimation of price elasticity across the EU-28, Zeleke (2016) observed that, while the average price elasticity remains relatively low, structural reforms such as deregulation and the expansion of public transportation have led to increased responsiveness in some countries. These results suggest that price elasticity is not uniform across the region, but can be significantly influenced by national-level policy choices and infrastructure development.

More recently, empirical results show that price elasticity can change across EU countries. Alberini et al. (2021) estimated that the short-run price elasticities of gasoline in Germany are close to -0.25, while Baranzini and Weber (2013) found a lower elasticity of -0.09 in Switzerland. On the other hand, Fridstrøm and Østli (2021) showed that gasoline price elasticity was significantly higher in Norway, approximately at -1.08. These variations show how important the national context is, infrastructure accessibility, and fuel taxes are in defining how consumers react to changes in energy price.

Further differentiation emerges when the price elasticity of fuel demand relative to car usage is disaggregated by income level. Berry and Börjesson (2022) used micro panel data to demonstrate that lower-income households exhibit greater fuel price sensitivity compared to higher-income counterparts, particularly in car usage (Berry & Börjesson, 2022).

The concept of energy intensity, defined as the ratio of energy consumption to economic output, has gained renewed relevance in the EU context as a proxy for both energy efficiency and climate change mitigation (Burke & Csereklyei, 2016). Declining energy intensity is often seen as a positive indicator of decoupling economic growth from fossil energy use, although the underlying drivers are complicated. (Wing, 2008). According to Burke and Csereklyei (2016), these drivers range from improvements in energy efficiency to structural economic changes, such as the transition from manufacturing to service-based sectors. Historically, industrialized EU countries have experienced a steady decline in energy intensity since the 1970s, a trend accelerated by successive waves of technology adoption, environmental regulations, and the integration of renewable energy sources (Wing, 2008). Metcalf (2008) explored these patterns in the U.S. context, but his findings regarding the role of economic structure and policy instruments apply equally to the EU. Similarly, Oseni (2009) demonstrated that among 16 OECD countries, those with greater investments in energy-saving technologies and proactive policy frameworks experienced more significant declines in energy intensity.

Zhang (2023) highlighted how the pandemic temporarily disrupted energy intensity patterns in China, while Tesfu (2024) illustrated that the EU's response to the recent energy crisis involved accelerating renewable investments to reduce long-term energy intensity and exposure to fossil fuel volatility. Díaz et al. (2019) explored the relationship between economic growth, energy intensity, and the energy mix, revealing that countries emphasizing cleaner energy sources tend to exhibit stronger decoupling.

In conclusion, the decline in energy intensity across Europe has not been uniform. According to Gulzar and Farooq (2022), disparities in national energy mixes, industrial specialization, and policy enforcement levels create substantial variation. For instance, Eastern European countries tend to have higher intensity levels due to legacy infrastructure and greater dependence on coal-based energy.

The literature review on energy price elasticity shows that consumer responses to energy prices can change between countries, and sectors in the European Union. Therefore, it is important to understand these differences to develop better energy policies as energy intensity changes.

2.2 Energy markets uncertainty

Energy markets are susceptible to price volatility, which can be attributed to endogenous market mechanisms and exogenous shocks. Understanding this volatility is important, since significant and unexpected prices changes allows for an estimation of the elasticity of energy demand in the short term. Analysing how demand responds to changes in prices helps explain how consumers respond to energy price shocks, which is important for analysing the impact these shocks in different sectors. In the last twenty years, the European Union has faced several disruptions that have affected its energy systems. These include the global financial crisis in 2008, the collapse of oil prices between 2014 and 2015, the COVID-19 pandemic in 2020, and the energy crisis in 2022 that followed the invasion of Ukraine. Each of these events has posed challenges to the resilience of energy systems in the EU. They have also caused a chain reaction that impacted fuel prices, inflation levels, investment flows, and even the long-term direction of policy. (Kubinschi, Barnea, & Zlatcu, 2019). The study by Kubinschi, Barnea, and Zlatcu (2019) examined fuel price volatility across several European countries and highlighted strong interdependencies in energy pricing, suggesting the presence of systemic contagion effects within the region. These findings are in alignment with those of Shevchenko (2023), who emphasized the influence of external shocks and global market fluctuations on domestic energy price dynamics in Europe. Zhang (2023) further contributed to the field by illustrating how the pandemic amplified short-term volatility in gasoline prices, leading to erratic consumption behavior and temporary deviations from historical short run price elasticity patterns.

Hamilton (2009) and Ghoshray (2011) provided key information on the macroeconomic implications of oil shocks, demonstrating that increases in energy prices contribute to reduced output, higher unemployment, and inflationary pressure. Huynh (2016) used dynamic stochastic general equilibrium (DSGE) models to analyse the propagation of energy price shocks through the business cycle. Their findings indicated that such shocks influence economic performance.

Energy prices also have a significant impact on inflation, especially in energy import dependent EU economies. Arpa et al. (2006) and Punzi (2019) show that oil price shocks and energy price uncertainty can rapidly affect both headline and core inflation through CPI transmission and inflation expectations, often triggering restrictive monetary policy. In fact, Southern EU countries face greater inflationary impacts due to higher energy intensity and import dependence (Uche, 20-22; Roupas et al., 2011). These vulnerabilities highlight the need for tailored policy responses.

Energy policy instruments, including taxes, subsidies, and emissions trading systems, aim to modify consumption behaviors by changing price signals (Gillingham & Palmer, 2014; García-Álvarez et al., 2023). These instruments are necessary to resolve market failure, such as the external effects and differences in information, which are common in energy markets. As a result, these tools can have an impact on both short-term and long-term energy demand elasticities. By influencing the real cost of energy consumption and lead to changes in the economy, they determine how consumers and companies respond to energy price fluctuations over time. While the potential indirect effects of current policy instruments are recognised, they will not be addressed in this empirical analysis, which is mostly focused on energy prices and their direct effect on consumption behavior.

To conclude, there are important considerations in the literature about the rebound effect and the limitations of price-based mechanisms to fully capture consumer behaviour (Stern, 2012; Small & Van Dender, 2007), as well as the possible progressive impacts of carbon pricing and the need for equality in policy design. However, given their difficulty, these topics should be considered in future research.

2.3 The EU energy transition

The transition of the European Union towards a low-carbon economy is changing the conditions that affect how people use energy. Changes in energy systems, patterns of income distribution, and new challenges related to energy access all play a role in how people react to changes in prices and income. Even though this study mainly focuses on short-term factors that influence primary energy consumption, it is important to understand the wider aspects of the energy transition. This understanding helps us to better interpret consumption behaviors in a world that is continuously changing due to new economic and technological developments.

The European Union's transition to a low-carbon energy system has been marked by the accelerated deployment of renewable energy sources (RES) such as wind, solar, and bioenergy (Tesfu, 2024). There has been significant progress across the European Union, but this progress has also led to new challenges related to network stability and investment uncertainty, which require adjustments to changes in the economy and the market conditions. This expansion, driven by environmental and geopolitical imperatives, including the desire to reduce dependence on imported fossil fuels, has required substantial investments in system flexibility, energy storage, and smart grids (Bynoe & Moonsammy, 2023). Despite these advancements, the transition remains uneven, influenced by national differences in institutional strength, regulatory frameworks, and innovation capacity (Strielkowski et al., 2024; Nam & Jin, 2021). Furthermore, the ability of different countries to substitute fossil fuels for renewables varies according to structural factors, including capital-labor-energy substitution ratios and the existence of targeted policy incentives such as feed-in tariffs or renewable auctions (Li et al., 2023).

In addition to the technical challenges we face, the social aspect of the energy transition is becoming more important. Households with lower incomes tend to react more strongly to changes in energy prices, which raises concerns about unfair impacts if there are not enough compensatory policies in place. (Harold et al., 2017; Berry & Börjesson, 2024). The concept of energy vulnerability expands this view, considering not only economic access but also physical infrastructure and social exclusion (Bouzarovski & Petrova, 2015; Thomson et al., 2017). Although instruments like the Just Transition Fund aim to address these disparities, implementation gaps remain, particularly in countries with weaker administrative structures (Strielkowski et al., 2024).

To conclude, this literature review shows that technological innovation, energy system resilience, and economic and social adaptations are important for the European Union transition to a low carbon economy. An analysis of the elasticity of energy prices and income allows for a better understanding of consumer behavior, the impact of policies and economic weaknesses, and helps to define more effective policies focusing on a global economy in constant change

3 Data and analysis

This section presents the data and approach used to estimate the response of energy demand to the main macroeconomic variables and fuel prices in EU countries. Based on the work of Labandeira et al. (2017), Berry and Börjesson (2024) and Zeleke (2016), the analysis was designed to estimate the response of energy demand to changes in fuel prices and energy policies.

3.1 Data

Data and sources

This study uses a panel dataset covering 22 European Union Member States over the period 2001 to 2019. The sample selection was based on the availability and consistency of key indicators across countries and years, aiming to ensure comparability and reliable econometric estimation.

Some countries have been excluded from the dataset due to a lack of data for the variable used. These countries are Bulgaria, Croatia, Cyprus, Estonia, Latvia, Lithuania, Malta, Romania and Slovenia. They were removed to ensure that the final data set was complete and that data could be compared across countries and years in order to obtain valid results for econometric analysis.

The dataset includes annual observations for each country, resulting in 418 observations in total. The choice of the 2001–2019 period allows for the capture of major macroeconomic and energy-related events, including the 2008 global financial crisis, the

eurozone sovereign debt crisis, and the early stages of the COVID-19 pandemic, all of which are expected to influence short-term energy demand dynamics.

The core variables included in the empirical analysis are summarized in Table 1, below.

Table 1 – Selected variables overview

Variable	Unit	Relevance	Source	Link
Primary energy consumption	GJ per capita	Target variable (proxy for aggregate energy demand)	Our World in Data.	https://ourworldindata.org/grapher/primary-energy-cons
Gasoline price	USD per liter	Explanatory variable (direct fuel cost)	OECD Library annual reports.	https://www.oecd.org/en/publications/energy-prices-and-taxes_16096835.html
Diesel price	USD per liter	Explanatory variable (direct fuel cost)	OECD Library annual reports.	https://www.oecd.org/en/publications/energy-prices-and-taxes_16096835.html
Income	USD (current)	National income measure (indicator of purchasing power)	World Bank.	https://data.worldbank.org/indicator/NY.GNP.MKTP.CD
GDP per capita	USD per capita (2015 constant)	Economic affluence measure (income elasticity)	World Bank.	https://data.worldbank.org/indicator/NY.GDP.PCAP.KD
GDP	USD (current)	Total economic Output (indicator of economic size)	World Bank.	https://data.worldbank.org/indicator/NY.GDP.MKTP.CD
Unemployment rate	Percentage	Labor market indicator (economic constraint)	Eurostat.	https://ec.europa.eu/eurostat/databrowser/view/tps00203/default/table?lang=en
Inflation rate	Annual percent change	Control for price level and real purchasing power	Eurostat.	https://ec.europa.eu/eurostat/databrowser/view/prc_hicp_aand/default/table?lang=en
HICP	Index (2015 = 100)	General price index (broader macroeconomic sentiment)	Eurostat.	https://ec.europa.eu/eurostat/databrowser/view/teicp250/default/table?lang=en
Fossil fuel consumption (%)	Percent of total energy use	Structural control (energy mix and carbon intensity)	Our World in Data.	https://ourworldindata.org/grapher/global-fossil-fuel-consumption

The dependent variable is primary energy consumption per capita, measured in gigajoules (GJ) per person, which serves as a proxy for aggregate energy demand across

sectors. The main explanatory variables are retail fuel prices—gasoline and diesel—expressed in USD per liter.

Macroeconomic control variables are incorporated to account for broader economic conditions: GDP per capita (constant 2015 USD) measures economic affluence, GDP (current USD) captures the total economic output, the unemployment rate reflects labor market dynamics, and inflation rates capture changes in the general price level. Additionally, the Harmonized Index of Consumer Prices (HICP) is included to provide a broader measure of price developments across countries, and income (current USD) reflects the purchasing power and broader economic activity. Finally, the share of fossil fuels in total energy consumption, expressed as a percentage, serves as a structural control, capturing differences in energy mixes and carbon intensity among Member States.

Data were sourced from reputable international databases: Our World in Data, the OECD Library, the World Bank, and Eurostat. Table 1 provides a detailed overview of each variable, including units of measurement, sources, and links for reference. The data are annual and based on original observations, from 2001 to 2019 for each country, without interpolation.

Looking at the main characteristics of the data through a descriptive and comparative analysis across countries and years, Figure 3, below, shows the retail prices of gasoline and diesel by country for 2019. There are clear differences between Member States. Northern and Western countries, like Denmark, the Netherlands, and Italy, usually have higher fuel prices. This can be explained by stronger environmental taxation policies. On the other hand, Eastern European countries, such as Czechia, Hungary, and Poland, have lower fuel prices because of lower taxes and different market structures.

For example, in Denmark, Italy and Norway, fuel prices are almost twice as high as in Poland, Slovakia and Türkiye. These price differences are important when studying elasticity, as consumer reactions may depend on the initial price level and affordability. While some convergence in energy prices can be observed over time, significant differences between countries continue to exist, which reflect different fiscal policies and income levels.

Figure 3 –Retail price of gasoline and diesel by country (2019)

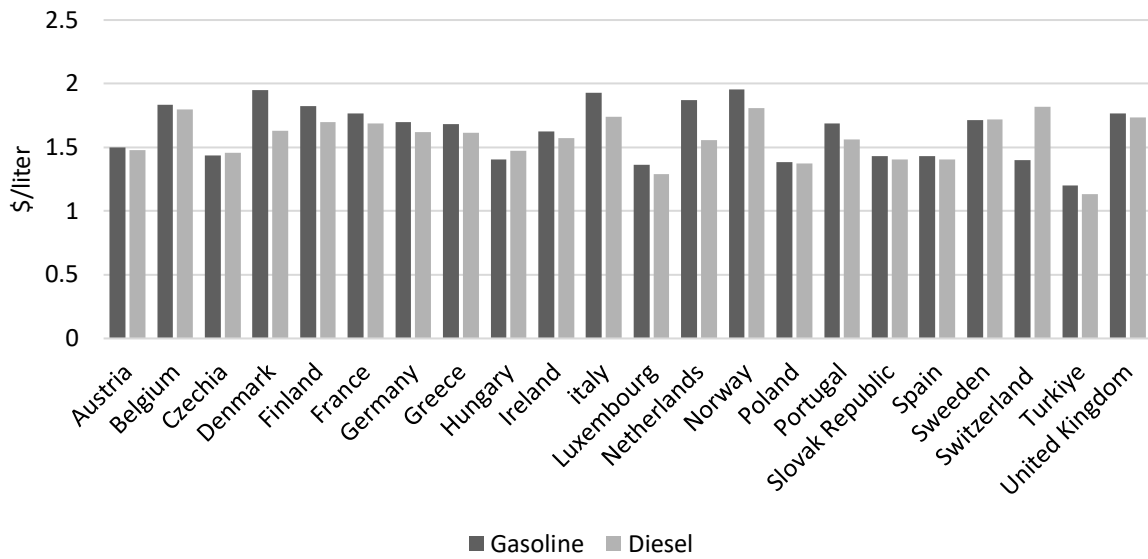


Figure 4 – Gasoline and diesel prices (\$/liter) in Portugal. 2001-2019

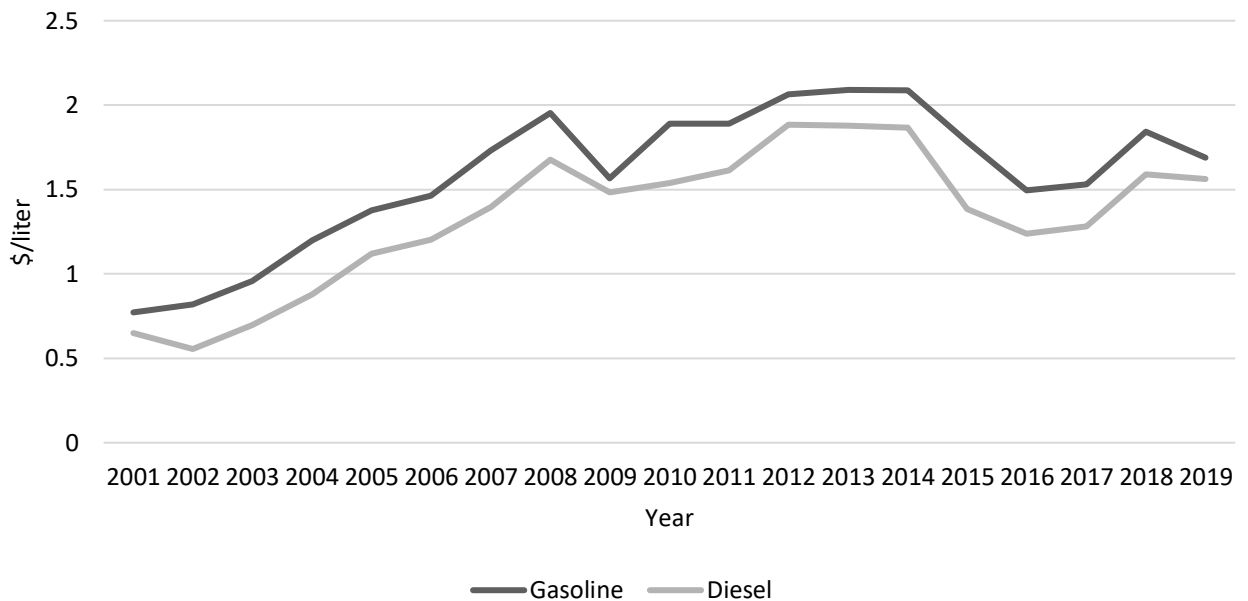


Figure 4, above, presents the prices of gasoline and diesel in Portugal for each year. Two important cycles can be seen. Prices rose until 2008, fell during the global financial crisis, and rose again before falling around 2014–2015. The rise in prices until 2008 is directly related to production restrictions implemented by OPEC, which aimed to control supply and maintain global oil prices. Meanwhile, the 2008 financial crisis caused a big drop in global energy

demand, which made prices go significantly lower. The increase in oil production in the United States and the concern about the energy transition in many countries, like renewable sources, have started to impact prices since 2014-2015, leading to a downward trend. These price changes are mostly caused by global factors, like production decisions, speculation, or geopolitical events. It is important to understand these changes because they cause shocks that affect short-run energy demand in different ways across countries. These impacts also depend on how much a country depends on energy. Countries with economies that depend a lot on fossil fuel imports are more vulnerable to price shocks, while countries with energy systems that are more diverse or have significant national production are more able to reduce these effects.

Figure 5 below shows the EU average primary energy consumption per capita. Overall, there is a declining trend, especially after 2008. This reduction is linked to better energy efficiency, economic changes from industry to services, and policies to support cleaner energy. But some countries, such as Finland and Sweden, keeping high levels of per capita energy consumption because of their colder climates, strong industrial sectors, and higher income levels. However, there are big differences between countries. Northern countries tend to consume more energy per person, partly because of colder climates and heavier industries, while Southern and Eastern countries consume less. The need for heating is also an important factor in this trend, as in northern countries, long and cold winters increase the demand for energy for residential and industrial use significantly, resulting in an increase in total energy consumption.

Data preparation

Before estimating the models, it was necessary to prepare the data. Several steps were taken to ensure the quality and consistency of the variables.

First, all monetary variables were converted into constant 2015 US dollars. This adjustment removes the effects of inflation and allows better comparison over time. Fuel prices and GDP per capita were deflated using standard price indexes from the World Bank and OECD.

Second, most continuous variables were transformed into natural logarithms. This helps stabilize the variance of the data and allows a direct interpretation of coefficients as elasticities. Variables like primary energy consumption per capita, gasoline prices, diesel

prices, GDP per capita, national income, and HICP were log-transformed. Inflation was also transformed when positive values were available. For observations where inflation was negative or zero, the values were excluded from the logarithmic transformation process to avoid undefined results, as the natural logarithm of zero or a negative value does not exist.

Some variables were lagged by one year, such as gasoline price, national income, and inflation. Lagging the variables helps reduce the risk of simultaneity bias and reflects more realistically how consumers respond to past changes rather than immediate ones. This choice was tested by comparing models with and without lagged variables, where models that included lags showed higher statistical performance, with more consistent coefficient estimation.

Missing values were handled carefully. When missing values were isolated and limited, simple linear interpolation was applied. In cases with multiple consecutive missing years, those observations were dropped from the panel

After these steps, the dataset was cleaned and structured for the econometric analysis. In total, 418 observations were available, maintaining a balanced panel across the 22 countries.

These procedures were essential to ensure that the econometric estimations would not be biased by data quality issues, and that the analysis would reflect true economic behavior rather than measurement problems.

Figure 5 –EU average primary Energy Consumption per capita (GJ/pc). 2001-2019

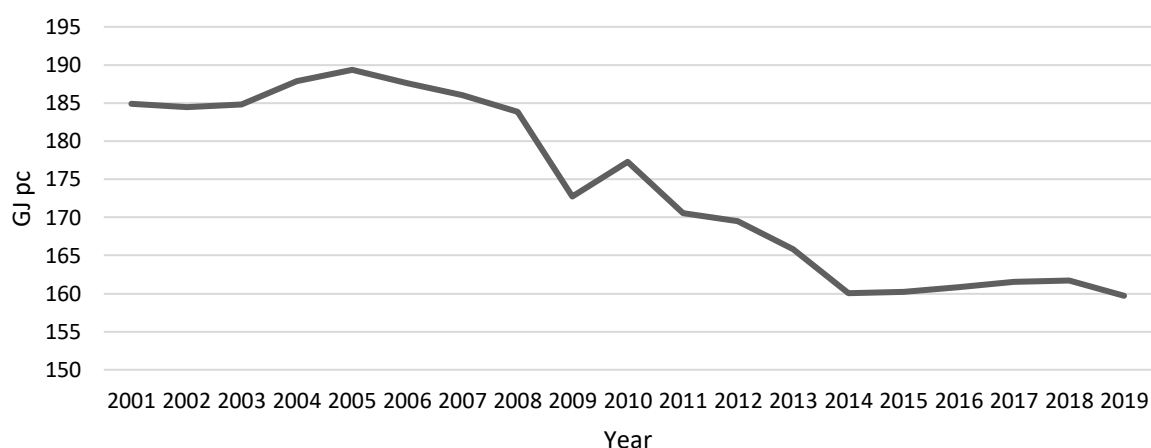


Table 2, below, gives the descriptive statistics for the main variables. There is a large variation across the sample. For example, GDP per capita varies from about 3,000 USD in the poorest countries to more than 100,000 USD in the richest. Gasoline prices range from under 0.60 USD/liter to over 2.60 USD/liter. Inflation and unemployment also vary significantly, showing how the EU countries were affected differently by crises like the 2008 recession and the sovereign debt crisis.EU

Table 2 – Descriptive statistics of the variables

Variable	Unit	Obs	Mean	Std. dev.	Min	Max
GDP	\$	418	1.33e+12	2.87e+12	6.45e+09	1.63e+13
GDPpercapita	\$/pc	418	36,015	23,661	3,169	112,418
Income	\$	418	5.07e+11	5.21e+11	8.71e+09	2.99e+12
Inflation	%	418	2.59	4.10	-1.14	54.40
HICP index	N	418	93.88	15.46	31.80	234.44
Unemployment	%	418	8.89	6.15	1.87	37.32
Gasoline price	\$/l	418	1.54	0.42	0.60	2.62
Diesel price	\$/l	418	1.42	0.41	0.53	2.40
Fossil fuel consumption	%/total energy	418	75.66	18.98	28.46	99.32
Primary energy consumption	Gj/pc	418	174.16	78.15	43.99	436.26

These initial observations show the importance of using econometric models that control for country and year effects. They also suggest that elasticities will not be the same in all countries, which supports the use of panel data methods that allow for this kind of difference.

3.2 Econometric model

This study uses a panel data structure to estimate short-run energy demand elasticities across European Union Member States. Panel data allows the observation of multiple countries over several periods, controlling for country-specific factors that do not vary over time, such as cultural preferences, long-standing infrastructure differences, and climatic conditions. As discussed by Wooldridge (2020), panel models offer distinct advantages over pure cross-sectional or time-series approaches, particularly by capturing unobserved heterogeneity across observational units. A pooled OLS estimation, ignoring the panel nature

of the data, would likely produce biased and inconsistent estimates due to the omission of relevant unobserved variables. By contrast, panel models effectively correct for this bias.

The period analyzed (2001–2019) covers several important macroeconomic and political events, such as the 2008 global financial crisis, the 2011 eurozone sovereign debt crisis, and the growth period stages just before the COVID-19 pandemic. These events introduce significant cross-country and temporal variations. By exploiting both the cross-sectional and time dimensions, the model captures not only static differences between countries but also the dynamic responses of energy consumption to economic shocks.

The dependent variable is the natural logarithm of primary energy consumption per capita, measured in gigajoules (GJ). Using a per capita specification ensures comparability across countries of different sizes, while the log transformation facilitates elasticity interpretation and stabilizes variance.

The key explanatory variables are:

- The lagged natural logarithm of real retail gasoline prices (USD/liter),
- The lagged natural logarithm of national income per capita (constant 2015 USD),
- The lagged natural logarithm of the Harmonized Index of Consumer Prices (HICP).

All monetary variables were deflated to constant 2015 US dollars to adjust for inflation. Logarithmic transformations were applied to continuous variables, following established best practices (Gujarati, 2009; Wooldridge, 2020). Inflation rates were log-transformed only when strictly positive, resulting in 33 missing observations due to deflation periods. Missing data were addressed using conservative imputation techniques, and sensitivity checks confirmed that the distribution of key variables was not significantly altered.

The main explanatory variables were lagged by one period to account for adjustment delays in consumer behavior and to reduce simultaneity bias.

The relationship between energy demand and its determinants was estimated using a linear panel data regression model. A log-log (double-log) specification was chosen because it allows for a direct interpretation of coefficients as elasticities (Gujarati, 2009).

Two models were initially considered: a fixed effects model and a random effects model. The fixed effects model allows correlation between country-specific factors and the regressors, while the random effects model assumes no such correlation, offering more

efficient estimates if the assumption holds. The Hausman test was used to choose between models. The result (p-value = 1.0000) supports the random effects specification, suggesting that country-specific effects are uncorrelated with the explanatory variables.

Although dynamic panel data methods such as the Arellano-Bond estimator (GMM) could be employed in contexts with strong endogeneity concerns, they were not considered necessary here. The primary interest lies in estimating contemporaneous short-run elasticities).

The econometric analysis was conducted using STATA software (StataCorp, 2021), which provided the necessary tools for estimating the panel data model and performing robustness checks.

Thus, the final model estimated is:

$$\ln(EnergyDemand_{it}) = \beta_0 + \beta_1 \ln(P_{gasoline_{i,t-1}}) + \beta_2 \ln(Income_{i,t-1}) + \beta_3 \ln(HICP_{i,t-1}) + \sum_{t=2003}^{2019} \gamma_t Year_t + u_i + \epsilon_{it}$$

Where:

- $\ln(EnergyDemand_{it})$ is the natural logarithm of primary energy consumption per capita in country i and year t.
- $\ln(P_{gasoline_{i,t-1}})$ is the lagged natural logarithmic of the gasoline price.
- $\ln(Income_{i,t-1})$ is the lagged natural logarithm of national income in constant dollars, a proxy for economic activity.
- $\ln(HICP_{i,t-1})$ is the lagged natural logarithm of the Harmonized Index of Consumer Prices.
- $Year_t$ are year dummy variables capturing time-fixed effects from 2003 to 2019.
- u_i represent the unobserved country- specific random effects.
- ϵ_{it} is the idiosyncratic error term.

Robust standard errors clustered at the country level were used to account for potential heteroskedasticity and autocorrelation.

4 Results and discussion

4.1 Main results

This chapter presents and discusses the results obtained from the econometric estimations of energy demand elasticities in European Union Member States over the period 2001–2019. The analysis focuses on the short-run responses of primary energy consumption to fluctuations in fuel prices, income, and inflation, using a linear panel data model with random effects and robust standard errors clustered at the country level.

The performance of the econometric model was evaluated using different indicators to check how well it explains the changes in energy consumption across countries and over time.

Overall, the results show that the model has a good fit and that the estimates are statistically reliable.

First, the within R-squared of the model is around 0.65. This means that the model explains about 65% of the changes in energy consumption inside each country during the period of study. Although this is not a very high value, it is acceptable for panel data analysis that works with economic and energy variables, which are often influenced by many other factors that are not included in the model. This result indicates that the selected independent variables capture an important part of what affects energy demand in the European Union.

Second, the Hausman test was performed to decide whether to use fixed effects or random effects. The result ($p\text{-value} = 1.0000$) showed that random effects are appropriate because the country-specific factors are not correlated with the independent variables. This makes the estimation more efficient and allows the model to use variation between countries as well as variation over time inside each country.

The decision to use lagged explanatory variables also improves the model. By including past values of gasoline prices, income, and inflation, the model assumes that changes in energy consumption respond to previous economic conditions, which reduces the risk of simultaneity problems. This approach makes the short-run elasticity estimates more consistent with real-world behavior.

Moreover, the inclusion of year dummies adds an important control for external shocks that could have affected all countries at the same time. These events, for example global crises or common EU policy changes, could distort the results if they were not controlled. By capturing the effects of these time-specific shocks, the model avoids bias in the estimation of the elasticities.

The diagnostic tests and model corrections suggest that the estimates are robust. The results can be considered reliable to describe how primary energy demand in the EU responds to short-term changes in economic variables and fuel prices between 2001 and 2019.

After validating the model, the main findings from the regression analysis were summarized in Table 4.1. The estimated coefficients for gasoline price, income, and inflation are all significant and show the expected signs based on economic theory.

Table 3 – Random-effects regression results for $\ln(\text{Energy Demand})$

Predictor	b	SE	z	P> z
$\ln_P_{\text{gasoline}} (L1)$	-0.095	0.042	-2.25	.025
$\ln_national_income (L1)$	0.020	0.005	3.84	.000
$\ln_prices_index (L1)$	0.458	0.032	14.40	.000
year 2003	-0.014	0.017	-0.83	.407
year 2004	0.007	0.018	0.42	.672
year 2005	0.006	0.021	0.29	.774
year 2006	0.007	0.025	0.29	.773
year 2007	-0.010	0.027	-0.38	.706
year 2008	-0.032	0.029	-1.11	.268
year 2009	-0.085	0.037	-2.31	.021
year 2010	-0.084	0.030	-2.85	.004
year 2011	-0.112	0.036	-3.14	.002
year 2012	-0.137	0.038	-3.64	.000
year 2013	-0.153	0.041	-3.76	.000
year 2014	-0.197	0.042	-4.71	.000
year 2015	-0.193	0.042	-4.58	.000
year 2016	-0.201	0.037	-5.48	.000
year 2017	-0.222	0.029	-7.66	.000
year 2018	-0.225	0.029	-7.64	.000
year 2019	-0.230	0.035	-6.58	.000
Constant	2.613	0.206	12.68	.000
Model fit statistics:				
Number of observations: 396				
Number of groups: 22 (countries)				
R^2 (Within): 0.648				
Wald $\chi^2(20) = 655.51, p < .001$				
$\sigma_u = 0.434$				
$\sigma_e = 0.055$				
$\rho = 0.984$				

Gasoline price elasticity

The estimated short-run gasoline price elasticity is -0.095, indicating that a 1% increase in the real retail price of gasoline leads, on average, to a 0.095% decrease in primary energy consumption per capita in the following year, holding other factors constant. This elasticity is statistically significant at the 5% level, as shown by the p-value of 0.025.

The negative sign is consistent with economic theory and previous studies such as Labandeira et al. (2017), who found that energy demand is generally price inelastic in the short

run. Consumers often cannot immediately adjust their energy consumption because of habits, lack of alternatives, or the nature of energy use in transportation and heating. As a result, the short-term reaction is usually smaller than the long-term adjustment.

The relatively low magnitude of the elasticity suggests that, although fuel price increases discourage energy consumption, the effect is limited in the short term. This may reflect the essential nature of energy in daily life, where individuals and companies have few immediate substitutes. It also highlights the importance of complementary policies, such as investments in public transport or improvements in energy efficiency, to strengthen the impact of price-based measures over time.

Moreover, the use of lagged gasoline prices in the model suggests that behavioral adjustments do not occur immediately after price changes, but rather with some delay, which is realistic given the time needed to adapt consumption patterns.

Income elasticity

The estimated short-run income elasticity is 0.020, positive and highly significant (p -value = 0.000). This implies that a 1% increase in income per capita leads, on average, to a 0.020% increase in energy consumption per capita.

The result is consistent with the theory that energy demand increases with economic growth. As incomes rise, households may purchase more energy-consuming goods and services, and industrial production may expand, both leading to higher overall energy use.

However, the relatively low value of the income elasticity compared to many previous works (such as Labandeira et al., 2017; Gao et al., 2021) suggests a weaker link between income and energy demand in the EU during the study period. This could reflect saturation effects, greater energy efficiency, or structural economic changes, such as a shift towards services and less energy-intensive activities.

It is also important to note that even if the effect is modest, the positive income-energy link still poses challenges for energy and climate policy. As economies grow, energy consumption tends to rise unless significant efforts are made to improve energy efficiency or to change consumption patterns. Therefore, achieving the EU's climate goals will require not only decoupling emissions from energy, but also decoupling energy consumption from economic growth itself.

Inflation elasticity

The coefficient for the lagged Harmonized Index of Consumer Prices (HICP) is estimated at 0.458 and is statistically significant at the 1% level (p -value = 0.000). This indicates that higher inflation is associated with a notable increase in primary energy consumption per capita.

One possible interpretation is that inflationary pressures may affect relative prices, shifting consumption patterns in ways that increase energy use. Alternatively, during periods of inflation, energy may be treated as a basic necessity, resulting in relatively inelastic consumption patterns.

The relatively high magnitude of the inflation elasticity compared to previous expectations suggests that inflation dynamics can have a substantial impact on energy consumption, making it an important factor to consider in energy demand forecasting and policy design. Given the strength of this relationship, further research would be useful to better understand the channels through which inflation influences energy demand, particularly across different sectors and income groups.

All main explanatory variables are statistically significant, and their signs are aligned with theoretical expectations. These results indicate that macroeconomic conditions are crucial determinants of energy consumption patterns across the European Union, while short-run fuel price responsiveness remains limited. Policies that aim to manage energy demand must therefore integrate both market-based instruments and broader macroeconomic considerations.

The estimated elasticities are consistent with the previous findings in the literature review. For instance, Labandeira et al. (2017) find that short run price gasoline price elasticity, are typically between -0.1 and -0.3, which is close to the value obtained in this study (-0.095). Regarding income elasticity the results obtained was 0.020, which is lower than the values presented by Gao et al. (2021), where estimates are between 0.2 and 0.5. This difference could suggest a smaller relationship between income growth and energy consumption within the European Union during this period in analyse, possibly due to economic changes and improvements in energy efficiency.

Year Fixed Effects

In addition to the main explanatory variables, the regression model includes year dummy variables to capture the effects of time-specific shocks that were common across all countries during the period under analysis. The inclusion of year fixed effects is important because it controls for unobserved events that could simultaneously influence energy consumption in all Member States, such as financial crises, oil price shocks, or major policy changes at the EU level.

The estimated coefficients for the year dummies provide interesting insights into the historical evolution of energy demand.

The coefficients for the years from 2003 to 2008 are small in magnitude and statistically insignificant. This suggests that, during this earlier period, there were no strong common shocks affecting energy consumption across the European Union, or that national-level factors dominated the variation in energy demand.

However, starting from 2009, the year dummy coefficients become negative and statistically significant, particularly from 2009 onwards. For example, the coefficient for 2009 is negative and significant at the 5% level ($p\text{-value} = 0.021$), and the coefficients for the years 2010 to 2019 are increasingly negative and highly statistically significant ($p\text{-value} < 0.01$ for most years).

This pattern coincides with the impacts of the global financial crisis, the eurozone sovereign debt crisis, and the subsequent period of slow recovery and austerity policies across the EU. The most pronounced negative effects occur between 2012 and 2019, suggesting a persistent and strong downward pressure on energy demand during this period.

Factors such as reduced economic activity, tighter public and private budgets, improvements in energy efficiency, technological change, and structural shifts toward less energy-intensive sectors may have contributed to this sustained reduction in energy consumption.

Overall, the pattern of year fixed effects confirms that energy consumption in the EU is influenced not only by prices and income, but also by broader macroeconomic and political conditions. By explicitly controlling for these time-specific shocks, the model ensures that the estimated elasticities for gasoline prices, income, and inflation are not biased by external events that simultaneously affected all countries.

4.2 Policy analyses

Alignment with EU Policies

The short-run elasticities that we estimated in this study give helpful insights that match with the European Union's energy and climate policy frameworks until 2019, especially the European Green Deal and the Fit-for-55 Package. Even though our empirical analysis mainly looks at the effects of price, income, and inflation, the findings are useful to understand important challenges that EU policies aim to address.

First, the finding of low short-run price elasticity reinforces the EU's approach of combining price signals with regulatory and investment measures. Since energy consumption does not respond strongly to price increases in the short term, policies relying solely on carbon pricing or taxes are unlikely to achieve rapid demand reductions. The European Green Deal reflects this by emphasizing investments in clean energy infrastructure, energy efficiency, and sustainable mobility options, to gradually enable behavioral shifts.

Second, the positive, but very modest, income elasticity observed supports the EU's strategy of decoupling economic growth from energy consumption. Although the empirical evidence suggests that economic expansion still leads to slight increases in energy demand, this underlines the relevance of improving energy efficiency and encouraging low-carbon innovation, as promoted by EU initiatives.

Third, the limited but significant impact of inflation on energy demand highlights the importance of consumer protection measures. EU policies, such as the Governance Regulation and the Electricity Directive, already required Member States to monitor and mitigate energy poverty. The results of this study, showing consumers' limited ability to adjust energy use during price increases, reinforce the necessity of targeted support for vulnerable groups.

Finally, the period covered by the analysis, which includes the global financial crisis, shows the importance of integrating economic resilience into energy policy design. Instruments like the Just Transition Mechanism demonstrate the EU's recognition that energy and climate goals must be pursued with attention to broader economic and social stability. In summary, the estimated short-run elasticities support the EU's multifaceted energy transition strategy, combining market-based measures, regulatory standards, investment in

alternatives, and social protection to achieve a balanced and sustainable decarbonization process.

Gasoline prices and fiscal instruments

The empirical results presented in the previous chapter indicated that the short-run gasoline price elasticity of energy demand is negative and statistically significant but relatively small in magnitude. This finding is consistent with the broader literature on European energy consumption, which suggests that energy demand tends to be inelastic in the short term. Such evidence has important policy implications, particularly for the design and expected impact of fiscal instruments such as fuel taxes, subsidies, and regulated price interventions.

Given the low magnitude of short-run price elasticity, fiscal instruments based solely on price increases, such as higher fuel taxes, are unlikely to produce large immediate reductions in energy consumption. Instead, as shown in previous empirical studies, the principal short-run effect of fuel taxes is to raise government revenues rather than substantially curb energy use. These revenues can be strategically allocated to finance complementary policies, including investments in renewable energy, energy efficiency programs, or public transportation infrastructure, thereby supporting longer-term demand reduction strategies.

In addition, the results suggest that fiscal measures may have a stronger influence on consumer behaviour over the long term. Even if people do not change their energy use much right after prices go up, constant increases in energy prices might lead them to adjust gradually. This can include switching to more energy-efficient equipment, changing transport habits, or improving the insulation of their homes. Because of this, it is important for governments to send clear and steady price signals that help shape long-term changes in how energy is used.

With this in mind, fuel taxes should be introduced gradually and in a predictable way, rather than through sudden increases. This gives people and businesses time to prepare and change their consumption habits. It also makes the impact of fiscal policies more effective. At the same time, these taxes should be supported by other policies, like rules and public investment, to make cleaner options more available. For example, improving public transport or making electric vehicles and efficient appliances more accessible can help people make

better energy choices. If there are no good alternatives, people cannot easily change their behaviour, which reduces the effect of price-based policies.

Another important topic is the use of energy subsidies or price controls. In situations where prices increase suddenly or during economic hardship, temporary support measures like subsidies or price caps can help protect households, especially the most vulnerable. Because energy demand does not drop much in the short term, these kinds of interventions can prevent serious social problems without causing big increases in overall energy use. However, if these support measures stay in place for too long, they can reduce the motivation to save energy or move to more sustainable behaviours. For this reason, it is better to make these supports temporary and targeted rather than permanent or given to everyone.

Overall, the findings on short-run price elasticity support a policy strategy that combines moderate and predictable pricing instruments with complementary measures aimed at facilitating behavioral change. Fiscal tools alone are insufficient to achieve significant short-term reductions in energy consumption. A coherent mix of price signals, investment in alternative energy options, regulatory measures, and consumer support policies is necessary to foster a gradual and sustainable adjustment of energy demand patterns across EU Member States.

Income, economic growth, and green growth

The empirical results obtained in the previous chapter showed that income elasticity of primary energy demand in the European Union is positive but very small in the short run. This finding is consistent with the hypothesis that increases in national income are associated with modest increases in energy consumption, particularly over short periods. Although the magnitude of the elasticity is low, the positive sign has important implications for the relationship between economic growth and energy demand, especially in the context of the EU's climate neutrality objectives.

A positive but limited income elasticity indicates that, even as economies grow, energy consumption tends to increase, although at a slower rate. This partially confirms the process of relative decoupling observed in several European countries, where gross domestic product (GDP) has expanded while energy use has remained stable or even declined. Nonetheless, the positive income elasticity estimated suggests that economic growth continues to exert

upward pressure on energy demand, requiring constant efforts to sustain and deepen decoupling trends.

From a policy point of view, this result shows how important it is to follow strategies that support economic growth while also improving energy efficiency. The European Green Deal and earlier EU climate and energy plans already focus on the need to separate economic growth from the use of natural resources. In this situation, it becomes especially important to improve energy efficiency in different sectors, modernise industrial systems, and support low-carbon innovations. The small but still positive income elasticity found in this research gives more reason to keep working on these policy goals.

The findings also support the idea of "green growth," which is one of the main goals of the EU. This idea aims to combine economic development with a lower impact on the environment. The low income elasticity in the short term means that efforts like improving energy efficiency, investing in clean transport, and increasing the use of renewable energy could play a strong role in shaping how the economy and energy use evolve over time. However, for this to work well, policies need to be reviewed regularly and adjusted when needed, so that energy demand does not go up again when the economy grows.

Even though the model used in this study does not give specific estimates for each country, the general situation in the EU suggests that policies might need to be adapted depending on each Member State. Countries in the EU have different income levels, energy systems, and types of economies, so the way energy demand reacts to economic growth may not be the same everywhere. Because of this, national energy and climate policies should be flexible and adapted to local realities. At the same time, they should still match the overall goals set by the EU. Coordinating national strategies with wider EU frameworks will be very important to make sure that climate and energy targets are reached together.

Inflation and energy needs

The empirical model estimated in this study included the Harmonized Index of Consumer Prices (HICP) as a control variable to account for the general price level's influence on energy demand. The coefficient for HICP was found to be positive and statistically significant, with a relatively substantial magnitude compared to typical short-run elasticities. This suggests that, in the short run, increases in general price levels, including energy inflation, can have a notable effect on primary energy consumption. The statistical significance of inflation in the model reinforces the broader relevance of price stability and consumer purchasing power for energy demand behavior.

From a policy perspective, even moderate inflationary pressures can have important social consequences, particularly for vulnerable groups. Although energy demand remains relatively inelastic, meaning that consumption patterns do not adjust strongly when prices rise, the real burden of higher prices falls disproportionately on lower-income households. Households with lower incomes tend to allocate a larger share of their budgets to essential energy services, such as heating, lighting, and transportation. Therefore, even moderate increases in inflation can exacerbate energy poverty, reducing the affordability of basic energy needs.

The empirical results reinforce the importance of protecting consumers, especially vulnerable groups, during periods of price volatility. In the EU context, energy affordability is recognized as a fundamental aspect of the energy transition, with several policy measures already in place before 2019, such as social tariffs, energy subsidies for vulnerable households, and obligations on Member States to monitor and address energy poverty. These measures are justified by the observed limited flexibility of household energy consumption: because many households cannot easily reduce their energy use in response to price increases, targeted assistance is necessary to avoid social exclusion and ensure a just transition.

Past economic crises (2008–2013)

The dataset used in this study covers the period of the global financial crisis of 2008 and the eurozone debt crisis. Although no structural breaks were explicitly estimated, the year dummies included in the model capture some effects of these events, as shown by the negative and increasingly significant coefficients observed from 2009 onwards, particularly after 2012.

The results suggest that economic crises contributed to reducing primary energy consumption in the European Union. This pattern is consistent with the broader literature, where recessions typically lead to declines in industrial activity, household consumption, and transport use, all of which affect energy demand. However, these reductions are not the result of deliberate energy policy and come at significant social and economic costs.

From a policy perspective, the experience from previous economic crises shows how important it is to develop energy policies that can handle large macroeconomic shocks. Drops in energy demand that happen during economic downturns are not sustainable in the long term and should not be taken as a model for reducing emissions. Instead, it is important that energy policies are designed to keep supporting the energy transition, even when the economy is under pressure or going through instability.

Also, the different impacts seen across EU countries between 2008 and 2013 highlight the need for flexibility at the national level, even when working under a shared EU strategy. Member States that already had stronger renewable energy systems and better support for vulnerable groups were more successful in keeping energy affordable and available during the crisis.

In conclusion, the patterns seen during these economic shocks show that energy policy should not be treated separately. It needs to be linked with wider strategies that also focus on making the economy stronger and protecting people during hard times. This kind of approach will help build a more stable and fair path toward the EU's long-term energy goals.

5 Conclusions

In this study, we examined how primary energy demand reacts in the short term to changes in macroeconomic conditions and gasoline prices across 22 EU Member States over the period from 2001 to 2019. To carry out the analysis, a random effects panel data model was applied in order to estimate how variations in gasoline prices and income per capita affect energy consumption patterns. The main objective of this research was to improve the understanding of how these economic variables are related to energy usage in the EU context.

The findings showed that the elasticity of energy demand with respect to gasoline prices is negative and statistically significant, although its value is relatively small. This means that

when gasoline prices increase, there is a decrease in primary energy consumption per person, but the size of this effect is limited in the short term. This result suggests that using fuel prices as the main policy tool may not be enough to quickly lower energy use, especially because many people may not have easy access to alternatives such as public transport or cleaner transport options.

The estimated income elasticity is positive and statistically significant, but also modest. This means that as income increases, energy demand also increases, although at a relatively slow rate. This supports the idea that economic growth still puts pressure on energy consumption, but that there is also potential for decoupling. It becomes possible to grow economically without a proportional increase in energy use, especially with the help of energy efficiency improvements.

Another important conclusion that can be drawn is about the necessity of a well-designed mix of policies. The model indicates that there is low short-run elasticity for both prices and income, which means that changes in behavior regarding energy demand require time. Thus, it suggests that policies should not depend only on pricing mechanisms alone. Investment in public transport, buildings that are more energy-efficient, and transitions in technology are very important. These efforts will make price signals more effective and help to decrease the long-term reliance on fossil fuels.

The results also support several priorities already defined in EU strategies like the European Green Deal. The limited responsiveness of energy demand in the short run confirms the importance of combining carbon pricing with regulation, investment, and targeted support for vulnerable consumers. This integrated approach is necessary to make the energy transition fair and economically viable.

This study has some limitations. It uses aggregated national data and a static model, which may not capture more detailed or long-term effects. It also does not differentiate between sectors, which could help explain more specific behaviours. Future research could improve on this by using dynamic models, sector-level data, and variables that capture energy policy, efficiency, or technology.

Overall, this study contributes to understanding of energy demand behaviour in the EU. It shows that macroeconomic and price factors are important, but also that their effect is limited without broader support. As the EU continues to work on its climate and energy goals,

it is necessary for policies to mix economic tools with long-term planning and social support. This way, it can help to guide the transition to a more sustainable and resilient energy system.

6 References

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