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ABSTRACT

Electric vehicles play a key role in the global energy transition, and the electric vehicle (EV) market has been driven by technological progress and policy support in recent years. Previous studies indicate that surges in fuel prices could lead to a substitution effect toward alternative vehicles. The aim of this thesis is to examine how oil price shocks affect EV adoption in Portugal from 2022 to 2024 by analyzing monthly vehicle registrations in Portugal alongside other economic factors. In addition, the analysis is extended to the European Union (EU) market to compare broader EV adoption patterns with the Portuguese case. The empirical approach combines baseline regressions, lag-structure specifications, and an Autoregressive Distributed Lag Model (ARDL) framework to identify substitution effects. The final results indicate that there is no clear electric vehicle-gasoline vehicle (EV-GV) substitution effect in either the Portuguese or EU market during periods of oil price shocks. By contrast, the time trend has a positive effect on EV adoption in both markets, reflecting the current rapid growth phase of EV adoption. The study's findings suggest that policymakers should continue to utilize financial incentives to boost EV adoption, while also improving EV-supportive infrastructure, such as expanding the number of charging points and reducing the cost of fast charging.

KEYWORDS: Electric Vehicles; Fuel Prices; Oil Price Shocks; Vehicle Adoption; Substitution Effect; Portugal.

JEL CODES: Q41; Q42; R41; C22; Q48.

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STATEMENT

In order to ensure the transparency of my Master's MFW, I hereby declare that I have used ChatGPT for a couple of auxiliary tasks, mainly for framework discussion, grammatical correction and programming assistance.

It is important to state that I have adhered to academic ethics throughout the process. All thesis writing was done by myself. Of course, any errors or mistakes that appear in this paper are my own responsibility.

GLOSSARY

ACEA – European Automobile Manufacturers Association
ARDL – Autoregressive Distributed Lag Model

BEV – Battery Electric Vehicle

BLP – Berry–Levinsohn–Pakes Model

CPI – Consumer Price Index

EU – European Union

EV – Electric Vehicle

GV – Gasoline Vehicle

IEA – International Energy Agency

INE – Instituto Nacional de Estatística (Statistics Portugal)

ISP – Tax on Petroleum and Energy Products

MFW – Master's Final Work

OLS – Ordinary Least Squares

PHEV – Plug-in Hybrid Electric Vehicle

UVE – Electric Vehicle Users Association (Portugal)

VAR – Vector Autoregressive Models

VAT – Value Added Tax

VECM – Vector Error Correction Model

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1. Introduction

The 2015 Paris Agreement aims to achieve carbon neutrality by the middle of this century, which implies the achievement of net-zero greenhouse gas emissions globally by around 2050. In order to further achieve the target of emissions reduction, the European Commission established the “Fit for 55” proposal in July 2021, which aims to reduce greenhouse gas emissions by at least 55% by 2030. In the context of global energy efficiency and emissions reduction, the energy transition plays a significant role, particularly in the transportation sector.

The vehicle industry has a strong impact on energy consumption, and electrification has become a key factor in the global energy transition and decarbonization. The electric vehicle market has expanded dramatically over the past five years, driven by improvements in charging efficiency, battery life, vehicle design, and the global momentum of environmental protection.

According to data from the International Energy Agency (IEA), the growth of the Battery Electric Vehicle (BEV) market illustrates this trend clearly. Between 2020 and 2024, electric car sales—including Plug-in Hybrid Electric Vehicles (PHEVs)— in China increased significantly, with a year-on-year growth of nearly 40% in 2024, maintaining China’s leading position in the global EV market. BEV sales increased from 0.9 million to 6.4 million, representing more than a seven-fold increase during this period. In the European Union (EU), BEV sales increased from 0.8 million to 2.2 million, ranking it as the second-largest BEV market globally.

In parallel with EV adoption, the supporting infrastructure has expanded significantly. According to data from European Automobile Manufacturers Association (ACEA), 632,423 public charging points were operating across the EU at the end of 2023. In that year alone, approximately 153,000 new public charging points were installed. Moreover, national-level purchasing subsidies from most EU member states have further stimulated the development of the EV market.

Fuel prices are a crucial variable influencing consumers' car purchasing decisions, as fuel demand exhibits relatively weak substitutability. Generally, consumers tend to shift their preferences toward low-energy-consuming vehicles, or choose electric vehicles or ethanol cars when petrol prices surge, particularly in countries that heavily rely on fuel imports.

In the first year of the COVID-19 pandemic, fuel prices plummeted to very low levels. However, after Russia invaded Ukraine, international sanctions led to a dramatic surge in energy prices, causing severe inflation and significantly affecting the European Union's energy market. Volatile fuel prices may push consumers to prioritize lower operating cost vehicles, such as EVs and PHEVs, or even to delay vehicle purchases in order to manage expenses, leading to older, less efficient cars remaining on the road for longer periods. Many studies show a strong correlation between rising fuel costs and increased demand for alternative vehicles. Reducing oil dependence in the transportation sector has become a key concern.

Portugal lacks domestic crude oil resources and relies heavily on imports. Consequently, the domestic transportation market is highly sensitive to international petroleum price fluctuations. Fluctuations in fuel prices could have a direct and significant impact on the cost of living across many sectors of the economy.

Petrol prices peaked at €2.14 per liter in Portugal in June 2022. The electric vehicle market has grown rapidly over the past five years, particularly in the post-COVID era. In 2020, 7,820 BEVs were registered in Portugal; by 2024, the figure increased to 41,757. A key question is how strongly fuel price surges influence consumers' vehicle purchase decisions and the market share of electric vehicles in the short run.

Previous studies have mainly focused on countries with large markets, such as the United States, China, and Germany. However, the existing literature provides limited evidence on the short-run effects of oil price spikes on the Portuguese electric vehicle market during the energy market instability in 2022. Therefore, this study aims to fill this gap by providing an empirical economic analysis with relevant policy implications.

This paper employs econometric distributed-lag models to analyze the short-term substitution effect in the Portuguese passenger vehicle market during periods of oil price fluctuations. Using data on Portuguese passenger vehicle registrations from 2021 to 2024, together with other macroeconomic indicators, this study focuses on market reactions to oil price shocks. Additionally, as an extension, we examine changes in the European Union's EV market share over the same period, allowing a comparison with the Portuguese EV market.

The analysis suggests that in a steadily expanding EV market, gasoline prices have a limited marginal impact on EV-GV substitution. This study fills a research gap regarding how gasoline price shocks influence EV adoption in Portugal in the post-2022 context, and provides a foundation for future research on EV adoption and consumers' vehicle purchase decisions in the Portuguese vehicle market.

The remainder of this paper is organized as follows: Section 2 reviews the relevant literature and provides background information and methodological foundation. Section 3 describes data sources and presents summary statistics from the dataset. Section 4 introduces the empirical models, drawing on the approach of Berry (1994). Section 5 analyzes the empirical results of the models and further discusses the underlying mechanisms and economic intuition behind the findings. Section 6 concludes the study and provides some policy implications.

2. Literature review

The global energy transition has intensified academic interest in technological progress within the electric vehicle market. Existing studies suggest that developments in EV technology have played a pivotal role in accelerating EV adoption.

Malik et al. (2025) examine the role of technological advancements in shaping the electric vehicle market and their implications for EV adoption. The study suggests that recent technological advancements— such as innovations in regenerative braking systems, battery thermal management, charging system architecture, and EV sustainability—have significantly accelerated EV diffusion. By considering technological, economic, environmental, and social dimensions, the authors provide a comprehensive overview of major development trends in the EV market. Their findings indicate that technological innovations have substantially improved energy efficiency and reduced life-cycle emissions compared with conventional vehicles, thereby fostering EV adoption.

Building on this technological foundation, Jiang et al. (2024) provide a broader perspective on the energy transition, emphasizing that widespread EV adoption could displace up to 8.5 million barrels of oil per day by 2040. This study highlights recent progress in EV technologies and evaluates the contribution of EVs to the ongoing energy transition, while also outlining the prevailing challenges that impede EV adoption. Beyond technological advancement, the authors also discuss the impact of policy. The authors argue that effective coordination and collaboration among governments, businesses, and the public is essential for accelerating EV adoption. They further stress the importance of government policy support, particularly through financial incentives.

Alden Peterson (2024) examines how price volatility influences consumers' vehicle purchasing behavior using quantitative data of the U.S. automotive market between 2012 and 2022. The study finds that both cost-saving and environmental concerns play important roles in shaping consumer decisions. In particular, younger consumers tend to exhibit higher sensitivity to fuel price fluctuations, whereas higher-income groups are relatively less sensitive. The analysis also highlights the role of macroeconomic factors—such as interest rates, GDP growth and unemployment—in affecting vehicle sales. Furthermore, the author shows that manufacturers respond to shifting consumer preferences by introducing more affordable models and increasing investment in electric and hybrid technologies, as part of their response to changing market conditions.

Haxhimusa and Liebensteiner (2025) examine how fuel price fluctuations influence road traffic and vehicle registrations across 17 European countries, using panel data covering the period from 2010 to 2022. They find that higher motorization rates reduce the responsiveness of driving behavior to fuel price changes, whereas greater railway length per capita offers viable alternatives to car travel and increases the price elasticity of traffic demand. Their findings indicate that higher fuel prices significantly reduce registrations of new gasoline and diesel cars and shift consumer demand toward fuel-efficient or alternative-fuel vehicles and public transport. These insights emphasize the importance of fuel prices and transport alternatives in shaping vehicle choice and provide relevant implications for understanding the dynamics of EV adoption.

Mutascu et al. (2024) explore the global interaction between the demand for electric cars and oil prices from January 2020 to March 2023 using a wavelet approach. Their results show that during periods of high oil price volatility, rising oil prices are associated with stronger demand for electric vehicles, whereas sharp oil price drops are linked to weaker consumers' interest in EVs. In addition, short-term dynamics depend on the magnitude of oil price changes and the way consumers respond to price signals. These dynamics remain robust after controlling for geopolitical risks, pandemic effects, car-industry indicators and battery-metal prices. Moreover, the authors document feedback effects whereby stronger EV demand may exert downward pressure on oil prices over the longer term. The authors also discuss policy implications, including energy source diversification, reduced reliance on imported oil, and support for investments in charging infrastructure and battery technology.

Berthelsen and Arteaga (2016) examine whether oil prices, lithium prices and EV sales co-move and influence each other. They develop a model to analyze the relationship between oil prices, lithium prices, and EV sales. Using VAR and VECM models with daily data from June 2011 to April 2016, the authors find that oil prices lead to changes in lithium prices, and both variables are found to Granger-cause EV sales. This implies that oil prices affect EV sales both directly and indirectly through their impact on lithium prices. The study also highlights that these relationships are highly complex, influenced by multiple external factors.

Bushnell et al. (2022) identify a pronounced asymmetry, showing that gasoline price fluctuations influence EV adoption roughly four times more than electricity price changes, drawing on detailed vehicle-registration data from California between 2014 and 2017. Consumers react strongly to gasoline price movements because fuel costs are highly salient and publicly visible. In contrast, electricity prices are far less noticeable and often poorly understood, as households typically face complex billing structures and are uncertain about their effective marginal electricity rate. These behavioral frictions substantially weaken the perceived cost advantage of EVs. Their estimates indicate that consumers place a very low weight on electricity costs compared with gasoline costs ($\gamma \approx 0.1$), implying that electricity prices are undervalued in consumers' expectations of EV operating expenses. These findings explain why oil price shocks translate more visibly into EV demand shifts, whereas electricity price variation generates only muted behavioral responses.

Similarly, Zhao et al. (2025) show that new EV sales in China respond 3.5–6 times more strongly to gasoline price changes than to electricity price changes, reflecting consumers' systematic undervaluation of electricity costs.

Holland et al. (2021) develop a dynamic model calibrated to the U.S. vehicle market to evaluate policies such as gasoline vehicle production bans. The model incorporates both exogenously and endogenously declining EV production costs and allows vehicle substitutability to evolve over time. Their results indicate that bans can increase welfare only when substitutability between gasoline and electric vehicles is sufficiently high, but they also create an inefficient pre-ban spike in gasoline vehicle production. The authors further find that an optimal EV subsidy can reduce deadweight loss at lower substitutability levels.

Berry (1994) develops a discrete-choice model to analyze a cross-section of oligopoly auto markets with differentiated products, incorporating both demand and supply considerations. Prices are endogenously set by price-setting firms and correlated with unobserved product characteristics, which creates the need for instrumental variable estimation. Consumer utility depends on observed product characteristics and individual taste parameters. A major contribution of the paper is the inversion of the market-share equation to recover mean utility. The subsequent Berry–Levinsohn–Pakes (1995) framework further incorporates random coefficients and explicitly models oligopolistic competition, enabling richer substitution patterns and joint estimation of demand and supply.

Salvo & Huse (2012) find that even when sugarcane ethanol is substantially cheaper than gasoline, a substantial share of motorists still do not switch, due to range concerns, habits, and non-price attributes. Similar mechanisms may also be relevant for EV adoption, suggesting that oil prices alone may not be sufficient to drive changes in market share.

Overall, the existing literature converges on several key findings. First, technological progress and policy support are primary drivers of EV adoption within the context of global energy transition, reflecting EV's comparative advantage in energy operating costs. Second, fluctuations in oil prices significantly influence consumers' vehicle purchasing behavior, although the magnitude of this effect varies across demographic and income groups. Moreover, consumer responses are shaped by the availability of alternative transportation options. Third, the literature documents that consumers tend to be less sensitive to changes in electricity prices relative to gasoline prices, which provides EVs with a potential advantage in consumer decision-making.

However, the existing literature mainly focuses on large economies, with relatively limited attention devoted to smaller European countries, particularly in the context of the 2022 oil price shocks. In addition, most studies emphasize individual-level purchase decisions and discrete choice preferences, rather than the relationship between gasoline price fluctuations and aggregate market share dynamics.

Building on these insights, this thesis investigates the short-term impact of oil price shocks on the relative EV–GV market share in Portugal using monthly time-series data from January 2022 to December 2024, and extends the analysis to the EU level to assess broader market dynamics. The existing literature provides a strong foundation for this study. Methodologically, prior research applies a range of econometric approaches to analyze EV adoption, including time-series models, panel data methods, and discrete choice frameworks. Building on these methodologies, this thesis extends the empirical analysis to examine EV–GV substitution dynamics in the context of oil price shocks.

3. Data

3.1 Data Description

This study uses monthly data covering the period from January 2022 to December 2024. Passenger vehicle registration data were obtained from the European Automobile Manufacturers' Association (ACEA), which publishes detailed statistics on new passenger vehicle registrations in European countries. Since ACEA does not provide monthly data for 2021, quarterly ACEA data for that year were used solely for a robustness check. All datasets were downloaded from the ACEA website and processed in Excel. The main empirical analysis relies exclusively on monthly data for 2022–2024, while quarterly data from 2021 to 2023 are employed as a robustness check by re-estimating the baseline specification at quarterly frequency to assess whether the main results remain qualitatively unchanged.

Monthly gasoline prices for 2021–2024 were collected from Trading Economics, which reports official fuel price statistics compiled by the Directorate-General for Energy and Geology (DGEG), the Portuguese governmental authority responsible for energy market regulation. Monthly crude oil prices were obtained from the World Bank.

Additional economic variables such as electricity prices were also examined during the preliminary analysis. However, their short-term variation appears to have limited relevance to monthly EV market share in Portugal; therefore, these variables are reported only for reference and are not included in the empirical model.

All variables are constructed at a monthly frequency to ensure consistency across datasets. The dependent variable measures the relative market position of electric vehicles in the Portuguese car market. Instead of using the simple EV share of total registrations, this study adopts a conditional market share measure, defined as the ratio of newly registered electric vehicles to gasoline vehicles within the same month.

To facilitate model estimation and reduce the influence of large fluctuations, the dependent variable is expressed in logarithmic form. The logarithmic transformation stabilizes variance and provides a linear approximation suitable for modeling relative changes in EV market shares. No additional smoothing or seasonal adjustment is applied, as the sample period is relatively short (three years), and the analysis aims to capture short-term fuel price shocks without altering the original data pattern.

3.2 Summary Statistics

Summary statistics provide an initial overview of the short-run dynamics between fuel prices and vehicle registrations in Portugal.

Table I

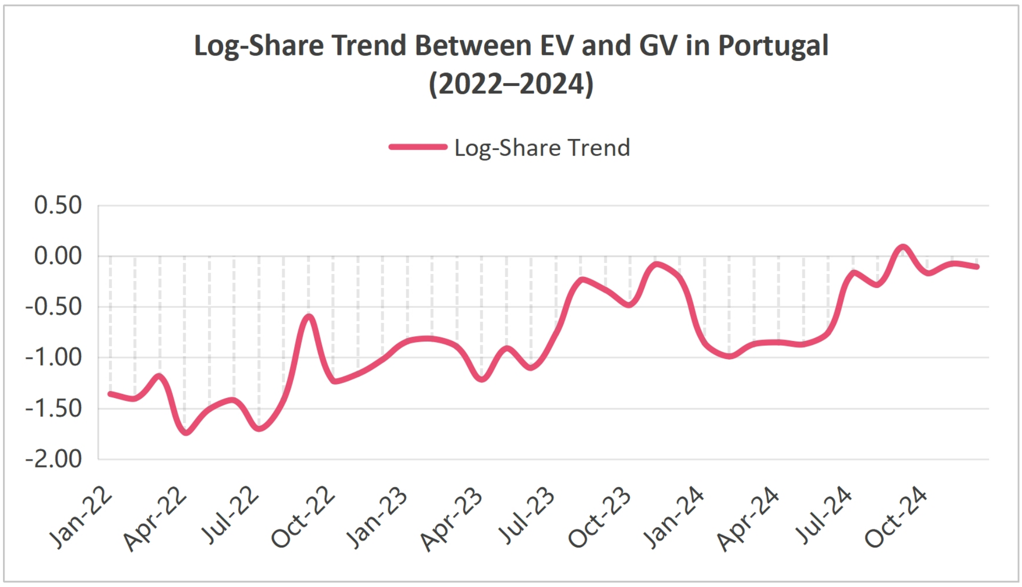
Summary Statistics: Portugal (Monthly Data, 2022–2024)

Variable	Mean	Std. Dev.	Min	Max
Monthly CPI (%)	4.87%	2.96%	1.42%	10.14%
Gasoline Price (€ / L)	1.76	0.12	1.61	2.14
EV Registrations	2,676	1,054	962	5,142
GV Registrations	5,793	1,754	3,292	9,880
Log(EV/GV)	-0.82	0.50	-1.74	0.09

Notes: EV and GV denote monthly registrations of electric and gasoline vehicles; Log(EV/GV) is the natural logarithm of the EV-to-GV registration ratio.
Sample: Jan 2022–Dec 2024 (36 observations).
Data Sources: ACEA, Trading Economics (based on Statistics Portugal/INE), DGEG.

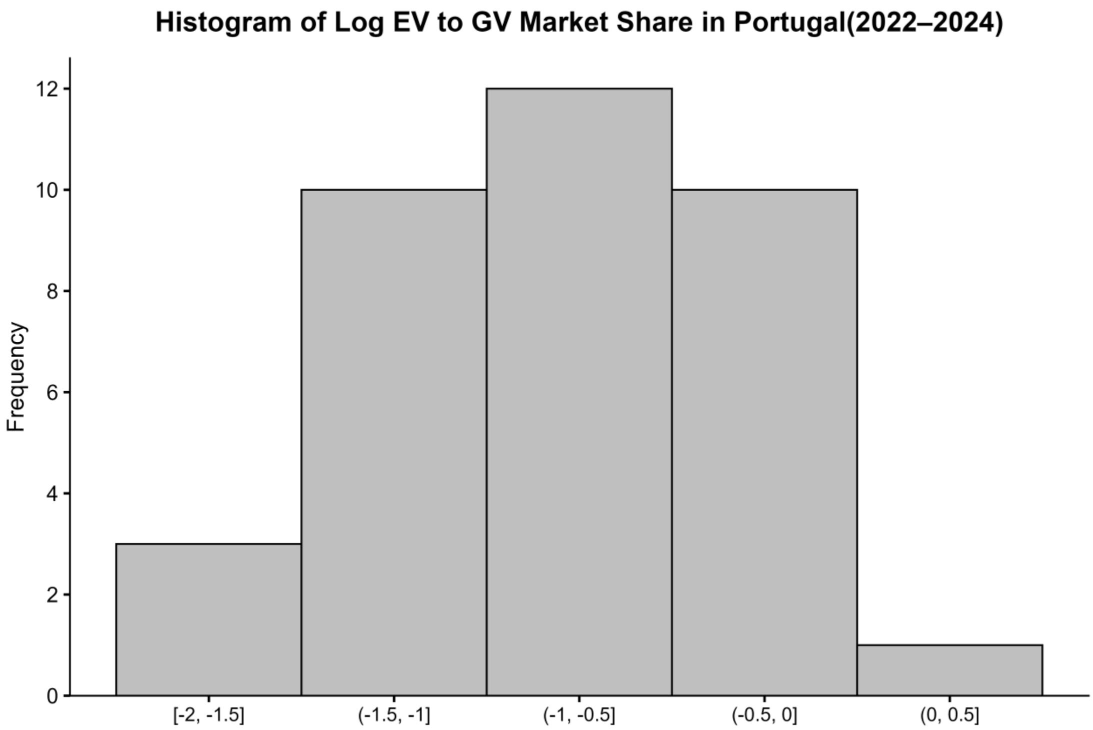
To assess the distributional properties of the dependent variable and identify potential outliers, Figure I (a) plots the log relative EV–GV market share over time in Portugal, while Figure I (b) presents the histogram of the log relative market share.

Figure I (a)



Notes: EV and GV denote monthly registrations of electric and gasoline vehicles; Log(EV/GV) is the natural logarithm of the EV-to-GV registration ratio.
Sample: Jan 2022–Dec 2024 (36 observations).
Data Source: ACEA.

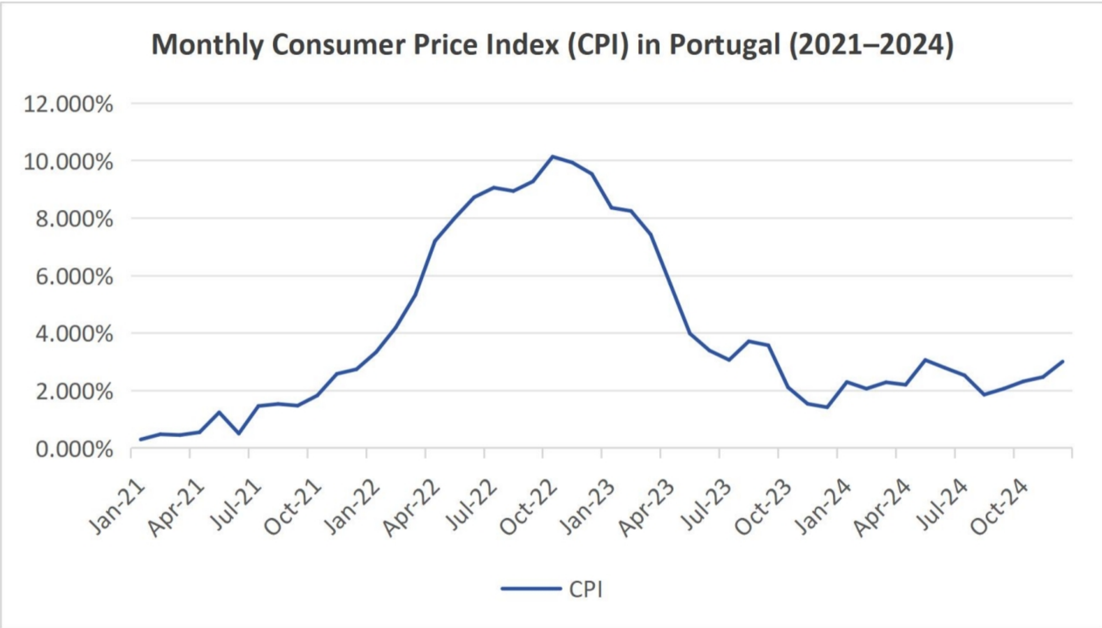
Figure I (b)



Notes: EV and GV denote monthly registrations of electric and gasoline vehicles; Log(EV/GV) is the natural logarithm of the EV-to-GV registration ratio.
Sample: Jan 2022–Dec 2024 (36 observations). Data Source: ACEA.

Inflation increased rapidly from February 2022 in the context of the geopolitical crisis in Ukraine and regional market instability. The inflation rate, as measured by the CPI, reached a peak of 10.14% in October 2022, nearly 7 percentage points higher than in January 2022. Afterward, the inflation declined steadily but remained above 5% until April 2023. Subsequently, inflation stabilized at a more moderate level.

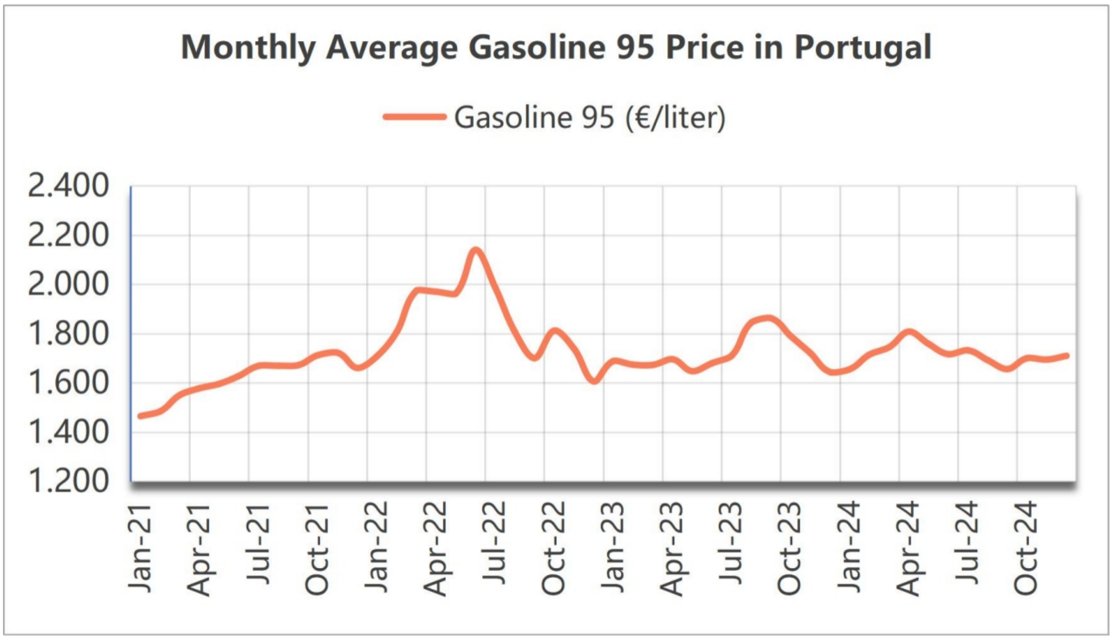
Figure II



Sample: Jan 2021–Dec 2024 (48 observations).
Data Source: Statistics Portugal (INE), accessed via Trading Economics.

Gasoline prices display strong short-run volatility. Prices rose rapidly during early 2022 and reached a local peak of €2.14 per liter in June 2022, before gradually declining from July 2022, with moderate fluctuations into early 2023. Prices increased again during the third quarter of 2023, before stabilizing at a moderate level during the remaining months of 2023 and throughout 2024.

Figure III

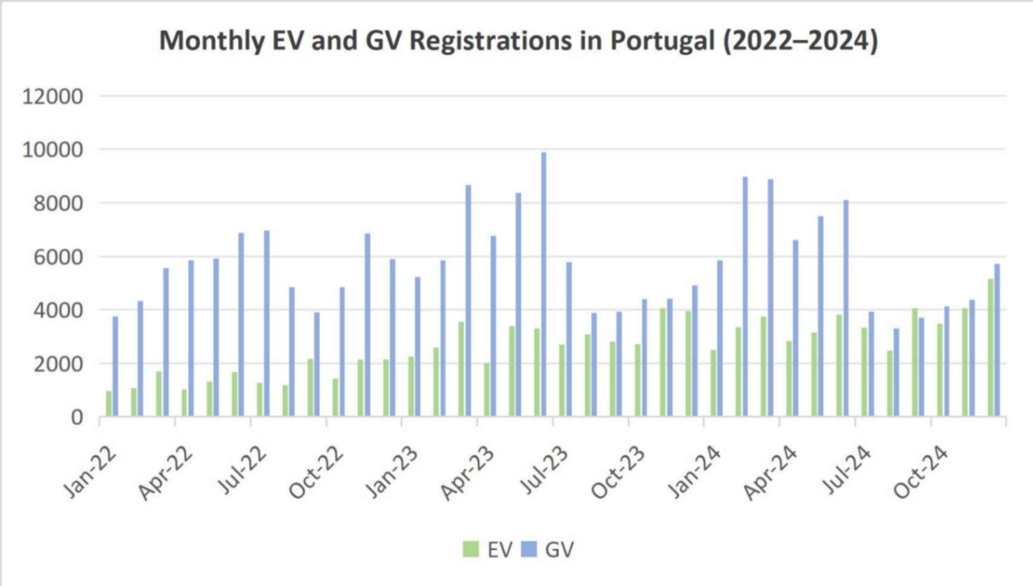


Sample: Jan 2021–Dec 2024 (48 observations).

Data Source: Directorate-General for Energy and Geology (DGEG).

GV registrations remain higher than EV registrations in absolute terms. From April 2022, GV registrations increased at a slow pace before declining after July 2022 with noticeable fluctuations. In the first half of 2023, GV registrations increased rapidly and reached a peak of 9,880, the highest level observed in the sample. In subsequent months, GV registrations remained relatively high in several months—such as 8,884 in March 2024 and 8,093 in July 2024—while continuing to fluctuate over time.

Figure IV



Sample: Jan 2022–Dec 2024 (36 observations).
Data Source: ACEA.

EV registrations fluctuated markedly in 2022 and reached a within-year peak level of 2,150 in September, exhibiting an overall upward trend. Throughout 2023 and 2024, EV registrations increased moderately. In some periods, EV and GV registrations moved in the same direction, while in other periods, EV registrations increased as GV registrations declined, or vice versa.

During several periods in 2022 characterized by rising gasoline prices, EV registrations were observed to increase temporarily, whereas GV registrations often declined or stagnated within short periods. Throughout 2023, gasoline prices moderated, while EV registrations continued to exhibit an upward trend, suggesting the coexistence of short-run price fluctuations and longer-term structural dynamics.

Semi-annual household electricity prices ranged between €0.2071 and €0.2626 per kWh over the period 2021–2024. Although some variation is observed, electricity prices remain relatively stable over the sample period. Existing studies suggest that consumers tend to be less sensitive to electricity price changes than to gasoline price fluctuations. Accordingly, electricity prices are not included as an explanatory variable in the empirical analysis.

The European Union EV market exhibits trends broadly similar to those of

Portugal. Over the period 2022–2024, the relative EV market share increased with moderate fluctuations, while EU CPI and crude oil prices were influenced by international market conditions.

Table II

Summary Statistics: EU Market (Monthly, 2022–2024)

Variable	Mean	Std. Dev.	Min	Max
Monthly CPI (%)	5.41%	2.92%	1.70%	10.6%
Crude Oil Price (€/barrel)	79.93	11.89	65.20	110.53
EV Registrations	114,162	32,680	58,578	193,271
GV Registrations	295,590	41,618	213,057	407,533
Log(EV/GV)	-0.98	0.29	-1.48	-0.30

Notes: EV and GV denote monthly registrations of electric and gasoline vehicles in the EU market; Log(EV/GV) is the natural logarithm of the EV-to-GV registration ratio.
Sample: Jan 2022–Dec 2024 (36 observations).
Data Sources: ACEA, Trading Economics (based on Eurostat), and the World Bank.

Outlier diagnostics are conducted for the Portuguese market using both the IQR-based boxplot method and a percentile-based criterion (2%–98%). The boxplot reveals no extreme observations. The two tail observations identified by the percentile approach lie close to the cutoff boundaries and exhibit moderate magnitudes. Applying the same procedures to the EU market yields consistent results, with even smoother distributional properties observed. Therefore, winsorization is not applied to either market.

Overall, the descriptive evidence suggests possible short-run associations between fuel price movements and EV–GV registrations. However, descriptive analysis alone cannot isolate the price effect from other macroeconomic influences, which motivates the empirical analysis in the next section.

4. Methodology

According to previous research, higher gasoline prices can raise the operating costs of conventional vehicles and make EVs or other alternative vehicles more financially attractive, generating a short-run substitution effect in vehicle choice. However, descriptive statistics cannot clearly show this relationship because several other factors operate simultaneously.

The analysis focuses on monthly variations and models the relative EV-GV market share as a function of oil price fluctuations, time trends, and relevant macroeconomic controls. Using a log ratio of EV registrations to GV registrations allows the model to capture substitution effects directly. Incorporating a time trend accounts for the long-run diffusion of EV technology, while lagged terms make it possible to test whether consumers respond gradually to fuel price shocks.

In this section, the models are used to describe how consumers make purchasing decisions and to link these decisions to the empirical analysis of market shares. Equations (1)–(9) are based on the Berry (1994) framework and outline the consumer-choice setting underlying the analysis. To simplify the exposition, these relationships are expressed in annualized form. Equations (10)–(17) then translate this framework into the empirical specification used in the subsequent analysis.

Before analyzing the market share segment, a set of utility functions is introduced to understand consumer choice preferences and to provide theoretical foundations for empirical analysis of market share and consumer decision-making. Equations (1)-(4) define the conceptual cost framework.

$$\Delta TOC_y = TOC_y^{EV} - TOC_y^{GV} \tag{1}$$

In general, operating costs are one of the major factors influencing consumers' purchasing decisions. Equation (1) measures the difference in annual ownership costs between EVs and GVs, where y denotes the year and TOC stands for total operating cost. Given that EVs have lower ownership costs, ΔTOC_y is expected to be negative.

$$OC_y^{EV} = M_y \eta^{EV} P_t^{elec} + m_y^{EV} + fix_y^{EV} + v_y^{EV} \tag{2}$$
$$OC_y^{GV} = M_y \rho^{GV} P_t^{gas} + m_y^{GV} + fix_y^{GV} + v_y^{GV} \tag{3}$$

The annualized operating costs are an important component of total ownership costs. These costs are decomposed into annual energy expenditure, maintenance costs, and fixed costs such as taxes, insurance, license fees. In equations (2) and (3), y denotes year and t denotes month. The term fix represents fixed costs, m denotes maintenance costs, v captures unobserved cost components. For electric vehicles, energy expenditure depends on electricity prices P_t^{elec} and energy consumption measured in kWh per kilometer η^{EV}, multiplied by annual mileage M_y. For gasoline vehicles, energy expenditure depends on gasoline prices and fuel consumption measured in liters per kilometer ρ^{GV}, multiplied by annual mileage M_y.

$$TOC_y^j = \frac{P^j}{H^j} + OC_y^j + Tax_y^j - Subsidy_y^j + \xi_y^j\ ,\ j \in \{EV, GV\} \quad (4)$$

Note: H^j denotes expected years of use for vehicle type j.

For a given vehicle type $j \in \{EV, GV\}$, total ownership costs are determined by annualized vehicle purchase cost, operating costs, taxes net of subsidies, and an unobserved component. Subsidies are typically applicable to EVs.

$$u_{ijy} = x_j\beta - \alpha TOC_y^j + \xi_y^j + \epsilon_{ij} \quad (5)$$

To quantify consumer purchase behavior, utility functions are introduced. The utility of a certain year y that consumer i derives from vehicle type j depends on product characteristics x_j, total ownership costs, an unobserved product-specific component ξ_y^j, and an error term ϵ_{ij}, where β represents average taste parameters associated with vehicle characteristics.

$$u_{ijy} = x_j\beta + \xi_y^j - \alpha TOC_y^j + v_{ij} \quad (6)$$

with

$$v_{ij} = \left[\sum_k x_{jk}\sigma_k\zeta_{ik}\right] + \epsilon_{ij}\ ,$$

$$\max_{j\in\{EV,GV\}} U_{ijy} \;\; s.t.\; TOC_y^j \leq \lambda Y_i,\; \lambda \in (0,1).$$

Furthermore, the utility function represents the mean utility that consumer *i* derives from vehicle *j*, combining observable product characteristics, the negative effect of total ownership costs, and unobserved attributes.

The term v_{ij} captures individual-specific deviations from mean utility arising from random taste shocks that interact with product attributes, together with an idiosyncratic error. Consumer choice is subject to an affordability constraint, whereby total ownership costs cannot exceed a fraction λ of annual disposable income Y_i.

$$Mean\, utility{:}\quad \delta_{jy} = x_j\beta - \alpha TOC_y^j + \xi_y^j \;\; (7)$$

The mean utility term captures the average valuation of vehicle j across consumers before accounting for individual-specific taste.

$$\ln\left(\frac{s_{EV,y}}{s_{GV,y}}\right) = \delta_{EV,y} - \delta_{GV,y} \;\; (8)$$

Utility influences consumer preferences and drives changes in vehicle market shares. When electric vehicles provide higher utility than gasoline vehicles, consumers are more likely to shift their purchase choices toward EVs, leading to an increase in the market share of EVs. Equation (8) links the relative market shares of EVs and GVs to the difference in their mean utilities. Specifically, the difference in mean utility between the two products corresponds to the natural logarithm of their market share ratio. This log-ratio expression follows directly from the multinomial logit framework developed in Berry (1994).

$$\ln\left(\frac{s_{EV,y}}{s_{GV,y}}\right) = (x_{EV} - x_{GV})\beta - \alpha(TCO_y^{EV} - TCO_y^{GV}) + (\xi_{EV,y} - \xi_{GV,y}) \;\; (9)$$

Substituting the mean-utility expressions into (8) yields Equation (9), which decomposes the market share ratio into observable characteristics, differences in total ownership costs, and unobserved factors. This formulation shows how the relative EV adoption responds to cost differences between EVs and GVs, while allowing for unobserved influences captured by the error term.

Equations (8) and (9) provide a structural framework linking utility differences to the logarithm of the EV-GV market share ratio. Since this study focuses on aggregate market-share dynamics under oil price shocks, the empirical specification does not model product characteristics or ownership-cost components separately. Instead, the reduced-form model estimated later can be interpreted as a simplified empirical representation of Equation (9), with the EV–GV market share ratio on the left-hand side and gasoline prices and macroeconomic controls capturing the main observable drivers.

To obtain an estimable reduced form, the study models the logarithm of EV–GV market share ratio as a function of gasoline prices and macroeconomic controls. This reduced form approach allows an examination of how gasoline price fluctuations affect the relative EV–GV market share.

$$S_{EV,t} = \frac{Q_{EV,t}}{Q_{TOT,t}}, \qquad S_{GV,t} = \frac{Q_{GV,t}}{Q_{TOT,t}}, \qquad S_{o,t} = 1 - (S_{EV,t} + S_{GV,t}). \ (10)$$

Absolute market shares describe overall market composition. Equation (10) presents the standard calculation of absolute market shares for EVs and GVs. The remaining share $S_{o,t}$ captures other vehicle types and is treated as the outside option. To highlight comparability, this study employs a relative market share measure which implicitly assumes that the outside good affects both alternatives symmetrically. Under this specification, fuel price shocks primarily induce substitution between electric and gasoline vehicles, while the aggregate demand for other vehicle types remains relatively stable over time.

$$S_{EV,t}^{c} = \frac{Q_{EV,t}}{Q_{EV,t} + Q_{GV,t}}, \quad S_{GV,t}^{c} = 1 - S_{EV,t}^{C}. \quad (11)$$

The expression defines the conditional market shares within a two-technology market consisting only of EVs and GVs.

$$y_t = \ln\left(\frac{S_{EV,t}^{c}}{S_{GV,t}^{c}}\right) = \ln\left(\frac{Q_{EV,t}}{Q_{GV,t}}\right) \quad (12)$$

Through the transformation in equation (12), conditional market shares are expressed as the quantity ratio of EVs to GVs, which follows directly from the logarithmic relative market share framework.

Equation (9) provides a theoretical link between relative market shares and utility differences, but it is not estimated directly in the empirical analysis. Instead, the empirical analysis adopts a reduced-form specification, relating relative market shares to observable fuel prices and macroeconomic controls：

Baseline Model: $$y_t = \alpha + \beta_k \ln P_{t-k}^{gas} + \gamma \ln CPI_t + \delta t + \epsilon_t, \quad k = 0,1,2,3 \quad (13)$$

Extending the structural framework to a dynamic setting would require estimating a dynamic discrete choice model, which involves modeling consumers' intertemporal decision-making and solving a dynamic optimization problem. Given data limitations and the scope of this thesis, the empirical analysis adopts a reduced-form specification with lagged gasoline prices to capture short-run adjustment dynamics in EV–GV market shares. The model includes lagged gasoline prices P_{t-k}^{gas}, where k =0,1,2,3 to capture both immediate and short-run delayed effects on EV-GV market share dynamics. The variable $\ln CPI_t$ controls for inflationary pressure, which may influence households' sensitivity to vehicle operating costs. A linear time trend δt accounts for underlying technological progress and structural changes in the vehicle market.

Equations (1)–(9) provide the theoretical foundation that links consumer utility differences to observed relative market shares. The empirical specification in equation (13) departs from equation (9) and adopts a reduced-form approach, allowing consistent estimation of short-run substitution dynamics under data constraints. Based on this theoretical framework, the empirical analysis focuses on how gasoline price fluctuations affect the relative EV–GV market-share ratio.

ARDL Model: $$y_t = \alpha + \phi y_{t-1} + \beta_0 \ln p_t^{gas} + \beta_1 \ln p_{t-1}^{gas} + \gamma \ln CPI_t + \delta t + \epsilon_t \quad (14)$$

The EV–GV relative market share may be associated with oil price fluctuations, as well as with persistence in market dynamics. Equation (14) extends the baseline specification by adding a lag of the dependent variable, allowing for short-run persistence in the relative EV–GV market share. Since the Berry framework is static, the baseline specification remains consistent with the Berry structure, while Equation (14) is interpreted as a reduced-form dynamic extension that captures short-run adjustment dynamics in EV–GV market shares.

Current and lagged gasoline prices capture contemporaneous and lagged correlations between fuel price movements and relative EV–GV market shares, while CPI controls for inflationary pressure and the time trend captures gradual structural changes in the vehicle market.

$$\theta = \frac{\beta_0 + \beta_1}{1 - \phi} \quad (15)$$

Equation (15) expresses the steady-state effect of gasoline prices in the ARDL model. It combines the current and lagged coefficients, β_0 and β_1, and normalizes them by $1-\phi$. This expression summarizes the overall response of the relative EV–GV market share to gasoline price changes after accounting for monthly dynamics.

$$y_q = \alpha + \beta \ln p_q^{gas} + \delta q + \epsilon_q \quad (16)$$

Given that ACEA provides only quarterly data for 2021, a quarterly robustness analysis is conducted to examine market dynamics before and after the oil price surge. Equation (16) uses quarterly frequency data from 2021 to 2023, providing a smoother view of market trends.

$$y_t = \alpha + \beta_k \ln P_{t-k}^{crude} + \gamma \ln CPI_t^{EU} + \delta t + \epsilon_t, \quad k = 0,1,2,3 \quad (17)$$

For the EU market share analysis, the study retains the log market share specification defined in equation (12), but applies it to EU-level data. Domestic gasoline prices are replaced by international crude oil prices, since EU-wide retail gasoline prices are difficult to obtain. EU-level CPI is included to control for broader inflationary conditions. This specification allows for a direct comparison between the Portuguese and EU results.

5. Empirical Analysis

In this part, the study examines the impact of oil price shocks on the log EV-GV market share by employing econometric models based on equations (13)-(17). All reported standard errors are heteroskedasticity-robust standard errors (HC1).

The first subsection estimates a baseline model to examine immediate and lagged effects on changes in market share. In Section 5.2, the ARDL model is used to examine whether the EV market share is associated with current and lagged oil prices and depends on its previous market share. In Section 5.3, a robustness check is conducted using quarterly data from 2021 to 2023. Subsequently, an overall review of the Portuguese market is provided based on the empirical results. In Section 5.4, the study analyzes the European Union’s EV market share in comparison with that of Portugal. In Section 5.5, the paper provides further discussion of the underlying mechanisms behind the empirical findings.

5.1 Baseline and Lag Structure Results

This section presents the baseline model analysis based on equation (13). In order to improve interpretability and avoid undefined values when CPI values are close to zero, all models in this paper apply the transformation ln(1+CPI). This approach preserves relative changes in inflation while improving numerical stability in the estimation.

Table III reports the baseline estimation results of Model (13), in which the dependent variable is the logarithm of the EV–GV market share ratio. Outlier diagnostics reported in the data section indicate that no influential extreme observations are present in the dataset. Therefore, the regressions are estimated using the original data. The regression results show that gasoline prices do not exhibit a statistically significant effect on the relative EV market share in Portugal. Similarly, the inflation control variable is not statistically significant.

Table III. Baseline Model Results (k = 0)

Variable	**(1)**
Fuel Price	-0.641
	(0.416)
ln(CPI)	-1.579
	(1.998)
Time Trend	0.032***
	(0.005)
Intercept	-0.205
	(0.755)
Observations	36
R^2	0.670
R^2 Adj.	0.639

Notes: Standard errors in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

In contrast, the time trend is positive and statistically significant at the 1% level, indicating a strong and persistent diffusion process in the Portuguese EV market. This result suggests that the evolution of EV adoption in Portugal is primarily driven by long-term structural dynamics rather than short-run fuel price fluctuations.

However, consumers may be in a “wait-and-see” stage when fuel price shocks occur, as they may take some time to observe the energy market trends and decide whether to delay their EV purchase. Therefore, alternative lag structures of gasoline prices are specified, followed by models incorporating lagged fuel prices to assess potential delayed substitution effects.

The results from Table IV show that lagged fuel price terms remain statistically insignificant across specifications, while the time trend remains robust and highly significant. These findings suggest that fuel price movements do not play a dominant role in shaping short-run EV adoption dynamics in Portugal, even when lagged effects are considered.

Table IV. Lagged Fuel Price Effects (k = 1–3)

Variable	**(1) k=1**	**(2) k=2**	**(3) k=3**
Fuel Price (t−1)	-0.595		
	(0.401)		
Fuel Price (t−2)		0.072	
		(0.516)	
Fuel Price (t−3)			0.664
			(0.598)
ln(CPI)	-0.940	-1.184	-1.068
	(2.550)	(3.055)	(3.357)
Time Trend	0.034***	0.037***	0.042***
	(0.006)	(0.008)	(0.008)
Intercept	-0.350	-1.579	-2.741**
	(0.755)	(0.991)	(1.067)
Observations	35	34	33
R^2	0.656	0.625	0.644
R^2 Adj.	0.623	0.588	0.607

Notes: Standard errors in parentheses. * p < 0.1, ** p < 0.05, *** p < 0.01.

Overall, the baseline and lagged models demonstrate a reasonably strong fit, as reflected by the relatively high R-squared and adjusted R-squared values across specifications. The strong and persistent time trend indicates that EV market expansion is largely driven by long-term dynamics rather than short-term price shocks. These results motivate the use of a dynamic ARDL framework in the next section to further explore adjustment processes and possible long-run relationships.

5.2 ARDL

To further examine the dynamic mechanism underlying the EV market shares, the ARDL framework extends the baseline model by incorporating lagged market shares and lagged fuel prices, thereby capturing persistence and path dependence in EV adoption.

The results reported in Table V indicate a statistically significant coefficient on the lagged dependent variable y_{t-1} , suggesting substantial persistence in relative EV market shares. In addition, the time trend remains statistically significant at the 5% level. The pattern reflects that part of the underlying time trend is absorbed by the lagged market share and manifests itself through the internal persistence of EV adoption. These findings imply that current EV adoption is strongly influenced by past market outcomes, consistent with a gradual diffusion process.

Table V. Dynamic ARDL Model

Variable	**(1)**
Lagged Share (t−1)	0.406***
	(0.152)
Fuel Price	-0.499
	(0.679)
Fuel Price (t−1)	-0.008
	(0.674)
ln(CPI)	-0.995
	(2.398)
Time Trend	0.018**
	(0.009)
Intercept	0.131
	(0.873)
Observations	35
R^2	0.717
R^2 Adj.	0.668

Notes: Standard errors in parentheses. * p < 0.1, ** p < 0.05, *** p < 0.01.

In contrast, fuel prices—both contemporaneous and lagged—remain statistically insignificant in the dynamic specification. This suggests that short-term fluctuations in fuel prices do not exert a meaningful impact on the relative EV market shares, once market inertia is taken into account. Similarly, inflation does not display a robust effect on EV market shares.

Overall, the dynamic ARDL results highlight that the expansion of the EV market is primarily driven by persistent adoption dynamics and gradual diffusion processes, while short-term fuel price signals play a limited role. Consequently, the steady-state effect of gasoline prices implied by equation (15) is not statistically significant. These findings reinforce the view that EV market growth is shaped more by long-term structural forces and accumulated adoption momentum than by short-term oil price fluctuations.

5.3 Robustness and Summary for the Portuguese Market

ACEA does not provide detailed monthly data for 2021; instead, it reports quarterly figures. Therefore, we also estimate a quarterly model over 2021–2023 as a robustness check. This quarterly specification smooths out sharp month-to-month fluctuations and offers a clearer view of how fuel price shocks may affect EV market share in Portugal. More importantly, the sample allows a comparison between the periods before and after fuel price shocks in 2022. All quarterly variables are constructed as the average of the three monthly observations within each quarter.

The quarterly analysis (Table VI) continues to reveal a strong and statistically significant upward trend in relative EV market shares, while fuel prices remain statistically insignificant. Overall, taken together with the results from the previous models, these findings consistently suggest that the long-term expansion of the EV market in Portugal is primarily driven by structural and diffusion-related forces rather than short-term gasoline price fluctuations.

Table VI. Quarterly Robustness Check

Variable	**(1)**
Fuel Price	0.035
	(1.237)
Time Trend	0.134***
	(0.028)
Intercept	-2.062***
	(0.644)
Observations	12
R^2	0.716
R^2 Adj.	0.653

Notes: Standard errors in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

The coefficient on fuel prices in the quarterly model is substantially smaller than in the monthly baseline specification. This difference is likely driven by the aggregation of monthly fuel prices into quarterly averages, which smooth short-term fluctuations and reduce the estimated short-run effect. Moreover, the smaller sample size in the quarterly estimation may further contribute to coefficient variability.

Next, this section explores the mechanisms behind these findings. One plausible explanation is that retail gasoline prices in Portugal are partially buffered by a large tax component. Retail gasoline prices in Portugal are relatively high in the EU, especially compared with Eastern European countries. For instance, before the sharp increase, the average retail gasoline price was €1.709 per liter in January 2022. Of this amount, only €0.741 per liter reflects the pre-tax component; the remainder consists of taxes, including ISP and other levies, as well as VAT. This breakdown implies that roughly 43% of the pump price corresponds to the pre-tax component, while more than 55% is accounted for by taxes. As a result, because a large share of the pump price consists of relatively stable tax components, fluctuations in the underlying fuel costs may translate into more moderate changes in the final retail price. Meanwhile, during the 2022 energy crisis, the Portuguese government implemented temporary fuel tax reductions to cushion the impact of rising international oil prices, which may have moderated fluctuations in retail gasoline prices.

Moreover, gasoline prices can change frequently, particularly during periods of energy shocks. By contrast, vehicle purchases are infrequent and tend to be forward-looking decisions that involve substantial planning. Therefore, fuel prices and vehicle purchase decisions operate on different time scales.

The cost advantage of EVs is not solely determined by gasoline prices. Instead, it is shaped by a broader set of factors, including subsidies and tax exemptions, convenience, environmental benefits, and long-run ownership costs. To illustrate differences in operating costs, statistics from UVE show that a gasoline vehicle consumes approximately 5.62 liters per 100 km, resulting in a fuel cost of around

€9.90 per 100 km at current gasoline prices. By contrast, electric vehicles consume around 15.65 kWh per 100 km, implying substantially lower energy costs than gasoline vehicles. If consumers rely on public charging, the operating cost is about €8.04 per 100 km, which is approximately 20% lower than the operating cost of gasoline vehicles. When charging at home, the cost falls to €3.19 per 100 km under standard household electricity tariffs and €2.11 per 100 km under off-peak tariffs. Such operating cost advantages are more likely to appeal to households with sufficient purchasing capacity that are sensitive to long-run ownership costs.

In this section, the findings suggest that the dominant driver of EV market share growth is the time trend component. To provide a broader perspective, these findings are further discussed alongside the EU market analysis.

5.4 EU Market Comparison

Table VII presents the results for EU-level baseline model with current and lagged crude oil prices. The results are consistent with the findings obtained from Portugal, crude oil prices do not exhibit statistically significant effects on the relative EV market share at the aggregate EU market level. In contrast, the time trend remains positive and statistically significant across all specifications. These findings suggest that the expansion of the EV market both in the EU and Portugal is primarily driven by long-term diffusion dynamics rather than short-term energy price fluctuations.

Table VII. Lagged Crude Oil Price Effects in the EU Market

Variable	**(1) k = 0**	**(2) k = 1**	**(3) k = 2**	**(4) k = 3**
Crude Price	-0.589			
	(0.367)			
Crude Price (t−1)		-0.214		
		(0.337)		
Crude Price (t−2)			-0.083	
			(0.387)	
Crude Price (t−3)				-0.302
				(0.475)
ln(CPI)	4.744	4.345	4.599	6.542
	(2.907)	(3.430)	(4.068)	(5.354)
Time Trend	0.021***	0.024***	0.026***	0.030***

	(0.004)	(0.006)	(0.009)	(0.011)
Intercept	0.950	-0.712	-1.334	-0.562
	(1.540)	(1.425)	(1.676)	(1.857)
Observations	36	35	34	33
R^2	0.437	0.345	0.304	0.306
R^2 Adj.	0.385	0.282	0.235	0.235

Notes: Standard errors in parentheses. * $p < 0.1$, ** $p < 0.05$, *** $p < 0.01$.

To explore the mechanisms underlying this phenomenon, the study integrates market background information to provide further intuition.

Electric vehicles began to emerge in EU member states around 2015, and the EU EV market share has increased steadily over the past five years, although the pace of EV market share growth has been highly heterogeneous across countries.

This aggregate trend is reflected in the EU average EV market share, which reached approximately 40.87% in 2024, representing an increase of over 29 percentage points compared with 2020. Over the same period, the absolute number of EV registrations increased by more than 900,000 units, corresponding to a 169% increase. Similarly, the EV market share in Portugal increased sharply in the post-COVID era, rising from 27.52% in 2022 to 58.75% in 2024, which is approximately 46 percentage points higher than in 2020. In absolute terms, EV registrations increased by 433% relative to their 2020 level.

The statistics suggest that both EV sales in Portugal and in the EU have entered a rapid-growth phase, whereas the growth rate in Portugal is faster than in the EU, particularly since 2023. Moreover, the EU plans to phase out the sale of new internal combustion engine vehicles by 2035, suggesting that the pace and timing of EV market share growth are shaped by a clear policy framework at the aggregate level.

The results suggest that the association between gasoline prices and relative EV–GV market shares weakens over time, while the time trend remains an important driver of adoption dynamics.

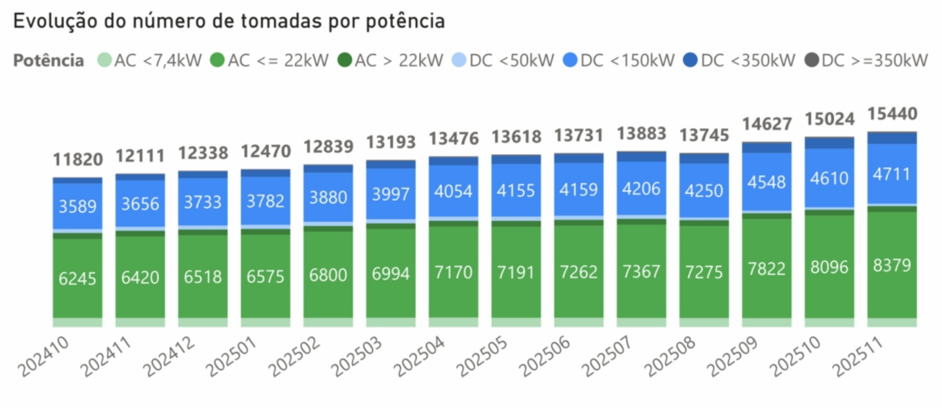
5.5 Further Discussion

In this section, the study further explores the role of the time trend in EV adoption. In general, this trend reflects the combined effects of technological progress, the expansion of charging infrastructure, policy support and shifts in consumer preferences.

Technological progress is a key driver of EV adoption. In a long-run competitive market, utility maximization remains the primary concern for consumers and is largely determined by technological and price advantages. In recent years, EV technology has improved significantly. According to data from ACEA, Tesla was the leading EV manufacturer in Portugal in 2024. The standard versions of Model 3 and Model Y are equipped with battery capacities of 66 kWh and 62 kWh, respectively. This results in driving ranges exceeding 500 km under WLTP standards. The long-range versions of both models feature battery capacities exceeding 75 kWh and deliver ranges well beyond 500 km. In addition, Tesla vehicles support fast charging with a peak DC charging power of 250 kW, allowing the battery to be charged from 10% to 80% within approximately 30 minutes. Technological development has expanded the range of EV models, leading to tougher market competition and more international EV manufacturers entering the EU market. BYD's market share increased sharply in Portugal, ranking third in December 2024. The brand offers approximately 18 EV models, thereby addressing a wide range of consumer preferences.

Improvements in charging infrastructure also play a significant role. According to UVE data, the public charging network in Portugal expanded rapidly, reaching 15,440 charging points, which represents a 27.49% increase compared with November 2024. Moreover, policy measures have a direct influence on the EV market, particularly through purchase subsidies. Most EU countries provide, or have previously provided, subsidies for EV purchases. In Portugal, private individuals are eligible for a conditional subsidy of €4,000 when purchasing EVs priced up to €55,000 (including VAT) in 2025. Additionally, EVs are exempt from several taxes, including vehicle registration tax, vehicle excise duty, and autonomous taxation.

Figure V. Number of Charging Points in Portugal



Data Source: UVE.

Consumers' cognitive preferences shift over time. Many products undergo an adoption period when they enter a new market, during which consumers need time to understand and accept the product before making purchasing decisions. Shifts in consumers' preferences are influenced by peer effects and demonstration effects. Electric vehicles may take several years to transform from a novel product into a mainstream market choice.

In general, the EV market experiences a structural transformation as the long-term trend evolves. This transition represents a typical diffusion process.

6. Conclusion

This thesis applies distributed-lag market share models, including an ARDL specification, to examine how gasoline price shocks influence the substitution effect between electric vehicles and gasoline vehicles in Portugal, based on monthly data from 2022 to 2024. In addition, a quarterly robustness test is conducted using data from 2021 to 2023, and an extension of the analysis is performed at the EU level with aggregate market data.

The results indicate that the time trend significantly shapes both the Portuguese and EU electric vehicle markets. Both vehicle markets experience a phase of rapid EV growth and undergo a structural transformation, particularly post-2022. As a consequence, the role of oil prices in Portugal and the EU appears to be weakened and largely absorbed by the prevailing time trend.

Overall, given the strong long-term trend toward EV adoption in the EU, the findings suggest that policymakers should allocate public resources to structural improvements supporting the ongoing transition, such as expanding charging infrastructure in suburban areas and small towns to improve charging accessibility for vehicle owners as well as reducing public charging tariffs. In addition, policymakers should continue to encourage EV adoption through subsidies and tax incentives, while providing a stable and predictable policy framework for the market. Such an environment can help attract more international manufacturers to establish production facilities in the EU and ultimately enhance consumer welfare.

This study is limited by the relatively short sample period and the lack of detailed data on EV pricing. Future research may explore the long-run effects in the electric vehicle market by considering seasonal variations and heterogeneous responses across regions or income groups. Moreover, future work may employ micro-level data to estimate consumer preferences through discrete-choice models and examine how technological progress affects EV adoption in the Portuguese market.

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