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Drivers of Electric Vehicle Adoption in the EU-27

A Country-Year Panel Analysis of Policy, Market Dynamics, and Infrastructure (2015–2024)

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Contents

Abstract

The European automotive market is undergoing a profound technological and regulatory transformation, marked by accelerating electrification, ambitious climate policies, and evolving consumer attitudes. Rather than focusing primarily on forecasting vehicle sales, this thesis aims to identify and quantify the key drivers behind the shift from internal combustion engine (ICE) vehicles to electric powertrains across European Union member states. The analysis will examine how regulatory frameworks, government incentives, macroeconomic conditions, fuel and electricity prices, charging infrastructure, and consumer perception jointly influence the adoption of electric vehicles.

To assess the relative weight of these factors, the research will employ a linear regression model using a panel dataset constructed at the country–year level. Independent variables will include GDP per capita, household electricity prices, retail fuel prices, EV charging availability, and indicators of national incentive schemes. In addition, separate analyses are conducted for battery-electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs) to explore potential differences in adoption patterns across technologies.

Data will be sourced from publicly available institutions such as the World Bank, Eurostat, the European Commission's Weekly Oil Bulletin, the European Alternative Fuels Observatory (EAFO), the International Energy Agency (IEA), and the European Environment Agency (EEA).

By systematically evaluating the contribution of each driver to the uptake of electric vehicles, this thesis seeks to enhance academic understanding of the mechanisms guiding Europe's transition toward sustainable mobility. Leveraging a country–year panel dataset covering the period 2015–2024, the empirical strategy exploits both cross-country variation and within-country changes over time to identify how policy, economic, and structural factors interact in shaping the uneven trajectory of EV adoption across EU member states.

Thesis Structure

This thesis is organized into six chapters**,** each addressing a key component of the research process, moving from the theoretical and institutional background to empirical analysis and policy implications. The structure follows a logical progression: starting with the motivation and research questions, reviewing existing literature, presenting the data and methodology, and finally discussing empirical findings and their implications for the European automotive transition.

Chapter 1 – Introduction

This chapter introduces the motivation and objectives of the study. It discusses the ongoing transformation of the European automotive sector driven by climate policy and technological change, highlighting the increasing relevance of electric vehicles (EVs) in achieving EU decarbonization targets. The chapter presents the research questions, outlines the contribution of the thesis, and situates the analysis within the broader debate surrounding the electrification of road transport and the planned phase-out of internal combustion engine vehicles by 2035.

Chapter 2 – Literature Review

This chapter reviews the existing academic and institutional literature on the determinants of electric vehicle adoption. It examines several key themes, including the impact of European automotive regulation, shifts in vehicle registrations by powertrain, consumer perception and behavioral drivers of EV adoption, and the interaction between policy incentives, economic conditions, and infrastructure development. The chapter identifies key gaps in the literature and motivates the empirical approach adopted in the thesis.

Chapter 3 – Data and Methodology

This chapter presents the dataset and the methodological framework used in the empirical analysis. It describes the construction of the panel dataset covering EU member states, the sources of the data, and the definition of the main variables, including EV market shares, incentives, macroeconomic indicators, energy prices, and charging infrastructure. The chapter also introduces the econometric approach based on a fixed-effects panel regression model and discusses the rationale behind the selected empirical strategy.

Chapter 4 – Empirical Analysis

This chapter presents the empirical investigation of the drivers of EV adoption across European countries. It begins with a descriptive analysis of the evolution of EV diffusion and key explanatory variables, followed by the estimation of the baseline fixed-effects model. The chapter then explores heterogeneous effects across different powertrain technologies, comparing battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs). Several robustness checks are conducted to assess the stability of the results under alternative model specifications.

Chapter 5 – Discussion and Policy Implications

This chapter interprets the empirical findings in the broader context of the European transformation of the automotive industry. The discussion focuses on the role of charging infrastructure, policy incentives, and market dynamics in shaping EV adoption patterns across EU member states. The chapter also examines the implications of the results for European climate policy and the ongoing transition toward zero-emission mobility.

Chapter 6 – Conclusion

The final chapter summarizes the main findings of the thesis and highlights their implications for both academic research and policy design. It discusses the limitations of the study and proposes directions for future research, particularly regarding the evolving role of infrastructure development, technological innovation, and regulatory frameworks in the electrification of road transport.

Contribution of the Thesis

Beyond its structural organization, this thesis aims to contribute to the ongoing academic and policy debate on the determinants of electric vehicle adoption in the European Union. In particular, the study provides an empirical assessment of the relative importance of several potential drivers of EV diffusion, including financial incentives, macroeconomic conditions, energy prices, and charging infrastructure availability.

Using a panel dataset covering EU member states over the period 2015–2024 and a two-way fixed-effects econometric framework, the analysis isolates within-country variation over time while controlling for structural cross-country differences and common European trends. This approach allows the thesis to provide new evidence on how infrastructure expansion and policy frameworks interact with market dynamics during the early phases of the electric mobility transition.

In addition, the thesis contributes to the literature by exploring heterogeneous adoption patterns across different electrified powertrain technologies, distinguishing between battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs). This comparison provides further insights into how infrastructure availability and regulatory signals may influence the technological trajectory of the European automotive transition.

Overall, the thesis aims to bridge insights from economics, policy analysis, and industrial transformation in order to better understand the systemic drivers of electric vehicle diffusion across European markets.

The following chapters develop the analysis step by step, starting from the existing literature and institutional background and progressing toward the empirical investigation of EV adoption drivers across European countries.

1. Introduction

The European automotive sector is undergoing the most profound transformation in its modern history. Driven by increasingly stringent climate objectives, rapid technological innovation, and shifting consumer preferences, the transition from internal combustion engine (ICE) vehicles to electric vehicles (EVs) has accelerated across the European Union. Since transport remains one of the largest contributors to greenhouse gas emissions in Europe, and road transport accounts for most of these emissions, understanding the mechanisms behind this transition is essential. The European Union’s climate neutrality objective for 2050, along with intermediate targets such as the 2035 phase-out of new ICE car sales, has created a regulatory environment that strongly favors electrification. At the same time, national governments have introduced a wide variety of purchase subsidies, tax incentives, and infrastructure investments intended to stimulate EV and hybrid adoption.

However, despite a common overarching regulatory framework, EV uptake varies substantially across EU member states. While countries such as Norway (non-EU), the Netherlands, Sweden, and Germany have experienced rapid growth in BEV registrations, others show slower adoption rates despite facing similar environmental objectives. These cross-country differences raise important questions about the relative importance of economic, regulatory, infrastructural, and perceptual factors in shaping vehicle purchase decisions. Fuel and electricity prices, household income, charging availability, and the structure of national incentive schemes may influence consumers' choices differently across Europe, and additionally consumer perception and brand loyalty add another layer of complexity: although many Europeans express environmental concern, attitudes toward new technologies, and perceived risks of EV ownership may positively or negatively influence adoption.

Existing literature has identified several determinants of EV diffusion, such as purchase incentives, infrastructure density, energy prices, and environmental beliefs. Yet, many studies focus on individual countries or short time periods, and few provide a harmonized comparative analysis across the entire EU, combining regulatory factors, macroeconomic conditions, and consumer perceptions into a single empirical framework. Furthermore, most prior studies rely on qualitative policy descriptions rather than systematically coded numerical indicators, making cross-country comparisons difficult. This thesis contributes to this gap by constructing a country-year panel dataset for the EU27 covering 2015-2024, which includes standardized measures of EV incentives, energy and fuel prices, macroeconomic indicators, and EV market outcomes.

The main objective of this thesis is to identify and quantify the key drivers behind the shift from ICE vehicles to electric powertrains across EU member states. Using a linear regression model with country and year fixed effects, this study evaluates the relative importance of financial incentives, energy prices, fuel price, GDP and charging infrastructure availability in shaping EV market shares. The analysis also aims to highlight whether certain policy instruments are consistently more effective than others, and whether socio-economic conditions mediate or amplify their impact.

Overall, this thesis provides an integrated, comparative assessment of the forces driving Europe’s automotive transition.

1.1 Research Question

What are the main country-level drivers of electric vehicle adoption across EU member states over the period 2015–2024, and to what extent do policy incentives, economic conditions, energy prices, and charging infrastructure explain cross-country differences in electrification dynamics?

Do the determinants of electrification differ across battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs)?

1.2 Hypothesis

Public policies, economic conditions, and charging infrastructure are expected to influence electric vehicle adoption across EU member states, with charging infrastructure likely playing a particularly important role in supporting EV diffusion.

2. Literature Review

2.1 Impact of EU Automotive Regulations on Car Buying Behavior

European policymakers have implemented stringent regulations to steer the automotive market towards lower emissions, and studies show these policies significantly influence what consumers buy. A landmark EU rule was the CO_2 fleet-average target of 95 g/km for new cars in 2020/21, which effectively compelled manufacturers to offer more low-emission vehicles. Following the entry into force of this 2020 CO_2 standard, sales of electric cars surged beyond expectation: electric vehicles (EVs) jumped to over 10% of new car sales in 2020 (from just a few percent a year prior). By 2021, EVs were projected to reach 15% of sales, illustrating that once automakers supplied adequate electric models (to meet regulations), consumers responded by purchasing them in large numbers. This regulatory push not only accelerated EV adoption but also drove industry investment into electrification (e.g. new battery factories), underlining how climate rules doubled as industrial policy[1].

Academic analyses corroborate that regulatory incentives have a measurable effect on car buying behavior. For instance, a recent study using data from 30 European countries (2012–2021) found that direct purchase incentives (subsidies, tax rebates) are strongly associated with increased registrations of battery-electric (BEV) and plug-in hybrid vehicles (PHEV). The effect of purchase incentives persists over time and is especially pronounced for BEVs. In contrast, more indirect "ownership" incentives (like reduced road taxes or free parking) showed no significant impact on EV uptake. These findings suggest that financial carrots at the point of purchase are effective in shifting consumer choices, whereas post-purchase perks alone are insufficient. Another estimates that, in EU, increasing purchase incentives by €1,000 yields a 5–7% rise in the electric share of new registrations, underscoring a sizable price sensitivity in consumer demand[2]. In addition to subsidies, EU-wide emissions standards themselves have reshaped buying patterns: by making high-CO_2 models costly to manufacturers (via fines), these rules encouraged a broader offering of efficient cars and EVs, thereby nudging consumers toward lower-emission choices.

The transport sector is among the largest contributors to EU greenhouse gas (GHG) emissions, making emission reductions in this area vital to achieving the EU's climate neutrality objective by 2050 (which means achieving net-zero GHG emissions by balancing emissions produced with those removed from the atmosphere, for example, through carbon sinks or offsetting measures). As part of this long-term strategy, the European Union has set increasingly strict CO_2 reduction targets for new vehicles – 15% by 2025, 55% by 2030 (relative to 2021 levels), and a 100% reduction by 2035[3]. In practice, the 2035 target implies a de facto ban on new internal combustion engine (ICE) car sales after 2034, a policy already shaping automakers' long-term product planning. This ban reinforces the trajectory toward electrification and may influence current consumer choices, especially among buyers who consider future resale values and technological viability when selecting a new vehicle. [4]

Overall, the literature confirms that EU regulatory frameworks – from emissions standards to phase-out mandates – have been a powerful catalyst in shifting both manufacturer behavior and consumer purchase patterns. The clearest evidence is the sharp uptick in EV sales coinciding with policy milestones. Notably, as soon as the 95 g/km CO_2 rule took effect, the EV share of new cars in Europe effectively tripled from 2019 to 2020 (rising from ~3.5% to 11.6% of registrations). This one-year surge in zero- and low-emission car sales directly caused a 12% drop in average CO_2 emissions of new EU passenger cars – the largest annual decline ever recorded[5]. Such shifts underscore that regulations can rapidly transform the market, provided automakers comply by offering attractive low-carbon models and consumers are willing to buy them.

2.2 Shifts in Vehicle Registrations by Powertrain: Institutional and Industry Insights

Data from European institutions and industry sources further illustrate how policy frameworks have altered the landscape of vehicle powertrains.

According to data from the European Environment Agency (EEA) and the European Automobile Manufacturers' Association (ACEA), electric vehicles accounted for over 22% of all new car registrations in the EU in 2023, up from roughly 2% in 2018.
The evolution of electric vehicle registrations and their share of total new car sales in the European Union over the past decade is illustrated in the Appendix (see Figure A.1).

The expansion of EV registrations accelerated particularly after 2019, reflecting the combined impact of EU climate policies, national incentive schemes, and increasing model availability.

In recent years, the European car market has undergone a remarkable transformation in its powertrain mix. This rapid growth has been driven by a combination of tighter EU climate policies, national incentive schemes, and shifting consumer sentiment. Battery electric vehicles (BEVs) in particular have seen a sharp rise - growing by 37% in 2023 alone - while plug-in hybrid sales declined slightly, indicating a clear consumer shift toward fully electric mobility.

As detailed in the Appendix (Figure A.2), conventional fuel cars have seen corresponding declines: in 2019, petrol and diesel dominated new sales, but as of 2023 petrol's share dropped to 35.3% and diesel to just 13.6%. In their place, electrified vehicles (including hybrids at 26% share) are becoming mainstream[6]. These statistics are not merely market whims, but they are closely linked to the regulatory environment. The EEA notes that "increasingly stringent regulations have resulted in the introduction and promotion of more fuel-efficient, less polluting vehicles," with the rising registrations of EVs serving as an indirect indicator of policy impact on the fleet[3]. In other words, Europe's policy framework (CO_2 standards, air quality rules, and incentives) has pulled the market toward alternative powertrains, which is plainly visible in registration data.

Specific reports highlight how certain policies correlate with spikes in EV uptake. The International Energy Agency's analyses observed that Europe's strong 2020 EV growth occurred "underpinned by supporting policies", noting that the convergence of EU CO_2 standards enforcement and enhanced national subsidies in 2020 led to Europe outpacing other regions in EV sales growth. The Global EV Outlook documented that while overall car sales dropped during the pandemic year 2020, EV sales in Europe surged, thanks to a combination of EU emissions mandates and stimulus measures favoring clean cars[7]. Likewise, the ICCT (International Council on Clean Transportation) found that in the 2020 target year, many automakers aggressively promoted EVs in the last quarter to meet fleet CO_2 limits, resulting in a pronounced EV sales spike at year-end. This led to a notable decrease in average new-car CO_2 emissions in 2020, reversing the upward trend seen in 2017–2019[5].

As policymakers raised emissions standards and signaled an eventual phase-out of ICE vehicles, automakers and consumers responded: manufacturers expanded the EV model lineup, and consumers began purchasing these vehicles in record numbers.

Institutional data show that the uptake of electric vehicles across Europe remains uneven, largely depending on the strength and stability of national incentives and local policy frameworks. Norway, while not part of the EU, stands out with an EV share exceeding 90% of new car registrations in 2023. Among EU countries, Sweden reached a 61% EV share the same year, while Denmark reported two out of every three new cars being electric (approximately 66%), and both the Netherlands and Finland reached about one in three (around 33%). By contrast, in lower-income EU member states where incentives have been weaker or introduced more recently, battery electric vehicles (BEVs) still represent less than 7% of new registrations. This disparity is often traced to the level of incentives and local regulatory support, as well as infrastructure readiness. ACEA's report underscores that "monetary and fiscal incentives are a cornerstone" of Europe's EV transition, and where such support is robust (e.g. purchase grants or tax breaks), EVs are rapidly entering the mainstream market. It cites recent cases in Poland, Slovenia, Spain, and Portugal, where well-designed incentive schemes led to immediate spikes in EV registrations: Poland doubled its BEV sales after new grants were introduced, Slovenia saw an 89% surge, and Portugal's EV share jumped above 21% once generous incentives took effect[8]. These real-world outcomes from industry reports reinforce the narrative that policy frameworks are strongly driving the shift in powertrain trends across Europe's new car market.

2.3 Consumer Perception and Vehicle Choice

Regulations and incentives alone do not guarantee consumer acceptance: consumer perceptions and attitudes play a pivotal role in vehicle purchase decisions. A body of research has explored how factors like environmental awareness, range anxiety, cost perceptions, and social influence impact Europeans' willingness to buy cleaner vehicles. Broadly, the literature finds a mix of motivators pulling consumers toward electric cars and barriers pushing them away. On the motivator side, heightened awareness of climate change and local air pollution is a significant driver for many consumers. In surveys worldwide (including Europe), the environmental benefits of EVs – especially the reduction of tailpipe emissions – consistently rank as a top reason people consider going electric. One recent global review found that *"reduction in air pollution is the most frequently cited motivator of EV adoption"* by consumers, often coupled with the availability of government incentives as a practical enabler[9]. This suggests European car buyers who are cognizant of climate issues or urban air quality may feel a stronger personal pull toward electric mobility, aligning their purchases with their environmental values.

However, consumers also cite numerous pragmatic concerns and misgivings that deter them from choosing EVs. Chief among these is cost: the high upfront purchase price of electric cars (relative to comparable conventional cars) has long been perceived as a major barrier[10]. Even as battery prices fall, many European consumers worry about whether an EV's total cost of ownership will truly offset the purchase premium. A closely related concern is driving range and charging, often encapsulated in the term "range anxiety." Studies confirm that Europeans frequently hesitate to buy BEVs due to fear that the vehicle's range may not cover their needs or that charging infrastructure is too sparse or inconvenient. An integrative review on range anxiety noted this psychological barrier leads drivers to overestimate the range they need and underestimate charging availability. Indeed, in a 2022 survey across ten EU countries, driving range and charging access remained top-of-mind issues: a plurality of respondents desired 300-500 km minimum range in an EV, and many highlighted the lack of public charging as a disadvantage to EV ownership. Charging speed is another aspect of this perception, EV drivers value fast recharging during travel, and slower charging is viewed negatively, which can color non-EV owners' perceptions of EV practicality.

Lack of consumer knowledge or awareness is another bias of perception, which can weaken the effectiveness of pro-EV policies. Paradoxically, even when financial incentives exist, not all consumers know about them. For example, an EU Alternative Fuels Observatory survey in 2023, interestingly found that 33% of the surveyed European drivers indicated that they are not aware of any subsidies for electric driving, even if in most of the surveyed countries a subsidy scheme was in place in that year. Many consumers also felt they lacked reliable information on EV battery durability, range in real-world conditions, and overall ownership costs. This informational gap means some car buyers continue to perceive EVs as riskier or costlier than they actually are, simply because they have not been exposed to accurate data (e.g., about total cost of ownership or government support). The EAFO report concluded that providing clearer information on EV range, charging infrastructure, and available financial support could help potential EV drivers to have a clearer opinion and overcome skepticism [11].

Public perception can be “biased by multiple factors such as fake news, prejudices and misgivings,” leading it to diverge from expert assessments of the technology. A 2025 study comparing public and expert perceptions in the EU highlighted this gap: while the general public tended to be more cautious about fully battery-electric vehicles (BEVs), often expressing a preference for plug-in hybrids as a more familiar compromise, experts - defined as individuals with in-depth knowledge or direct experience with EVs, such as early adopters or professionals in transportation and energy sectors - were notably more favorable toward BEVs, likely due to their familiarity with the technology and its long-term benefits.

For example, 40% of expert comments were positive toward BEVs (emphasizing good driving experiences), while the public’s positive sentiment was higher for PHEVs (35% of sampled tweets) than for BEVs. Experts also overwhelmingly flagged charging infrastructure shortcomings as a hindrance (30% expressing negative views on charging), whereas the public discourse was less focused on infrastructure and more on the driving experience and emotions of EV use[12]. This suggests that consumers may underappreciate certain practical barriers (until they personally encounter them) and instead respond to the experiential aspects and prevailing narratives about EVs. Overall, the literature on consumer perception in Europe indicates a complex mix of enthusiasm and caution: growing environmental awareness and technology optimism are driving interest in EVs, yet fears about cost, range, and the unknown still temper many buyers' willingness to take the leap[11]. Understanding these perceptions is crucial, as they dictate how receptive consumers will be to the market changes induced by regulation.

2.4 Interactions Between Policy and Perception

An important insight emerging from recent research is that policy measures and consumer perception are deeply interconnected in shaping car purchase behavior. Neither works in isolation: the effectiveness of incentives or regulations often depends on public attitudes, and conversely, consumer perceptions can be influenced (or corrected) by well-designed policies. Several studies and reports note that the success of government measures "depends heavily on consumers", since ultimately it is individual buyers who decide whether to embrace or ignore the options that policies make attractive[16]. For example, generous purchase subsidies for EVs may have limited impact if consumers remain very skeptical about the technology (they might still opt for a familiar petrol car despite the discount). On the other hand, a modest incentive can go a long way if consumers already perceive EVs positively and are looking for that final nudge. This interplay is evident in cross-country comparisons: Norway's world-leading EV adoption is often attributed to hefty incentives, but it also helps that Norwegian consumers generally perceive EVs favorably (viewing them as high-status, eco-conscious choices). In markets where public perception is less favorable or awareness I s lower, adoption has lagged even when financial incentives exist.

At the same time, policies can actively shape perceptions. Incentives do more than lower cost – they signal to consumers that EVs are supported and here to stay, boosting confidence. As one study framed it, financial incentives indirectly drive purchase decisions by improving consumers' evaluation of EVs' utility and convenience. By reducing the economic risk (through subsidies) and investing in infrastructure, governments can make consumers perceive EVs as more useful (able to fulfill their needs) and easier to use, addressing fears of inconvenience. For instance, Norway's incentives not only slashed prices but also increased consumers' trust that EVs would be practical (free tolls, parking and other perks addressed ease-of-use concerns).

Another analysis found that a tax exemption improving EV affordability reduced consumers' sensitivity to charging issues by 37%, meaning people worried less about range or charging when the price was right. In the language of technology adoption theory, policy can enhance the perceived usefulness and perceived ease of use of EVs, which in turn increases purchase intention. This underscores that well-crafted policies can change the narrative around EVs: for example, subsidy programs coupled with public charger rollouts can convince more skeptical consumers that the government "has their back" – making the leap to an EV feel less daunting.

Empirical evidence in Europe supports these dynamics. The ACEA's 2025 report observed that when governments introduce or expand EV incentives, market responses are swift and positive, but when incentives are withdrawn, momentum stalls. Cases in point: after France scaled back its EV purchase bonus and Germany ended certain EV purchase incentives in late 2023, EV sales growth in those markets slowed markedly, even as supply of new models continued to increase. Consumers, suddenly facing higher effective prices, appeared to hesitate – indicating that the perceived affordability and value proposition of EVs changed when policy support waned. This suggests that some consumers on the fence were only persuaded to buy when the incentive tipped the scales, and without it their underlying concerns over price (or other uncertainties) resurfaced. ACEA bluntly concludes that infrastructure and model availability alone aren't enough – affordability remains the keystone of mass adoption, and that requires stable policy support[6]. In other words, favorable perceptions (e.g. believing an EV is affordable and convenient) often result from, and depend on, consistent policy signals.

Conversely, public perception can influence policy design and uptake. If public sentiment toward EVs improves – say, due to increasing environmental concern or simply more neighbors driving EVs – there may be greater political appetite for stronger incentives or ICE restrictions. Additionally, consumer demand (shaped by perception) can lead automakers to lobby for or against certain regulations. For example, a strong consumer desire for low-emission vehicles strengthens the case for stricter CO_2 targets (since industry sees a market opportunity instead of just a compliance cost). This interplay can create a virtuous cycle: positive perceptions lead to more ambitious policies, which further improve adoption and perceptions. The literature also notes potential feedback loops: as more people own EVs, word-of-mouth and visible EV usage can demystify the technology, alleviating doubts for others (reducing psychological barriers like range anxiety over time)[12].

In summary, policy and perception in the European car market are two sides of the same coin. Incentives and regulations set the stage, but consumer attitudes determine the finale.

2.5 Brand Loyalty as a Barrier to EV Adoption from Foreign Manufacturers

European car buyers have long exhibited strong loyalty to domestic brands, and this loyalty is now shaping their EV choices. Surveys indicate that 62% of Europeans plan to stick with the same car brand for their next purchase, and a striking 74% say they would have a problem buying an imported vehicle. This home-market bias favors legacy European automakers (Volkswagen, Peugeot, BMW, etc.) and poses a hurdle for foreign EV entrants like Tesla or China's BYD and MG. Indeed, brand loyalty is viewed as a key defense for incumbent manufacturers to shield their market share against these new electric competitors[13].

However, the transition to electric mobility is beginning to erode traditional loyalties. One industry survey of 5,000 European buyers found that 45% still consider brand reputation a top buying factor, yet 28% of respondents are more inclined to buy an EV from a new or unfamiliar marque than they would be with a gasoline car. Buyers cited superior battery range and affordability as motivators for trying new brands, although nearly 29% expressed distrust in the reliability of models from these upstart EV makers. Tesla has managed to overcome much of this skepticism, establishing itself as the most trusted EV marque in Europe: almost half of buyers ranked Tesla as the top EV brand, far ahead of any single European make. (By comparison, the next-most-recognized EV brands were Volkswagen and BMW at 26% each, while newer entrants Polestar and BYD were cited by only 11% and 9% of buyers [14]. This shows that while a foreign brand with strong EV credentials can earn European consumers' confidence, many buyers still gravitate to familiar badges. As traditional automakers roll out competitive EVs, loyalty to European brands is reasserting itself – in one 2024 survey, Tesla fell from first to fourth in Europeans' "most-wanted" car brands, overtaken by Audi, Mercedes-Benz, and BMW. Meanwhile, Chinese automakers face an even tougher climb. Their name recognition remains low (MG and BYD only recently entered the top 25 in European brand familiarity rankings), and only about one in five European car owners would even consider purchasing a Chinese-made car at all. In fact, roughly half of European consumers say they would only buy a Chinese EV if it were 15% cheaper than an equivalent European model [15] , underscoring the trust gap and value hurdle these brands must overcome. Nonetheless, there are signs that consumer attitudes are slowly shifting. As new entrants demonstrate their value, some European buyers are venturing outside their comfort zone, for example, China's BYD has seen explosive growth in EV sales, registering a 359% year-on-year surge in Europe that even enabled it to outsell Tesla in a recent month (April 2025). Such trends suggest that while brand loyalty remains a powerful force in Europe's EV transition – often making consumers cautious about EVs from unfamiliar foreign brands – it is not insurmountable. With compelling offerings and improvements in reputation, non-European EV makers are gradually chipping away at the loyalty wall, leading to a market where performance and value can trump legacy brand allegiance.

2.6 Regulatory and Market Context

In the context of Europe's transition towards zero-tailpipe emissions vehicles, the planned ban on sales of new internal-combustion-engine (ICE) passenger cars by 2035 has been a pivotal policy anchor. Initially agreed under the European Green Deal and the 'Fit for 55' package, the regulation set a target of 100 % reduction in CO_2 emissions for new cars and vans from 2035 onwards.

However, in recent years this policy has become the centre of substantial political and industrial debate. Several member states, most notably Germany and Italy, along with large automotive groups have called for a reassessment of the 2035 ban, arguing that the timeline and technological path may no longer fit evolving market realities, supply-chain constraints and consumer behaviour [17]. Industry actors such as Stellantis have formally requested more flexibility, including the possibility of extending ICE sales under alternative fuels or hybrids beyond 2035 [18].

Observers warn that revisiting the ban carries both industrial and environmental implications. On one hand, a delay or weakening of the ban might alleviate immediate pressures on European vehicle manufacturers, many of which face falling demand, Chinese competition and high costs of EV transition [19]. On the other hand, altering such a cornerstone regulation could undermine policy credibility, delay consumer adoption of EVs, and jeopardise investments in charging infrastructure and battery manufacturing across Europe [20].

In the empirical framework of this thesis, this regulatory debate is not only a contextual backdrop: it may itself be treated as a policy indicator affecting EV adoption, through the mechanism of anticipation effects. For example, uncertainty about the ban's enforceability may slow purchase decisions or reduce the expected lifetime of ICE vehicles, thereby influencing registration behaviour.

Ultimately, understanding how a major regulatory milestone is being questioned provides a richer, more nuanced picture of the European automotive transition. It highlights those beyond financial incentives, policy signaling, regulatory stability and industry expectations matter.

2.7 Gaps in the Literature and Future Research Directions

While there is extensive research separately on the effects of regulation and on consumer perceptions, the joint influence of these factors on new car sales remains an area calling for deeper exploration. Many academic studies analyze policy impacts in terms of sales statistics or fleet emissions, and a growing number examine consumer attitudes through surveys and psychological models. However, few studies truly integrate both angles to understand their interaction. As noted above, questions such as *to what extent do consumer perceptions mediate the effectiveness of EV incentives?* or *how do policy changes alter public perception over time?* are not yet fully answered by the literature. In particular, the literature falls short in explaining variance in outcomes when strong policies in some regions yield different results than expected due to local consumer sentiment. For example, if two countries offer similar EV incentives but see different uptake rates, what role did public perception, awareness, or cultural factors play? Such comparative, mixed-method studies are scarce.

Another gap is in longitudinal analysis of perception shifts in response to policy. We have snapshots of consumer opinion (e.g., before and after a subsidy introduction), but more research could track how perceptions (like range anxiety or cost concerns) evolve as the market grows, and policies tighten. Do consumers naturally become more amenable to EVs as they see more of them on the road (a social normalization effect), or is policy intervention needed to actively dispel myths and highlight benefits? The current literature provides hints (for instance, range anxiety tends to diminish as charging infrastructure improves and early adopters share positive experiences[12]), but a cohesive understanding is lacking.

Furthermore, the combined impact of "hard" factors (like price/incentives) and "soft" factors (like attitudes and awareness) on the decision-making process could be better modeled. Behavioral economic studies or technology adoption models that incorporate both financial incentives and psychological barriers would help predict uptake under different scenarios.

Several studies have used behavioral frameworks such as the Theory of Planned Behavior (TPB) and the Technology Acceptance Model (TAM) to explain consumers' intentions to adopt electric vehicles. According to TPB, adoption decisions are influenced by individual attitudes toward the technology, social influences, and perceived control over the behavior, such as affordability or access to charging infrastructure. TAM instead focuses on users' perceptions of a technology's usefulness and ease of use as key drivers of adoption.

While these frameworks provide useful insights into consumer decision-making, they often overlook the role of public policy. Factors such as financial incentives, regulatory targets, and charging infrastructure availability may significantly affect EV adoption. Integrating these policy variables into behavioral models therefore represents an important direction for future research. Understanding this interaction is also relevant for policymakers. If consumers are not aware of available incentives, their impact may be limited. Conversely, information campaigns could increase the effectiveness of existing subsidies by improving public awareness and influencing adoption decisions.

Lastly, segment-specific research is limited. Consumer perception is not monolithic; it varies by demographic groups, income levels, and regions. We know from ACEA's findings that lower-income countries have lower EV uptake, pointing to affordability issues[8] – but also possibly to differences in perception (e.g., less exposure to EVs, different priorities). Likewise, perceptions may differ in urban vs. rural populations (range anxiety might be higher in rural areas with few chargers). The intersection of policy with these segments is a ripe area: perhaps certain incentive designs work better for particular groups, or certain messaging is needed to reach consumers who are skeptical for non-economic reasons. The current literature only partially addresses these nuances.

In conclusion, this review highlights that regulatory frameworks and consumer perceptions both critically influence car purchase behavior in Europe, yet the nexus between them is under-researched. Existing studies provide evidence that strong policies can drive market change and that consumer attitudes can accelerate or hinder this change, but an integrated analytical approach is often missing. By identifying this gap, the present research (as proposed by the user) is well-justified: it aims to contribute a more holistic understanding of how policy and perception together shape the evolution of new car sales. Such insights could help design policies that not only set the right economic conditions but also positively influence public perception – thereby bridging the gap between regulatory intent and consumer action. As Europe moves toward its climate goals (e.g. the 2035 zero-emission mandate), closing this knowledge gap will be vital for ensuring that both legislation and public sentiment align to achieve the desired transition to sustainable mobility.

3. Data and Methodology

3.1 Data and Variables

The empirical analysis is conducted using a balanced panel dataset covering the 27 European Union member states over the period 2015–2024. The dataset is structured at the country–year level, resulting in 270 observations. This configuration allows the analysis to exploit both cross-sectional variation across countries and temporal variation within countries over time.

The selected time horizon captures the critical phase of electric vehicle (EV) diffusion in Europe, encompassing early adoption years, the acceleration phase after 2019, and the post-pandemic market expansion.

3.1.1 Dependent Variables

The main dependent variable is the share of electric vehicles (EVs) in total new passenger car registrations within each country and year. This measure captures the degree of transition from internal combustion engine vehicles (ICE) to electrified powertrains.

$$EV_{share_{c,t}} = \frac{New\ BEV + PHEV\ sales_{c,t}}{Total\ new\ car\ sales_{c,t}}$$

To investigate heterogeneous adoption patterns, the overall EV share is further decomposed into:

- Battery Electric Vehicle (BEV) share

$$BEV_{share_{c,t}} = \frac{New\ BEV\ sales_{c,t}}{Total\ new\ car\ sales_{c,t}},$$

- Plug-in Hybrid Electric Vehicle (PHEV) share

$$PHEV_{share_{c,t}} = \frac{New\ PHEV\ sales_{c,t}}{Total\ new\ car\ sales_{c,t}}$$

All dependent variables are expressed as proportions between 0 and 1. Descriptive evidence shows substantial right-skewness, reflecting the rapid and uneven diffusion process across member states. Early years are characterized by very low adoption levels, while later years exhibit strong growth in a subset of countries.

Data are obtained from the International Energy Agency (IEA) Global EV Data Explorer, which compiles information from multiple sources including EV Volumes, MarkLines, ACEA, EAFO, and OICA**.**

3.1.2 Explanatory Variables

The empirical model includes five main explanatory variables:

Affordability-Weighted EV Incentive Index

Estimating the impact of public policies on Electric Vehicle (EV) adoption requires an appropriate quantification of government support. Previous studies often rely either on binary indicators capturing the presence of subsidies or on nominal monetary values such as the amount of a purchase grant. However, these approaches present important limitations when applied to a heterogeneous panel such as the EU-27.

First, nominal subsidies have different economic impacts depending on local purchasing power. A €5,000 grant represents a much stronger incentive in a lower-income country than in a high-income economy, potentially introducing measurement error when treated as equivalent across countries. Second, EV support policies typically consist of a broader policy mix including tax exemptions, infrastructure support, and penalties for internal combustion engine (ICE) vehicles rather than a single purchase subsidy.

To address these issues, this thesis constructs a composite indicator: the Affordability-Weighted EV Incentive Index. The index ranges from 0 to 10 and measures the intensity of EV policy support relative to local purchasing power.

Data Sources and Data Processing

The index is constructed for the EU-27 over the period 2015–2024. Policy information was primarily collected from the annual ACEA Tax Guides ("Tax benefits & purchase incentives in the EU"), which provide detailed descriptions of national EV support schemes.

To systematically extract relevant information on purchase subsidies, tax incentives, and corporate benefits, an AI-assisted structured coding process was implemented. Initially, multiple Large Language Models (LLMs) were tested to evaluate their natural language processing and information extraction capabilities on policy documents. After selecting the most performant model, an iterative prompting process was conducted to train and refine the LLM, thereby maximizing its extraction accuracy and ensuring the correct categorization of complex fiscal policies.

To prevent AI-generated hallucinations and ensure data integrity, this automated extraction was rigorously complemented by manual double-checks, wherein the output was continuously verified against the original ACEA documents. Furthermore, to ensure consistency across years and countries, the collected data were cross-validated with the European Alternative Fuels Observatory (EAFO) database. Finally, values expressed in non-Euro currencies were converted using annual exchange rates from Eurostat.

Construction Methodology

The final policy index is defined as the sum of four components, capped at a maximum value of 10.

The main component is the affordability-weighted subsidy, which adjusts the nominal purchase grant using GDP per capita in Purchasing Power Standards (PPS). This adjustment reflects the higher marginal impact of subsidies in lower-income countries. The weighted subsidy is then normalized so that approximately €2,000 of weighted support corresponds to one index point. A discount factor is applied when subsidies are limited by vehicle price caps. In cases where incentives varied across vehicle emission categories, the incentive applicable to battery electric vehicles was used.

The index also includes a fiscal score (0–3 points) capturing exemptions or reductions in acquisition taxes, ownership taxes, and corporate taxation. A malus component adds one point in countries implementing CO_2-based registration taxes or bonus-malus systems that increase the cost of internal combustion vehicles. Finally, an ecosystem support component assigns one point when national incentives for private charging infrastructure are available.

Validation and Stylized Facts

The resulting index captures both cross-country heterogeneity and major policy changes over time. For instance, the index reflects the sharp decline in Germany's policy support following the termination of the *Umweltbonus* in 2024. It also highlights the strong relative impact of generous subsidy schemes in lower-income countries such as Romania. In addition, the index captures the volatility of EV incentives observed in several countries, providing meaningful within-country variation for the econometric analysis.

Limitations

The index primarily captures demand-side financial incentives and simplifies the complexity of eligibility rules and administrative procedures. It also does not fully account for local or city-level policies unless they are nationally standardized.

Another limitation concerns the budget constraints of incentive programs. In many countries, EV subsidies are subject to annual funding caps or limited program budgets, which restrict the number of vehicles eligible for support. As a result, even generous incentives may benefit only a relatively small share of potential consumers if available funds are quickly exhausted.

Consequently, the index measures the potential intensity of policy support, but it may overestimate the effective policy exposure experienced by the average consumer when incentive programs are capacity-constrained. Nevertheless, it provides a more informative proxy for policy intensity than simple nominal subsidy measures.

GDP per Capita (PPS)

Gross Domestic Product per capita expressed in Purchasing Power Standards. This variable proxies household purchasing power and overall economic development, allowing cross-country comparisons that account for differences in price levels across EU member states.
Data are obtained from Eurostat, the statistical office of the European Commission.

Fuel Price (Oil Bulletin)

Retail fuel price index capturing variation in gasoline prices across countries and over time. The variable is constructed using the weekly average pump prices of Super 95 gasoline (including taxes) reported in the European Commission Oil Bulletin. Annual values are obtained by calculating the average of weekly observations, providing a consistent yearly indicator of fuel cost conditions faced by consumers.

Electricity Price

Household electricity price index reflecting operating cost conditions for electric vehicles. The data refer to final consumer electricity prices in consumption Band DC (2,500–4,999 kWh), which represents a typical household consumption range. As electricity price statistics are reported biannually, annual values are calculated by taking the average of the two semi-annual observations available for each year. Data are obtained from Eurostat.

Charging Infrastructure

Measured as the number of public charging points per 100,000 inhabitants.
Infrastructure is expressed in per-capita terms to allow meaningful cross-country comparisons and to mitigate distortions related to scale differences. Alternative specifications using logarithmic transformations are tested as robustness checks. Data are sourced from the International Energy Agency (IEA) Global EV Data Explorer. In a limited number of cases where observations were missing for specific country–year combinations, the dataset was

complemented using official national reports and institutional publications. When necessary, missing values were approximated using consistent estimates based on available data from adjacent years and national statistics in order to preserve the continuity of the panel dataset.

3.1.3 Descriptive Statistics

Table 1 reports the summary statistics for the main variables used in the empirical analysis.

Table 1 – Summary statistics

Variables	Obs	Mean	Std. Dev.	Min	Max	p1	p99	Skew.	Kurt.
EVsalesshare	270	.089	.126	0	.6	.001	.56	2.011	6.668
BEVsharesales	270	.054	.084	0	.519	0	.372	2.463	9.629
PHEVsharesales	270	.036	.051	0	.248	0	.225	2.14	7.411
Incentives	270	2.894	2.492	0	10	0	9.6	.62	2.527
GDPpercapitaPPS	270	102.307	42.921	49	279	52	267	2.189	8.263
OilBullettin	270	1.42	.249	.931	2.109	.984	2.074	.513	2.74
Energyprice	270	.146	.062	.077	.455	.079	.375	1.782	6.631
EVchargpointx100k	270	68.874	131.754	0	1047.766	.147	707.76	3.929	21.781

A detailed inspection of the table highlights substantial heterogeneity across EU member states and over time.

The average EV share across the sample period amounts to approximately 8.9%, although the distribution is highly dispersed. Early observations display adoption levels close to zero, while later years show significantly higher values in a subset of countries. This pattern is consistent with a non-linear diffusion process typical of emerging technologies.

When decomposing total EV adoption into BEV and PHEV shares, both technologies exhibit considerable variation across countries and years. BEVs account for a larger average share relative to PHEVs, although both segments demonstrate significant growth throughout the sample period.

Charging infrastructure presents the highest degree of dispersion among the explanatory variables. The number of public charging points per 100,000 inhabitants ranges from zero in some early-stage markets to over 1,000 in more advanced contexts. This wide spread indicates uneven infrastructure deployment across the EU.

GDP per capita also exhibits substantial cross-country variation, reflecting persistent economic heterogeneity within the Union. In contrast, fuel and electricity prices display comparatively narrower ranges, suggesting more limited dispersion in operating cost conditions relative to structural economic differences.

Overall, the dataset displays meaningful cross-sectional and temporal variation, providing a suitable empirical setting for panel data analysis.

3.1.4 Correlation Structure

Table 2 reports the pairwise correlation matrix among the explanatory variables included in the empirical analysis.

Table 2 - Correlation matrix

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
(1) EVsalesshare	1.000							
(2) BEVsharesales	0.962	1.000						
(3) PHEVsharesales	0.895	0.739	1.000					
(4) Incentives	0.343	0.315	0.330	1.000				
(5) GDPpercapitaPPS	0.281	0.272	0.250	-0.045	1.000			
(6) OilBullettin	0.654	0.615	0.609	0.384	0.157	1.000		
(7) Energyprice	0.528	0.516	0.459	0.277	0.389	0.644	1.000	
(8) EVchargpoint100k	0.747	0.772	0.581	0.171	0.367	0.524	0.467	1.000

The correlation coefficients suggest moderate associations between some variables, particularly between charging infrastructure and fuel prices, as well as between electricity prices and fuel prices. However, no correlation exceeds conventional multicollinearity concern thresholds (i.e., 0.7–0.8).

Charging infrastructure exhibits a positive correlation with GDP per capita, reflecting the structural tendency of wealthier countries to deploy charging networks earlier and more extensively.

Overall, the correlation structure does not indicate severe multicollinearity issues, supporting the joint inclusion of the selected regressors in the panel regression framework.

3.2 Stylized Facts and Descriptive Evidence

3.2.1 Aggregate diffusion of EV adoption in the EU27

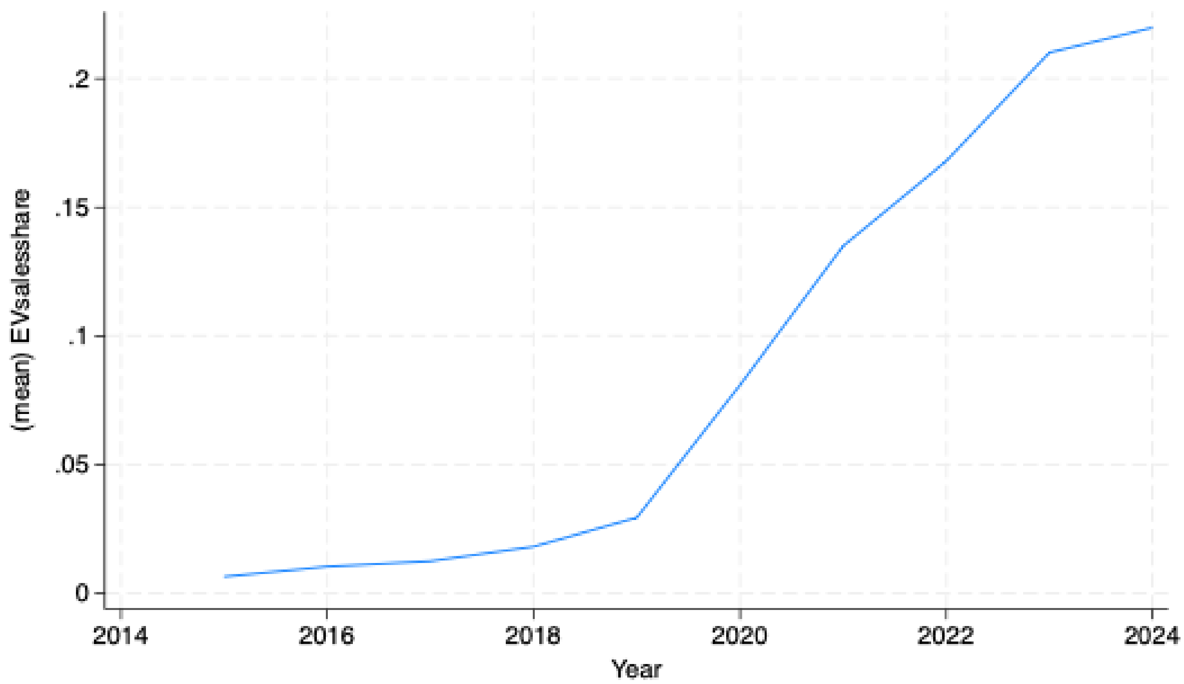

Figure 1 – Evolution of EV market share across EU27

The trajectory exhibits a clear non-linear diffusion pattern. Between 2015 and 2018, EV adoption increases gradually from near-zero levels, reflecting the early stage of market penetration. Starting in 2019, however, the growth rate accelerates markedly. The steep upward slope observed between 2020 and 2023 indicates a structural shift in the European automotive market, with EVs gaining substantial market share within a relatively short period of time.

By 2024, the average EV share across the EU27 exceeds 20%, representing a dramatic expansion compared to the beginning of the sample period. The pattern is consistent with a typical S-shaped diffusion process, characterized by slow initial uptake followed by rapid expansion once technological maturity, infrastructure availability, and consumer acceptance reach critical thresholds.

Importantly, this figure captures the aggregate European trend and does not reflect cross-country heterogeneity, which is examined in subsequent sections. Nonetheless, the pronounced acceleration after 2019 suggests that common EU-wide factors may have played a significant role in shaping the overall transition toward electric mobility.

Figure 2 presents the evolution of average battery electric vehicle (BEV) and plug-in hybrid electric vehicle (PHEV) market shares across the EU27 between 2015 and 2024.

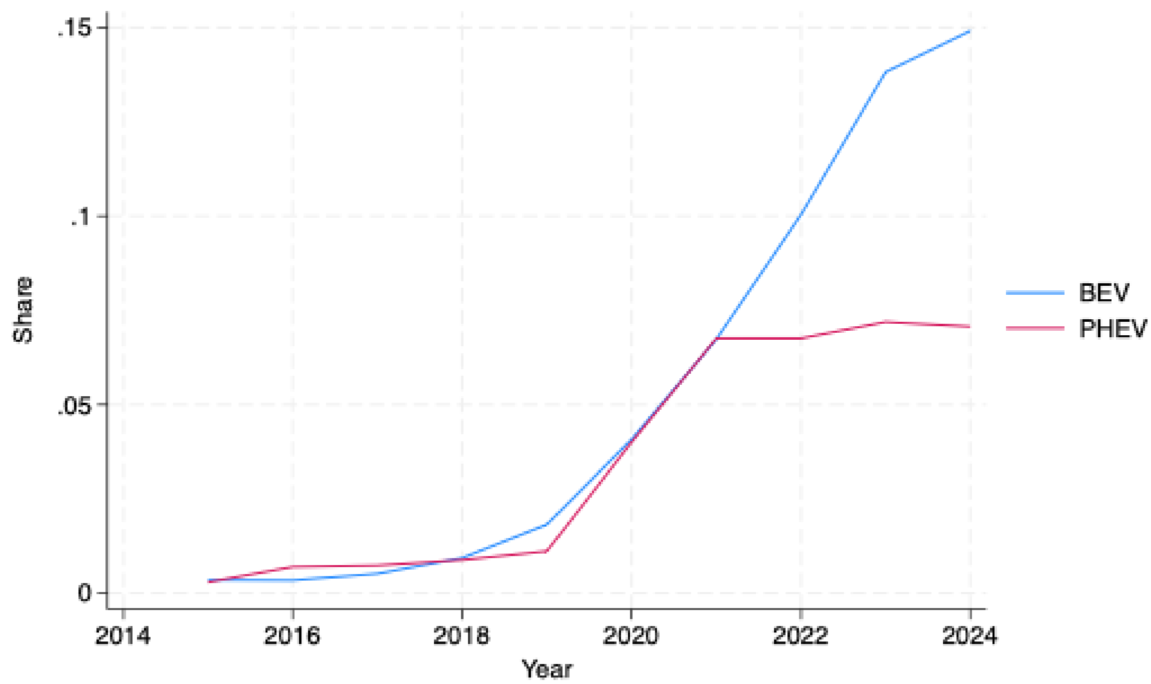

Figure 2 – Evolution of BEV and PHEV market shares across EU27

Both technologies display a clear upward trajectory over the sample period. During the early years, BEV and PHEV adoption levels remain closely aligned and relatively low, reflecting the initial phase of electrification in European markets. Beginning in 2019, both segments experience a pronounced acceleration, coinciding with the broader expansion observed in total EV adoption.

However, a noticeable divergence emerges after 2021. While PHEV growth stabilizes in the later years of the sample, BEV adoption continues to increase at a faster pace. By 2024, BEVs account for a substantially larger share of new registrations compared to PHEVs, indicating a gradual shift toward full electrification rather than hybrid-based electrification.

This compositional change suggests that the structure of EV adoption in the EU27 has evolved over time, with battery electric vehicles progressively gaining relative importance within the electrified vehicle segment.

3.2.2 Cross-Country Dispersion in EV Adoption

Figure 3 presents the distribution of EV market shares across EU27 member states for each year between 2015 and 2024.

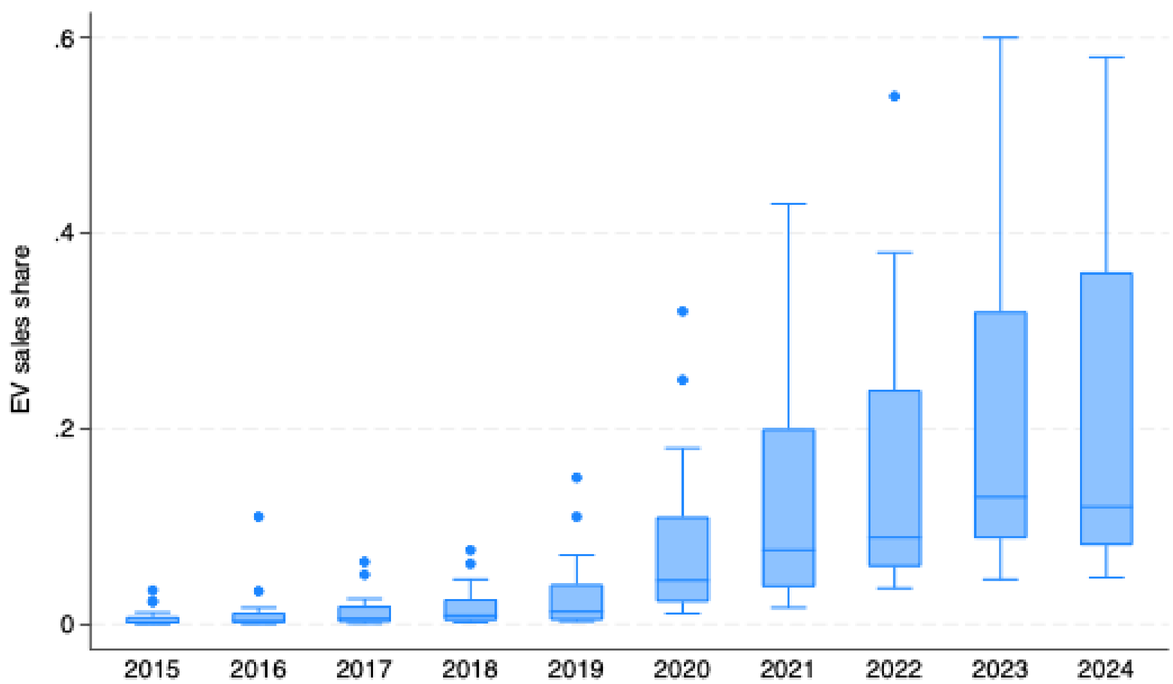

Figure 3 – Distribution of EV market shares across EU27

Two key patterns emerge. First, the median EV share increases steadily over time, confirming the aggregate upward trend previously observed. Second, cross-country dispersion widens substantially in the later years of the sample. While early observations display relatively compressed distributions centered near zero, the interquartile range expands markedly after 2019.

The upper tail of the distribution becomes particularly pronounced from 2021 onward, with some countries reaching EV shares above 40–50%, while others remain below 10%. This divergence indicates that the electrification process has not been uniform across the European Union.

The increasing dispersion suggests that national markets are progressing along different adoption paths, potentially reflecting differences in infrastructure deployment, policy design, income levels, and consumer preferences. However, this section remains descriptive; the determinants of such divergence are examined formally in the regression analysis.

3.2.3 Infrastructure Expansion in the EU27

Charging infrastructure exhibits a steady and sustained upward trajectory throughout the sample period. As reported in Figure 4, growth is relatively gradual between 2015 and 2018, followed by a noticeable acceleration beginning in 2019 and intensifying after 2020. By 2024, the average number of charging points per 100,000 inhabitants has increased severalfold compared to the initial years of the sample.

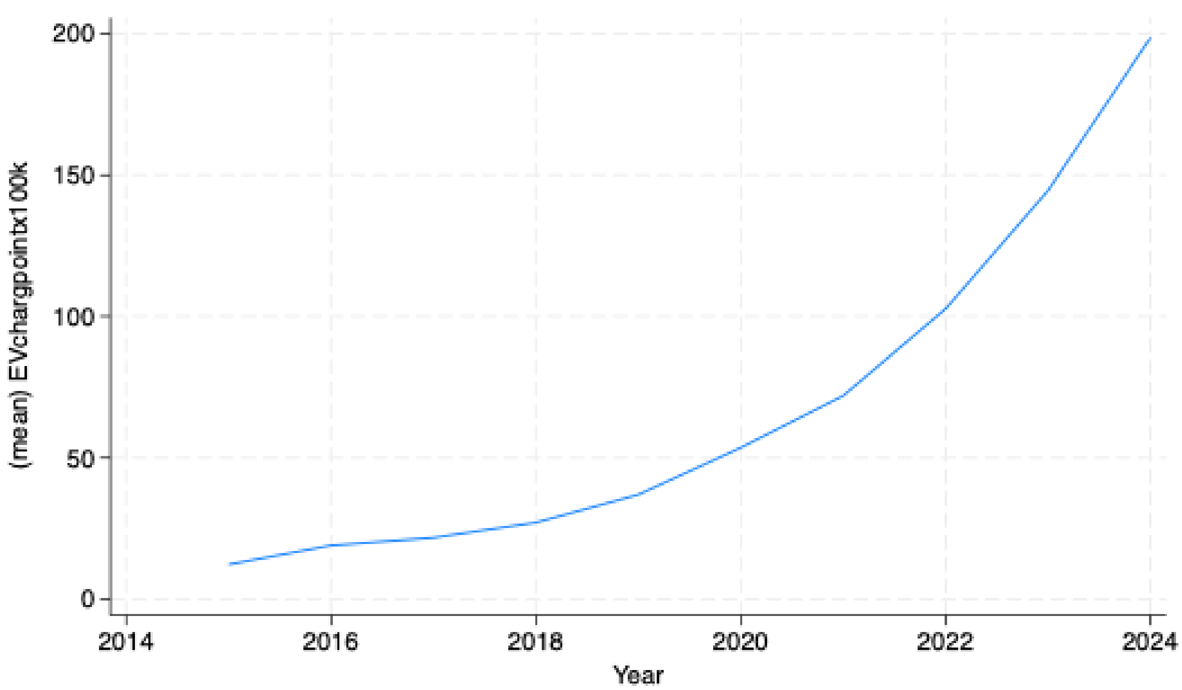

Figure 4 – Evolution of avg number of public charging points per 100,000 inhabitants across EU27

The timing of this infrastructure expansion broadly coincides with the acceleration in EV adoption observed in Section 3.2.1. While this temporal alignment suggests that infrastructure deployment and EV diffusion have progressed in parallel, this figure does not establish a causal relationship. Instead, it documents the aggregate evolution of public charging networks across the Union.

The substantial growth in charging availability indicates a structural transformation in the European mobility ecosystem, with infrastructure development becoming an increasingly central component of the electrification process.

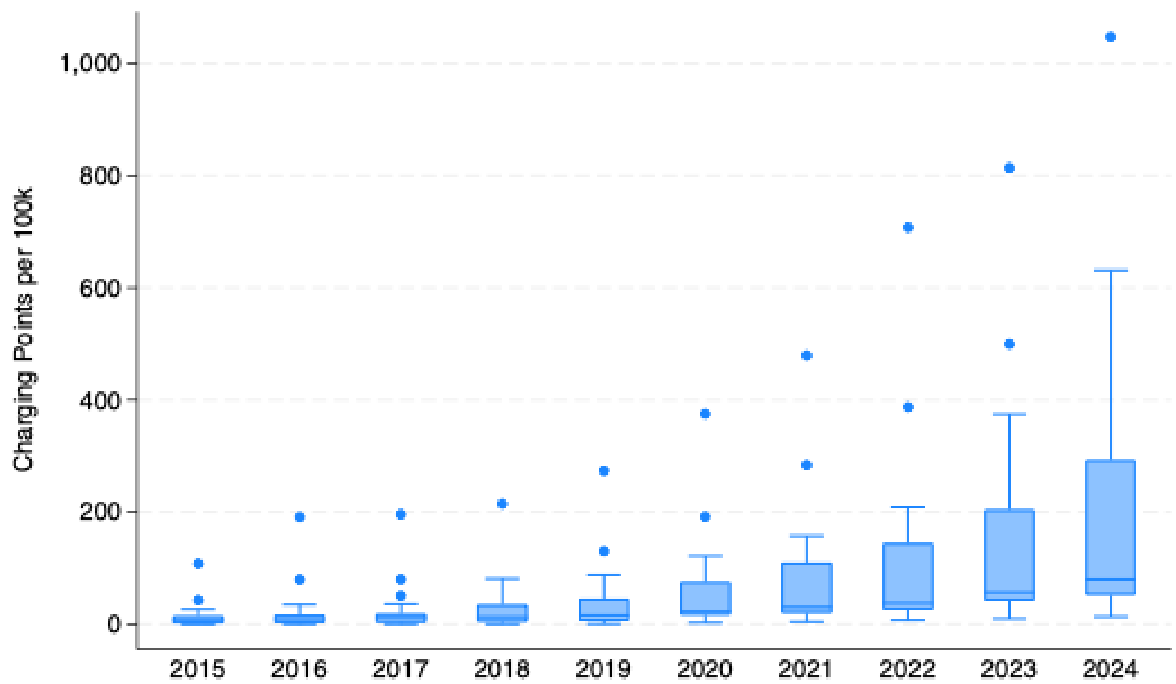

Figure 5 – Distribution of avg number of public charging points per 100,000 inhabitants across EU27

As with EV adoption, cross-country dispersion increases markedly throughout the sample period. As shown is Figure 5 while early years are characterized by relatively low and homogeneous infrastructure levels, the distribution widens substantially after 2019. By 2024, the upper tail of the distribution extends beyond 1,000 charging points per 100,000 inhabitants, whereas several countries remain below 100.

The interquartile range expands considerably in the later years, indicating that infrastructure deployment has followed heterogeneous trajectories across member states. Some countries appear to have invested heavily in charging networks, while others have adopted more gradual expansion strategies.

This divergence in infrastructure readiness mirrors the increasing heterogeneity observed in EV adoption rates, suggesting that the transition toward electric mobility has unfolded unevenly across the Union.

Importantly, this section remains descriptive. The extent to which infrastructure differences are associated with EV adoption patterns is formally examined in the econometric analysis presented in subsequent sections.

3.2.4 Cross-Sectional Association Between Infrastructure and EV Adoption

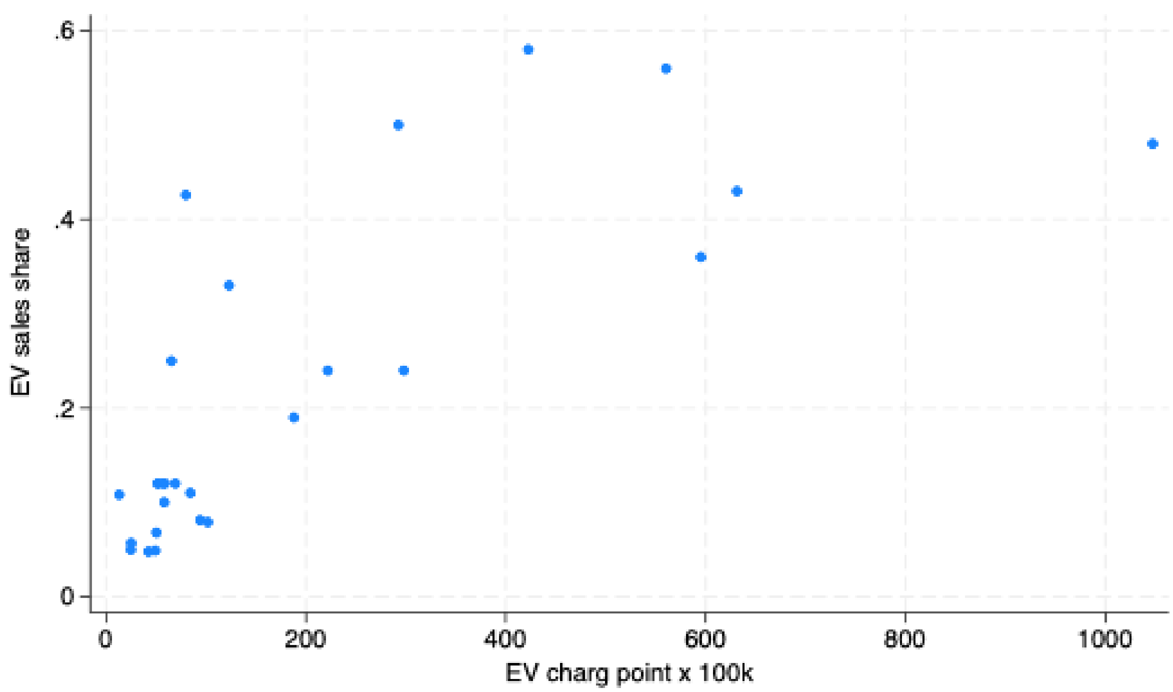

Figure 6 – Cross-Sectional Association Between Charging Infrastructure and EV Market Share (2024)

The scatter plot in Figure 6 reveals a positive association between the number of charging points per 100,000 inhabitants and the share of EV registrations. Observations with higher infrastructure levels tend, on average, to exhibit higher EV adoption rates. Countries with very high charging density frequently appear in the upper range of EV market shares.

However, substantial dispersion remains visible, especially among countries with intermediate levels of infrastructure. This suggests that charging availability alone does not fully explain differences in adoption rates.

It is important to emphasize that this figure reflects an unconditional cross-country relationship between charging infrastructure and EV market share across EU member states in the most recent year of the sample. As such, it does not control for country-specific structural characteristics, such as income levels, policy intensity, or market maturity, which may simultaneously affect both infrastructure deployment and EV adoption. The observed correlation should therefore be interpreted as descriptive rather than causal.

3.2.5 Policy Support Landscape

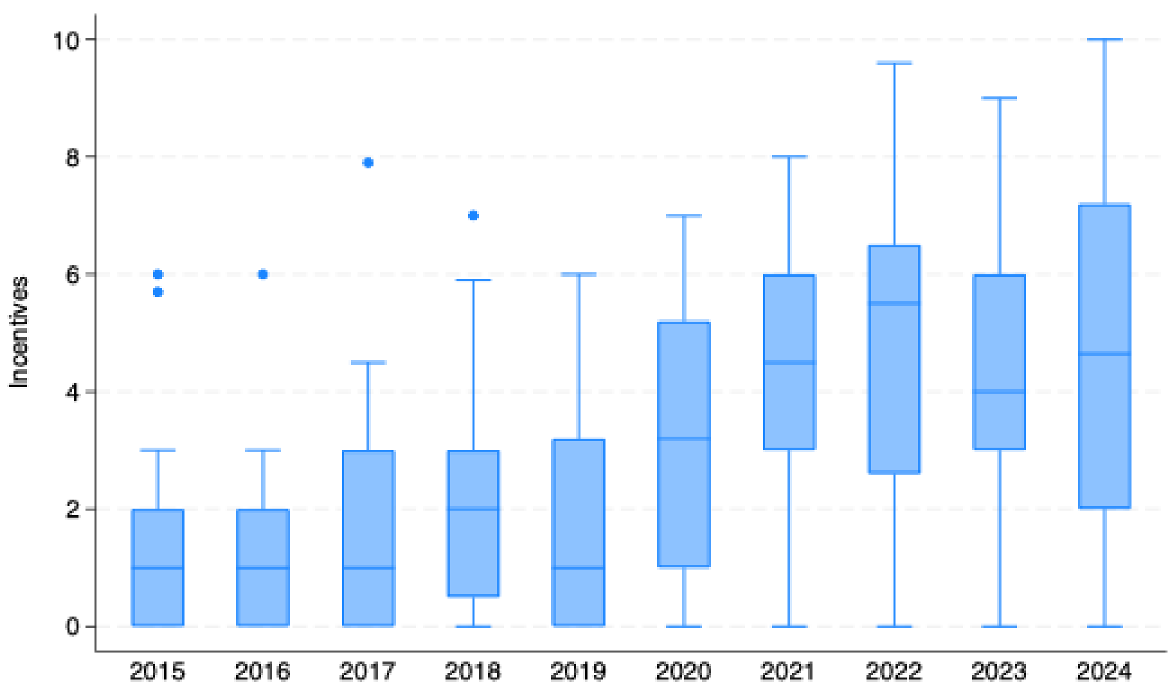

Figure 7 – Distribution of the incentives index across EU27

As presented in Figure 7, the median level of financial support for EV adoption increases gradually throughout the sample period. In the early years, most countries exhibit relatively low incentive intensity, with values concentrated near the lower end of the scale. Starting around 2020, the distribution shifts upward, indicating a general strengthening of national support schemes.

However, substantial cross-country heterogeneity persists. Even in the later years, some member states maintain limited fiscal incentives, while others adopt significantly stronger policy support frameworks, with index values approaching the upper bound of the scale.

The widening interquartile range in the post-2020 period suggests that national policy strategies have diverged rather than converged. This heterogeneous policy environment reflects differing national priorities, fiscal capacities, and strategic approaches to accelerating electric vehicle adoption.

3.2.6 Energy and Fuel Price Dynamics

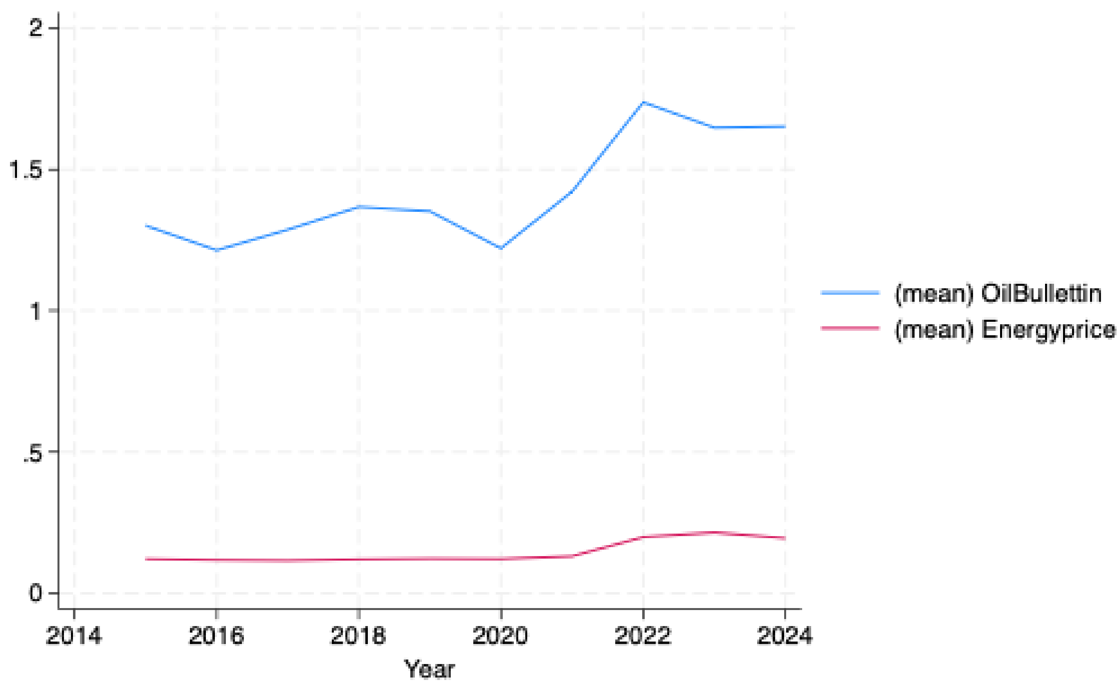

Figure 8 – Evolution of energy and fuel prices across EU27

As can be seen in Figure 8, fuel prices display moderate fluctuations during the early years, followed by a noticeable increase in the early 2020s. Electricity prices remain relatively stable until 2021, after which a visible upward shift occurs. Although the magnitude of variation differs between the two price indices, both exhibit upward movements in the later years of the sample.

Importantly, these price dynamics appear to affect the Union broadly rather than specific individual countries. As such, much of the observed variation may reflect common macroeconomic and energy market shocks. In the panel regression framework, these common movements are likely to be captured by year fixed effects.

The descriptive evidence suggests that energy price dynamics may play a role in shaping EV adoption decisions, but a formal assessment requires controlling for confounding factors, which is undertaken in the empirical analysis.

3.2.7 Heterogeneous National Adoption Paths

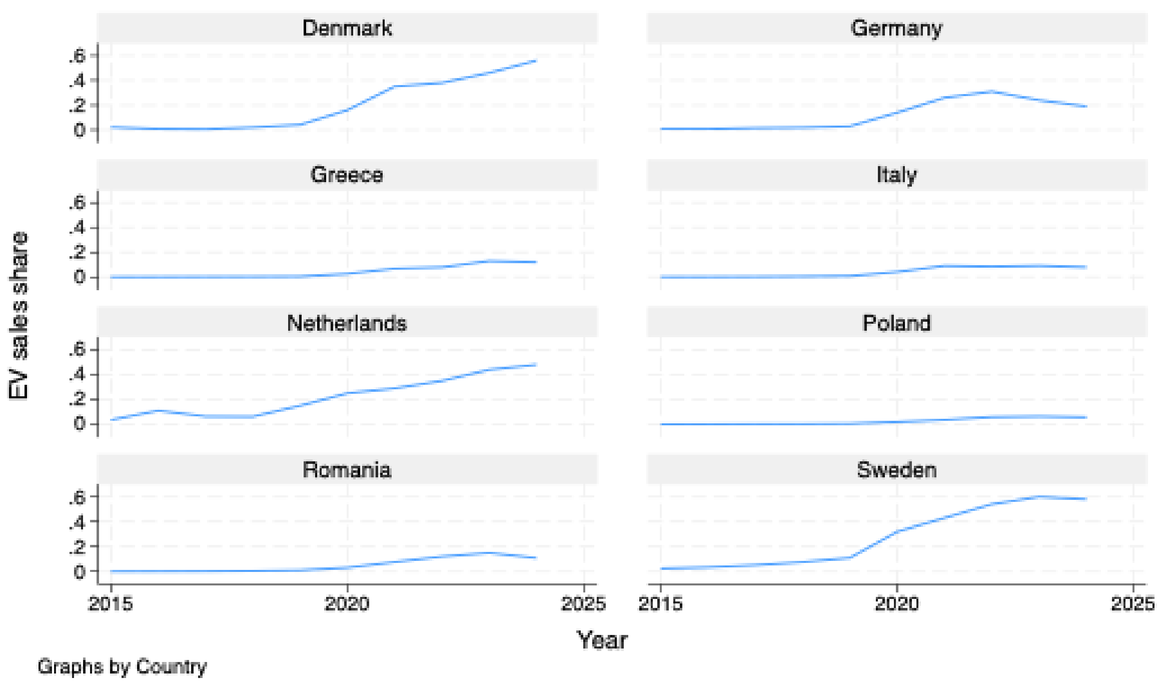

Figure 9 – Evolution of EV for a selected group of EU member states representing different adoption levels.

Figure 9 displays the trajectories reveal substantial heterogeneity in both timing and magnitude of adoption. Countries such as Denmark, Sweden, and the Netherlands exhibit early and sustained acceleration in EV uptake, with shares reaching very high levels by the end of the sample period. In contrast, countries such as Poland, Romania, and Greece display considerably slower growth trajectories, with EV shares remaining comparatively low.

Intermediate cases, such as Germany and Italy, show moderate but steady increases, although not reaching the levels observed in leading countries. Notably, some countries exhibit temporary slowdowns or stabilization phases after initial acceleration, highlighting the non-linear nature of the transition process.

These heterogeneous adoption paths indicate that the European electrification process is not uniform across member states. Differences in market structure, policy frameworks, infrastructure deployment, and consumer preferences likely contribute to the observed divergence.

4. Empirical Analysis

4.1 Baseline Specification

To investigate the determinants of electric vehicle adoption across the European Union, the analysis employs a panel data framework exploiting both cross-country and time variation.

The baseline econometric specification is defined as follows:

$$EV_{it} = \beta_1 \, Incentives_{it} + \beta_2 \, GDP_{it} + \beta_3 \, FuelPrice_{it} + \beta_4 \, ElectricityPrice_{it} + \beta_5 \, Infrastructure_{it} + \alpha_i + \gamma_t + \varepsilon_{it}$$

where:

- $\boldsymbol{EV_{it}}$ denotes the share of electric vehicles in total new car registrations in country *i* at time *t*.
- $\boldsymbol{Incentives_{it}}$ measures the intensity of national financial support schemes.
- $\boldsymbol{GDP_{it}}$ represents GDP per capita (PPS).
- $\boldsymbol{FuelPrice_{it}}$ captures retail fuel price dynamics.
- $\boldsymbol{ElectricityPrice_{it}}$ reflects household electricity prices.
- $\boldsymbol{Infrastructure_{it}}$ denotes charging points per 100,000 inhabitants.
- $\boldsymbol{\alpha_i}$ represents country fixed effects.
- $\boldsymbol{\gamma_t}$ represents year fixed effects.
- $\boldsymbol{\varepsilon_{it}}$ is the idiosyncratic error term.

The model is estimated using a linear fixed-effects estimator.

Country fixed effects (α_i) control for time-invariant structural differences across EU member states. These may include:

- Urban density and geographic characteristics
- Cultural attitudes toward environmental sustainability

- Historical automotive industry structure
- Long-standing regulatory environments

By incorporating country fixed effects, the model identifies the impact of explanatory variables using within-country variation over time, thereby eliminating bias stemming from unobserved, time-invariant heterogeneity.

Year fixed effects (γ_t) capture common shocks affecting all countries simultaneously, including:

- EU-wide regulatory initiatives
- Technological progress in battery development
- Macroeconomic shocks (e.g., pandemic effects)
- Supply chain disruptions
- Global energy price fluctuations

Including year fixed effects ensures that estimated coefficients reflect deviations from common European trends rather than general time dynamics in EV diffusion.

The model is estimated using the within estimator for panel data. Standard errors are clustered at the country level to account for:

- Heteroskedasticity
- Serial correlation within countries over time

Clustering is particularly important given the relatively small-time dimension (T = 10) and the persistence typically observed in technology adoption processes.

Given that the dependent variable is expressed as a share bounded between 0 and 1, the estimated coefficients can be interpreted as marginal effects on the EV market share.

For instance, the coefficient on charging infrastructure measures the change in EV share associated with an additional charging point per 100,000 inhabitants, holding constant country-specific characteristics and common time effects.

Although the dependent variable is fractional, a linear specification is retained for interpretability and consistency with standard empirical approaches in panel policy analysis.

4.1.1 Extension: Technology-Specific Models

To explore heterogeneous adoption dynamics, the baseline specification is replicated using BEV and PHEV market shares as dependent variables:

$$BEV_{it} = \mathrm{f}(\mathrm{X}_{\mathrm{it}}) + \alpha_{\mathrm{i}} + \gamma_{\mathrm{t}} + \varepsilon_{\mathrm{it}}$$

$$PHEV_{it} = \mathrm{f}(\mathrm{X}_{\mathrm{it}}) + \alpha_{\mathrm{i}} + \gamma_{\mathrm{t}} + \varepsilon_{\mathrm{it}}$$

This approach allows for a comparative assessment of how economic and policy drivers differentially affect full electrification versus hybrid adoption.

4.2 Potential Identification Challenges

Despite the inclusion of country and year fixed effects, the empirical strategy faces several potential identification challenges that must be acknowledged.

Reverse Causality

One major concern relates to reverse causality, particularly in the case of charging infrastructure.

While the model assumes that infrastructure expansion influences EV adoption, it is also plausible that higher EV demand induces governments and private actors to deploy additional charging points. In such a case, infrastructure would respond to adoption rather than strictly cause it.

Although the fixed-effects structure mitigates bias from time-invariant confounders, it does not fully eliminate potential simultaneity between EV uptake and infrastructure deployment.

To partially address this concern, alternative specifications incorporating lagged infrastructure measures are estimated as robustness checks.

Omitted Variable Bias

Another concern is the possibility of omitted time-varying country-level factors that simultaneously affect EV adoption and the explanatory variables.

Examples may include:

- National climate policy stringency
- Environmental awareness trends
- Local industrial policy shifts
- Urban mobility reforms

While country fixed effects control for persistent structural differences and year fixed effects absorbs EU-wide shocks, the model cannot fully account for all country-specific time-varying influences.

Common Trends and Diffusion Dynamics

The period under analysis coincides with a rapid acceleration in EV adoption across Europe. This diffusion process may be driven by technological progress, cost reductions in battery production, and regulatory coordination at the EU level.

The inclusion of year fixed effects absorbs common diffusion trends, ensuring that estimated coefficients capture deviations from the overall European trajectory rather than general market expansion. However, this also implies that the model primarily identifies within-country variation relative to the EU-wide trend.

Given these considerations, the results should be interpreted as conditional associations within a fixed-effects framework rather than definitive causal effects.

The analysis aims to identify robust patterns of correlation consistent with economic theory and policy dynamics, while acknowledging the inherent limitations of observational panel data.

4.3 Baseline Results – EV Adoption

Table 3 reports the results of the baseline two-way fixed effects specification, where the dependent variable is the share of electric vehicles in total new passenger car registrations.

Table 3 – Baseline EV Regression

EVsalesshare	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
Incentives	.001	.003	0.40	.693	-.005	.007	
GDPpercapitaPPS	0	.001	-0.31	.755	-.003	.003	
OilBulletin	.012	.105	0.11	.913	-.204	.227	
Energyprice	.081	.189	0.43	.672	-.307	.469	
EVchargpointx100k	.001	0	3.81	.001	0	.001	***
2015b	0	.	.	.	.	.	
2016	.001	.009	0.17	.87	-.017	.02	
2017	.001	.002	0.55	.588	-.004	.006	
2018	.003	.009	0.30	.767	-.015	.021	
2019	.009	.009	0.96	.347	-.01	.028	
2020	.052	.016	3.19	.004	.019	.085	***
2021	.092	.026	3.62	.001	.04	.145	***
2022	.099	.054	1.82	.08	-.013	.211	*
2023	.118	.046	2.60	.015	.025	.212	**
2024	.1	.054	1.87	.073	-.01	.211	*
Constant	.019	.209	0.09	.928	-.41	.449	

Mean dependent var	0.089	SD dependent var	0.126
R-squared	0.778	Number of obs	270
F-test	56.467	Prob > F	0.000
Akaike crit. (AIC)	-833.378	Bayesian crit. (BIC)	-783.000

*** p<.01, ** p<.05, * p<.1

The model includes country fixed effects, year fixed effects, and standard errors clustered at the country level. This specification exploits within-country variation over time while controlling for common European shocks and persistent structural differences across member states.

The within R-squared of 0.778 indicates that the model explains a substantial portion of the within-country variation in EV adoption over time.

Consistent with the descriptive patterns observed in Section 3.2, charging infrastructure emerges as the only variable that is robustly and statistically significant in the baseline specification.

The coefficient on charging points per 100,000 inhabitants is positive and significant at conventional levels. Quantitatively, an increase of 10 charging points per 100,000 inhabitants is associated with an increase of approximately 0.5 percentage points in EV market share, holding constant country-specific characteristics and common time effects.

This magnitude is economically meaningful given the substantial variation in infrastructure deployment documented in Figures 6 and 7. The result suggests that, within countries, periods of faster infrastructure expansion are associated with stronger increases in EV adoption.

Importantly, because year fixed effects absorb common diffusion trends, this coefficient captures deviations from the EU-wide adoption trajectory rather than the general upward trend observed in Figure 1.

The estimated year fixed effects display a clear and strongly increasing pattern over time. This confirms that a large portion of the growth in EV adoption reflects common European dynamics.

These time effects likely capture:

- EU-level regulatory coordination
- Technological progress in battery production
- Declining EV costs
- Post-2019 policy momentum
- Broader structural shifts in consumer preferences

The strong upward trajectory of year effects aligns with the aggregate acceleration documented in Section 3.2.1. Their inclusion ensures that the estimated impact of explanatory variables reflects country-specific deviations rather than global diffusion dynamics.

In contrast to infrastructure, public incentives do not display statistically significant coefficients once fixed effects are included. This indicates that within-country changes in the incentives index over time are not strongly associated with deviations in EV adoption from the EU-wide trend.

Similarly, fuel prices and electricity prices do not appear statistically robust in the two-way fixed effects framework. Given that much of the variation in energy prices reflects common macroeconomic shocks (as illustrated in Figure 8), these dynamics are largely absorbed by year fixed effects.

The absence of strong within-country effects does not imply that these variables are irrelevant in shaping cross-country differences. Rather, it suggests that short-run changes within individual countries may be limited relative to broader structural and common temporal forces.

Taken together, the baseline results indicate that infrastructure expansion is the primary observable correlate of within-country EV adoption over the period 2015–2024.

While the descriptive analysis revealed substantial cross-country heterogeneity, the fixed-effects specification isolates changes within countries over time. Within this framework, infrastructure stands out as the most consistent factor associated with rising EV market shares.

These findings should be interpreted as conditional associations rather than definitive causal effects, given the potential identification challenges discussed in Section 4.2.

4.4 Heterogeneous Effects Across Powertrains

4.4.1 Comparative Specification

To examine whether the determinants of electric vehicle adoption differ across technological segments, the baseline specification is re-estimated separately using BEV and PHEV market shares as dependent variables.

Table 4 reports the comparative results across BEV and PHEV specifications.

Table 4 – BEV regression

BEVsharesales	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
Incentives	.001	.002	0.42	.676	-.003	.005	
GDPpercapitaPPS	0	.001	-0.17	.865	-.002	.002	
OilBulletin	-.033	.094	-0.35	.728	-.227	.161	
Energyprice	.008	.124	0.06	.952	-.248	.263	
EVchargpointx100k	0	0	3.91	.001	0	.001	***
2015b	0	.	.	.	.	.	
2016	-.006	.008	-0.78	.442	-.021	.01	
2017	-.003	.002	-1.45	.158	-.008	.001	
2018	.001	.008	0.16	.876	-.015	.017	
2019	.006	.009	0.65	.524	-.012	.023	
2020	.016	.011	1.41	.171	-.007	.038	
2021	.04	.018	2.29	.031	.004	.076	**
2022	.07	.047	1.47	.153	-.028	.167	
2023	.086	.037	2.30	.03	.009	.163	**
2024	.074	.045	1.64	.113	-.019	.166	
Constant	.057	.168	0.34	.738	-.288	.402	

Mean dependent var	0.054	SD dependent var	0.084
R-squared	0.762	Number of obs	270
F-test	22.288	Prob > F	0.000
Akaike crit. (AIC)	-1014.943	Bayesian crit. (BIC)	-964.565

**** p<.01, ** p<.05, * p<.1*

Table 5 – PHEV regression

PHEVsharesales	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
Incentives	0	.001	0.25	.806	-.002	.003	
GDPpercapitaPPS	0	0	-0.61	.55	-.001	.001	
OilBulletin	.045	.038	1.16	.255	-.034	.123	
Energyprice	.074	.086	0.86	.398	-.102	.249	
EVchargpointx100k	0	0	2.14	.042	0	0	**
2015b	0	.	.	.	.	.	
2016	.007	.004	1.82	.08	-.001	.016	*
2017	.004	.001	3.45	.002	.002	.007	***

2018	.001	.003	0.42	.676	-.005	.008	
2019	.003	.003	1.13	.268	-.003	.009	
2020	.036	.01	3.66	.001	.016	.057	***
2021	.052	.015	3.56	.001	.022	.082	***
2022	.03	.02	1.46	.157	-.012	.072	
2023	.032	.017	1.91	.067	-.002	.067	*
2024	.026	.018	1.43	.164	-.011	.064	
Constant	-.038	.073	-0.51	.611	-.188	.112	

Mean dependent var	0.036	SD dependent var	0.051
R-squared	0.604	Number of obs	270
F-test	16.668	Prob > F	0.000
Akaike crit. (AIC)	-1193.947	Bayesian crit. (BIC)	-1143.569

**** p<.01, ** p<.05, * p<.1*

The comparative specification allows us to assess whether the determinants of electrification differ across technological segments, distinguishing between fully electric and hybrid adoption patterns.

All specifications include country and year fixed effects, with standard errors clustered at the country level.

The most striking result emerging from the comparative analysis concerns charging infrastructure.

The coefficient on charging points per 100,000 inhabitants remains positive and statistically significant across all three specifications. However, the magnitude differs substantially between BEVs and PHEVs.

For BEVs, the estimated coefficient is large and statistically significant at the 1% level. An increase of 10 charging points per 100,000 inhabitants is associated with an increase of approximately 0.43 percentage points in BEV market share.

For PHEVs, the effect remains positive but is considerably smaller in magnitude and only marginally significant. The same increase in charging infrastructure is associated with an increase of approximately 0.11 percentage points in PHEV market share.

These results suggest that charging availability plays a more pronounced role in supporting full electrification compared to hybrid adoption. The differential magnitude across powertrains is consistent with technological characteristics.

Battery electric vehicles rely entirely on charging infrastructure for operation. Consequently, improvements in charging availability may directly reduce range anxiety and enhance consumer confidence.

In contrast, plug-in hybrid vehicles retain an internal combustion engine as a backup option. As a result, infrastructure constraints may represent a less binding factor for adoption decisions.

The results therefore indicate that infrastructure expansion appears more strongly associated with transitions toward fully electric vehicles than toward hybrid alternatives. Incentives, fuel prices, electricity prices, and GDP per capita remain statistically insignificant across technology-specific specifications once fixed effects are included.

This suggests that, within countries and relative to the EU-wide diffusion trend, short-term changes in these variables do not display strong associations with deviations in adoption rates.

The lack of significance does not necessarily imply that these factors are irrelevant in shaping long-run differences across countries. Rather, it indicates that within-country variation over the sample period may be limited or absorbed by common time effects.

Taken together, the comparative results highlight that infrastructure deployment is closely aligned with the expansion of the fully electric segment.

While both BEVs and PHEVs contribute to the electrification of the vehicle fleet, the stronger infrastructure elasticity observed for BEVs suggests that charging network expansion may be particularly relevant for accelerating the transition toward zero-emission mobility.

This distinction is relevant from a policy perspective, as it indicates that infrastructure investments may disproportionately support full electrification rather than hybrid diffusion.

4.5 Robustness Checks

4.5.1 Logarithmic Specification of Charging Infrastructure

As a first robustness check, the charging infrastructure variable is transformed using a logarithmic specification. This transformation allows us to account for potential non-linearities in the relationship between charging availability and EV adoption.

Table 6 reports the results when the logarithm of charging points per 100,000 inhabitants is used instead of the level specification.

Table 6 – Robustness Check: Logarithmic Specification of Charging Infrastructure

EVsalesshare	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
Incentives	.002	.004	0.55	.585	-.006	.011	
GDPpercapitaPPS	-.003	.001	-1.99	.057	-.006	0	*
OilBullettin	.02	.123	0.16	.874	-.233	.273	
Energyprice	.413	.195	2.12	.044	.012	.813	**
EVchargpointLOG	-.035	.014	-2.52	.018	-.063	-.006	**
2015b	0	.	.	.	.	.	
2016	.019	.015	1.30	.205	-.011	.05	
2017	.03	.01	3.15	.004	.01	.05	***
2018	.044	.014	3.23	.003	.016	.072	***
2019	.067	.018	3.75	.001	.03	.104	***
2020	.141	.035	4.00	0	.068	.213	***
2021	.201	.041	4.89	0	.116	.285	***
2022	.212	.063	3.38	.002	.083	.341	***
2023	.261	.06	4.35	0	.138	.384	***
2024	.289	.066	4.37	0	.153	.425	***
Constant	.278	.237	1.17	.251	-.209	.765	

Mean dependent var	0.089	SD dependent var	0.126
R-squared	0.682	Number of obs	270

F-test	15.541	Prob > F	0.000
Akaike crit. (AIC)	-736.405	Bayesian crit. (BIC)	-686.027

*** *p<.01,* ** *p<.05,* * *p<.1*

The coefficient on the logarithmic infrastructure variable remains statistically significant, indicating that the association between charging availability and EV adoption persists under this alternative specification. However, the sign and magnitude of the coefficient differ from the baseline model, suggesting that the relationship may not be strictly linear.

One possible interpretation is that the marginal impact of additional charging infrastructure decreases at higher levels of network deployment. In the early stages of the transition, increases in charging availability may strongly reduce range anxiety and facilitate EV adoption. Once a sufficiently dense network is established, however, further expansion may have smaller incremental effects.

Overall, the results confirm that infrastructure availability remains an important correlate of EV adoption, while highlighting the possibility of diminishing marginal effects at higher infrastructure levels.

4.5.2 Lagged Infrastructure Specification

To further address potential simultaneity between EV adoption and infrastructure expansion, a lagged specification of the charging infrastructure variable is estimated. In this model, EV adoption in year t is explained using charging infrastructure measured in year $t-1$.

Table 7 reports the results of this specification.

Table 7 – Robustness Check: Lagged Charging Infrastructure (t-1)

EVsalesshare	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
Incentives	.002	.003	0.58	.565	-.004	.008	
GDPpercapitaPPS	-.001	.002	-0.41	.682	-.004	.003	
OilBullettin	.031	.111	0.28	.781	-.197	.259	
Energyprice	.036	.196	0.19	.854	-.367	.439	
LagEVcharg	.001	0	3.16	.004	0	.001	***

2016b	0	.	.	.	.	.	
2017	-.005	.01	-0.50	.623	-.025	.015	
2018	-.004	.019	-0.21	.837	-.042	.034	
2019	.005	.017	0.27	.786	-.031	.04	
2020	.052	.014	3.62	.001	.023	.082	***
2021	.088	.031	2.84	.009	.024	.151	***
2022	.096	.064	1.49	.147	-.036	.228	
2023	.12	.055	2.18	.039	.007	.233	**
2024	.102	.061	1.69	.104	-.022	.227	
Constant	.022	.212	0.10	.918	-.414	.458	

Mean dependent var	0.098	SD dependent var	0.130
R-squared	0.750	Number of obs	243
F-test	12.907	Prob > F	0.000
Akaike crit. (AIC)	-723.605	Bayesian crit. (BIC)	-678.195

*** *p<.01*, ** *p<.05*, * *p<.1*

The coefficient on lagged charging infrastructure remains positive and statistically significant. The estimated coefficient suggests that higher levels of charging availability in the previous year are associated with higher EV market shares in the current year.

Importantly, the magnitude of the coefficient remains broadly consistent with the baseline specification. This stability indicates that the association between infrastructure expansion and EV adoption is not solely driven by contemporaneous correlation.

Using lagged infrastructure helps mitigate concerns related to reverse causality, whereby charging infrastructure might be expanded in response to increasing EV adoption rather than acting as a driver of it. The persistence of the positive relationship in the lagged specification therefore strengthens the interpretation that infrastructure availability is closely linked to EV diffusion dynamics.

Overall, this robustness check confirms that the main empirical findings remain stable when accounting for potential timing effects between infrastructure deployment and adoption decisions.

4.5.3 Post-2020 Subsample Analysis

As a final robustness check, the baseline specification is re-estimated using only observations from the period 2020–2024. This subsample corresponds to the phase in which electric vehicle adoption accelerated substantially across European countries.

Table 8 reports the results for this restricted sample.

Table 8 – Robustness Check: Fixed-Effects Estimation (2020–2024 Subsample)

EVsalesshare	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
Incentives	.003	.002	1.99	.058	0	.007	*
GDPpercapitaPPS	-.001	.001	-0.57	.576	-.003	.002	
OilBulletin	-.018	.046	-0.38	.706	-.113	.078	
Energyprice	.035	.116	0.30	.764	-.204	.275	
EVchargpointx100k	0	0	4.97	0	0	.001	***
2020b	0	.	.	.	.	.	
2021	.048	.011	4.40	0	.025	.07	***
2022	.071	.023	3.03	.005	.023	.118	***
2023	.095	.021	4.44	0	.051	.138	***
2024	.083	.029	2.83	.009	.023	.143	***
Constant	.138	.125	1.11	.279	-.119	.395	

Mean dependent var	0.163	SD dependent var	0.144
R-squared	0.734	Number of obs	135
F-test	22.558	Prob > F	0.000
Akaike crit. (AIC)	-506.968	Bayesian crit. (BIC)	-480.820

*** *p<.01*, ** *p<.05*, * *p<.1*

The coefficient on charging infrastructure remains positive and highly statistically significant. The estimated magnitude indicates that increases in charging availability continue to be strongly associated with EV adoption even during the most recent phase of the transition.

The persistence of this relationship suggests that the role of charging infrastructure is not limited to the early stages of EV diffusion but continues to be relevant as the market expands.

Interestingly, the coefficient on public incentives becomes marginally significant in the post-2020 period. This pattern may reflect the increasing role of policy support during the rapid expansion phase of the EV market, when governments across Europe intensified subsidy schemes and regulatory incentives.

Overall, the results confirm that the main findings of the empirical analysis remain robust when the sample is restricted to the most recent years of the transition.

4.5.4 Market-weighted specification

As an additional robustness check, the baseline specification is re-estimated using analytical weights based on total EV sales in each country-year. This approach assigns greater importance to larger EV markets and ensures that the results are not disproportionately driven by smaller countries.

The results, depicted in Table 9, remain broadly consistent with the baseline specification. Charging infrastructure remains strongly and statistically significant. The estimated coefficient indicates that increases in charging availability are positively associated with EV adoption even when larger markets receive greater weight in the estimation. In this specification, the coefficient for electricity prices also becomes statistically significant. This suggests that in this scenario, variations in electricity costs may play a more visible role in shaping EV adoption dynamics.

These findings confirm that the relationship between infrastructure expansion and EV diffusion is not driven by the equal weighting of countries in the main specification.

Table 9 – Robustness Check: Market-Weighted Specification

EVsalesshare	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
Incentives	.003	.002	1.28	.211	-.002	.007	
GDPpercapitaPPS	-.001	.002	-0.53	.602	-.005	.003	
OilBullettin	.065	.135	0.48	.634	-.212	.342	
Energyprice	-.58	.249	-2.33	.028	-1.092	-.068	**
EVchargpointx100k	0	0	4.86	0	0	.001	***
2015b	0	.	.	.	.	.	

2016	.023	.013	1.88	.072	-.002	.049	*
2017	.001	.009	0.11	.911	-.017	.019	
2018	-.003	.013	-0.24	.81	-.031	.024	
2019	.017	.018	0.97	.342	-.019	.054	
2020	.11	.014	7.83	0	.081	.138	***
2021	.178	.044	4.00	0	.086	.269	***
2022	.22	.097	2.27	.032	.021	.42	**
2023	.238	.09	2.65	.013	.054	.423	**
2024	.183	.086	2.12	.043	.006	.361	**

Mean dependent var	0.089	SD dependent var	0.126
R-squared	0.924	Number of obs	270
F-test	.	Prob > F	.
Akaike crit. (AIC)	-324.551	Bayesian crit. (BIC)	-274.173

*** p<.01, ** p<.05, * p<.1

4.5.5 Alternative Specification Without Year Fixed Effects

As an additional robustness check, the baseline econometric model is re-estimated excluding year fixed effects while retaining country fixed effects. This specification allows the analysis to assess whether some explanatory variables capture common temporal dynamics that are otherwise absorbed by the two-way fixed effects framework.

Table 10 – Robustness Check: Alternative Specification Without Year Fixed Effects

EVsalesshare	Coef.	St.Err.	t-value	p-value	[95% Conf	Interval]	Sig
Incentives	.008	.003	2.40	.024	.001	.015	**
GDPpercapitaPPS	.001	.001	0.60	.555	-.002	.003	
OilBullettin	.121	.039	3.11	.005	.041	.2	***
Energyprice	.182	.163	1.11	.275	-.154	.518	
EVchargpointx100k	.001	0	4.03	0	0	.001	***
Constant	-.249	.106	-2.34	.027	-.467	-.03	**

Mean dependent var	0.089	SD dependent var	0.126
R-squared	0.722	Number of obs	270
F-test	19.511	Prob > F	0.000

Akaike crit. (AIC)	-790.451	Bayesian crit. (BIC)	-772.459

*** $p<.01$, ** $p<.05$, * $p<.1$

The results are reported in Table 10. Overall, the main findings remain broadly consistent with the baseline model. In particular, the availability of charging infrastructure continues to display a positive and highly statistically significant association with EV adoption. The coefficient on charging points per 100,000 inhabitants remains significant at the 1% level, confirming the robustness of infrastructure availability as a key structural determinant of EV uptake across EU countries.

Some differences emerge with respect to other explanatory variables. In this specification, both the policy incentive index and fuel prices become statistically significant. The estimated coefficient for the incentive index suggests that stronger financial support schemes are associated with higher EV market shares, while higher gasoline prices appear to increase the relative attractiveness of electric vehicles compared to internal combustion engine alternatives.

The change in statistical significance compared with the baseline specification can be explained by the role of year fixed effects in the two-way model. Year dummies absorb common time trends affecting all countries simultaneously, such as EU-wide regulatory developments, technological progress, or general market shifts in vehicle electrification. When these common trends are not controlled for, part of their effect may be captured by variables such as incentives or fuel prices, which often evolve alongside broader market dynamics.

Importantly, charging infrastructure remains statistically significant across specifications, suggesting that its relationship with EV adoption is not solely driven by common time trends but also reflects meaningful within-country variation over time.

Taken together, these results reinforce the interpretation that while policy incentives and energy prices may play a role in shaping EV adoption, the availability of charging infrastructure represents the most robust and stable correlate of EV uptake in the European Union over the period considered.

5. Discussion and Policy Implications

5.1 Interpreting the Drivers of EV Adoption in the European Union

The empirical analysis presented in Chapter 4 provides several insights into the drivers of electric vehicle (EV) adoption across European Union member states over the period 2015–2024. Overall, the results suggest that the diffusion of electric mobility in Europe is primarily associated with structural factors related to infrastructure availability, while short-term economic variables such as incentives and energy prices appear to play a more limited role.

The baseline fixed-effects specification indicates that charging infrastructure is the most robust correlate of EV adoption across all estimated models. The coefficient associated with charging points per 100,000 inhabitants is positive and statistically significant in the main specification as well as in multiple robustness checks. This finding suggests that countries experiencing faster expansion of charging infrastructure also tend to exhibit stronger growth in EV market shares. From a system perspective, this relationship highlights the importance of infrastructure availability in reducing barriers to electric mobility adoption.

The descriptive analysis conducted in Section 3.2 already revealed that the expansion of charging networks across the EU accelerated significantly after 2019, in parallel with the rapid growth in EV market shares. The econometric results reinforce this observation by showing that infrastructure availability remains strongly associated with EV adoption even when controlling for country-specific characteristics and common time effects. This suggests that the diffusion of electric mobility cannot be interpreted solely as a demand-side phenomenon driven by consumer incentives, but rather as a broader technological transition involving the co-evolution of vehicles and infrastructure systems.

At the same time, the results indicate that several commonly discussed drivers of EV adoption, such as financial incentives, fuel prices, and electricity prices, do not appear statistically significant in the baseline fixed-effects specification. One possible explanation is that these variables exhibit limited variation within countries over time relative to broader structural trends affecting the entire European market. In particular, the strong time fixed effects observed in the regressions suggest that a substantial portion of EV adoption growth reflects common European dynamics, including technological progress in battery technology, EU-level regulatory initiatives, and increasing societal awareness of decarbonization objectives.

Some alternative specifications presented in the robustness analysis suggest that certain variables, such as incentives or energy prices, may become statistically significant under different modeling assumptions. However, their effects appear less stable across specifications compared to charging infrastructure.

Taken together, these findings point toward an interpretation of EV adoption as part of a broader socio-technical transition rather than the result of isolated policy instruments. The expansion of charging infrastructure, technological improvements in electric vehicles, and coordinated regulatory frameworks appear to jointly shape the pace of electrification across European mobility systems.

From a managerial and policy perspective, this interpretation underscores the importance of considering electric mobility as an integrated system in which vehicles, infrastructure, and policy frameworks evolve together. Policies targeting only one component of this system may therefore have limited impact unless they are accompanied by complementary investments in infrastructure and broader regulatory coordination.

5.2 Charging Infrastructure as a System-Level Enabler

In all baseline and robustness specifications, the availability of public charging points remains positively and statistically associated with EV market share, suggesting that infrastructure expansion constitutes a critical enabling factor for the electrification of road transport.

From a socio-technical perspective, the relationship between electric vehicle adoption and charging infrastructure can be interpreted as a form of co-evolution between technology and supporting systems. Electric vehicles require a sufficiently dense and reliable charging network to become a viable alternative to internal combustion engine vehicles. In the absence of adequate infrastructure, potential consumers may face uncertainty regarding vehicle usability, particularly in terms of driving range and charging accessibility.

This phenomenon is often described in the literature as the “range anxiety” problem, which represents one of the main barriers to EV adoption during the early phases of the transition. The expansion of charging infrastructure directly addresses this barrier by reducing uncertainty and increasing consumer confidence in the practicality of electric mobility.

At the same time, infrastructure deployment and vehicle adoption tend to reinforce each other through network effects. As the number of EV users increases, the economic incentives for expanding charging infrastructure also grow, both for public authorities and private operators. Conversely, the availability of a more extensive charging network lowers the perceived risk associated with purchasing an electric vehicle. This creates a feedback mechanism in which infrastructure and vehicle adoption evolve simultaneously.

The empirical results obtained in this study are consistent with this system-level interpretation. Countries that experienced faster growth in charging infrastructure during the sample period also tended to display stronger increases in EV adoption. Importantly, this relationship remains robust across different model specifications, including lagged infrastructure variables and weighted regressions that account for differences in market size.

From a managerial and policy perspective, these findings highlight the importance of infrastructure investments as a strategic lever for accelerating the transition toward electric mobility. While consumer incentives and vehicle subsidies may stimulate short-term demand, the long-term scalability of electric mobility appears closely linked to the availability of a reliable and accessible charging network.

In the European context, this insight aligns with recent policy initiatives aimed at expanding charging infrastructure across the continent. In particular, the Alternative Fuels Infrastructure Regulation (AFIR) sets ambitious targets for the deployment of publicly accessible charging stations along major transport corridors and urban areas. The results of this study suggest that such infrastructure-focused policies may play a crucial role in sustaining the long-term diffusion of electric mobility within the European Union.

5.3 Market Dynamics and the Role of Economic Incentives

While charging infrastructure emerges as the most robust correlate of EV adoption in the empirical analysis, the results also indicate that several commonly cited economic drivers—such as financial incentives, fuel prices, and electricity prices—do not display statistically significant effects in the baseline fixed-effects specification. At first glance, this finding may appear counterintuitive, given the prominent role that consumer subsidies and fiscal incentives have played in many European national electrification strategies.

However, the absence of statistically significant coefficients for these variables should not be interpreted as evidence that economic incentives are irrelevant for EV adoption. Rather, it reflects the nature of the econometric identification strategy employed in the analysis. The fixed-effects framework focuses on variation within countries over time, controlling for persistent cross-country differences and common European shocks. As a result, the estimated coefficients capture only the impact of changes in these variables within a given country relative to its own historical trajectory.

In practice, many incentive schemes in Europe have remained relatively stable over extended periods or have evolved gradually rather than through large discrete policy changes. Consequently, the within-country variation in the incentives index over the sample period may be limited, reducing the statistical power of the baseline specification to detect significant effects.

Another important factor relates to the role of common time dynamics across European markets. The strong year fixed effects observed in the regressions suggest that a substantial portion of EV adoption growth reflects structural trends affecting the entire European automotive sector. These trends include rapid technological improvements in battery performance, declining battery costs, expanding model availability, and increasing regulatory pressure on automotive manufacturers to meet fleet emission targets.

In addition, many European policy initiatives aimed at promoting electric mobility have been implemented in a relatively coordinated manner across countries, particularly following the introduction of the European Green Deal and the “Fit for 55” legislative package. As a consequence, part of the policy-driven momentum behind EV adoption may be captured by the year fixed effects rather than by the country-specific incentive variable included in the model.

Robustness checks suggest that some variables, including financial incentives, fuel prices, and electricity prices, may become statistically significant under alternative specifications. However, these effects appear less stable across models than the effect of charging infrastructure, which remains consistently significant throughout the empirical analysis.

From a market dynamics perspective, these results suggest that EV adoption in Europe may be driven less by short-term price signals alone and more by long-term structural transformations in the automotive ecosystem. Declining technology costs, regulatory pressure on manufacturers, and infrastructure expansion appear to play a more decisive role in shaping the overall trajectory of electrification.

This interpretation is consistent with the broader literature on technological transitions, which emphasizes the importance of systemic changes in technology, regulation, and infrastructure rather than isolated policy instruments. In this context, financial incentives may still contribute to accelerating adoption, particularly during early market development phases, but their impact may be more difficult to isolate empirically once broader transition dynamics are taken into account.

5.4 BEV vs PHEV: Different Technological Transition Paths

The comparative analysis between battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs) provides additional insights into the heterogeneous dynamics of the electrification process within the European automotive market. The results presented in Chapter 4 indicate that charging infrastructure has a stronger association with the adoption of BEVs than with the diffusion of PHEVs.

This finding can be interpreted in light of the technological characteristics of the two vehicle types. Battery electric vehicles rely entirely on electricity as their energy source and therefore depend directly on the availability of charging infrastructure for both daily use and long-distance travel. In contrast, plug-in hybrid vehicles combine an electric motor with an internal combustion engine, allowing drivers to rely on conventional fuel when charging infrastructure is unavailable or inconvenient. As a result, infrastructure constraints are likely to represent a more binding factor for BEV adoption than for PHEV diffusion.

From a consumer perspective, the presence of an internal combustion backup engine reduces the perceived risks associated with vehicle range and charging accessibility. This makes PHEVs a more flexible transitional technology, particularly in markets where charging infrastructure is still developing. In such contexts, consumers may perceive PHEVs as a compromise solution that allows partial electrification without fully relying on the emerging charging ecosystem.

The stronger relationship between infrastructure availability and BEV adoption observed in the empirical analysis therefore suggests that charging network expansion plays a particularly important role in enabling the transition toward fully electric mobility. As charging infrastructure becomes more widespread and reliable, the relative attractiveness of fully electric vehicles is likely to increase compared to hybrid alternatives.

This distinction also reflects broader technological and regulatory developments within the European automotive sector. Over the past decade, BEVs have progressively moved from a niche segment to the central focus of electrification strategies adopted by both policymakers and manufacturers. European emissions regulations and long-term decarbonization targets increasingly favor zero-emission technologies, which further reinforces the strategic importance of fully electric vehicles.

From a system transition perspective, PHEVs may therefore represent an intermediate stage in the electrification process rather than a long-term technological endpoint. While hybrid technologies can contribute to short-term emission reductions, the expansion of charging infrastructure appears more closely aligned with the diffusion of fully electric vehicles. The empirical results of this study support this interpretation by highlighting the stronger association between infrastructure availability and BEV market growth.

These findings suggest that policies aimed at expanding charging infrastructure may disproportionately support the adoption of fully electric vehicles and accelerate the transition toward zero-emission mobility in the long term.

5.5 Implications for European Electrification Policy

The results of this study carry several implications for the design of policies aimed at accelerating the electrification of the European transport sector. In particular, the empirical evidence suggests that the expansion of charging infrastructure plays a central role in supporting the diffusion of electric vehicles across European countries.

Over the past decade, the European Union has progressively strengthened its regulatory framework to support the transition toward low-emission mobility. Initiatives such as the European Green Deal and the “Fit for 55” legislative package have established ambitious decarbonization targets for the transport sector, including the progressive reduction of fleet emission limits for new passenger vehicles. Within this broader policy framework, the development of charging infrastructure has emerged as a key enabling component of the electrification strategy.

The findings of this research provide empirical support for infrastructure-oriented policy approaches. The positive and robust relationship between charging availability and EV adoption suggests that investments in charging networks may represent one of the most effective policy levers for accelerating the transition toward electric mobility. By reducing barriers related to vehicle usability and range anxiety, infrastructure expansion can enhance consumer confidence and facilitate the large-scale diffusion of electric vehicles.

In this context, the Alternative Fuels Infrastructure Regulation (AFIR) represents a particularly relevant policy initiative. The regulation establishes binding targets for the deployment of publicly accessible charging stations along major European transport corridors and urban areas. By ensuring a minimum level of charging coverage across the European territory, AFIR aims to address one of the key structural constraints that historically limited the adoption of electric vehicles.

At the same time, the results of the empirical analysis suggest that demand-side incentives alone may not be sufficient to drive long-term electrification if they are not accompanied by complementary investments in infrastructure. While financial subsidies and fiscal incentives may stimulate short-term demand for electric vehicles, the sustainability of the transition depends on the development of a reliable and widely accessible charging ecosystem.

From a broader socio-economic perspective, the electrification of road transport can therefore be interpreted as a systemic transformation involving technological innovation, infrastructure deployment, regulatory frameworks, and market dynamics. Policymakers seeking to accelerate this transition may need to adopt a coordinated approach that simultaneously addresses these different dimensions.

In particular, the empirical findings presented in this study suggest that policies focusing on infrastructure expansion and long-term system development may play a crucial role in sustaining the diffusion of electric mobility across European markets. By supporting the co-evolution of vehicles, infrastructure, and regulatory frameworks, such policies can help ensure that the transition toward electric mobility progresses in a stable and scalable manner.

6. Conclusion

6.1 Summary of Findings

This thesis examined the main drivers of electric vehicle adoption across the European Union over the period 2015–2024. Using a panel dataset covering the EU27 countries and a two-way fixed-effects panel regression framework, the analysis investigated the relationship between EV adoption and several potential explanatory factors, including charging infrastructure availability, public incentives, energy prices, fuel prices and GDP. To overcome the limitations of nominal national subsidy values, this study introduced an original Affordability-Weighted EV Incentive Index to better capture the real economic intensity of national support schemes relative to local purchasing power.

While the initial hypothesis assumed that public policies, economic conditions, and charging infrastructure could all contribute to EV adoption, the empirical findings provide the strongest support only for the role of charging infrastructure.

Countries experiencing faster growth in charging infrastructure tend to display stronger increases in EV market shares, suggesting that infrastructure availability represents a key enabling factor for the electrification of road transport.

In contrast, variables such as financial incentives, fuel prices, electricity prices, and GDP per capita do not appear statistically significant within the baseline specification. This finding suggests that within-country variation in these variables over time may be relatively limited compared to broader structural dynamics affecting the European automotive sector. Strong common time effects indicate that a substantial portion of EV adoption growth reflects Europe-wide technological and regulatory trends. At the same time, some alternative specifications suggest that the effects of incentives and energy prices may become visible under different modeling assumptions, although these effects appear less stable than those associated with charging infrastructure.

The comparative analysis between battery electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs) further reveals heterogeneous adoption dynamics across powertrain technologies. Charging infrastructure appears to be more strongly associated with the diffusion of fully electric vehicles than with hybrid technologies. This result is consistent with the technological characteristics of BEVs, which depend entirely on charging availability for their operation.

Taken together, the findings of this study suggest that the electrification of the European passenger car fleet should be interpreted as a broader socio-technical transition in which vehicles, infrastructure, and policy frameworks evolve simultaneously. Within this system-level transformation, the expansion of charging infrastructure emerges as a particularly important component supporting the large-scale diffusion of electric mobility.

6.2 Limitations of the Study

Despite the insights provided by the empirical analysis, several limitations should be acknowledged. First, the econometric approach adopted in this study identifies statistical associations rather than strict causal relationships. While the fixed-effects framework controls for unobserved country characteristics and common time trends, potential endogeneity issues may remain. For example, the expansion of charging infrastructure may itself be influenced by growing EV adoption, creating potential bidirectional relationships between the two variables.

Second, the analysis relies on country-level data, which may mask important regional heterogeneity within individual countries. Charging infrastructure availability, policy incentives, and consumer adoption patterns often vary significantly across regions and urban areas. Future analyses using more granular regional data could provide additional insights into the spatial dynamics of electric vehicle adoption.

Third, the measurement of certain policy variables, such as financial incentives, may not fully capture the complexity of national policy frameworks. Incentive schemes often include multiple components, including purchase subsidies, tax benefits, and regulatory advantages, which may vary across vehicle types, income groups, and ownership structures. In some countries, for example, incentives may depend on household income thresholds or vehicle price caps, while in others the most generous support schemes target corporate fleets rather than private consumers. As a result, reducing this multidimensional policy environment to a single numerical index inevitably involves a degree of simplification.

Furthermore, while the AI-assisted extraction process proved highly efficient for handling large volumes of policy reports, the automated interpretation of complex and highly heterogeneous fiscal legal texts carries inherent risks of oversimplification. Although mitigated by rigorous manual double-checks, the nuance of certain highly specific national caveats may not be fully captured.

Finally, the relatively short time horizon of the dataset reflects the early stages of the electric mobility transition. As EV adoption continues to accelerate and infrastructure networks expand, the relative importance of different drivers may evolve over time.

6.3 Directions for Future Research

Future research could extend the analysis presented in this thesis in several directions. One promising avenue would involve the use of more detailed regional datasets that capture spatial variation in charging infrastructure and EV adoption. Such an approach could help identify local network effects and urban mobility dynamics that may not be visible in country-level analyses.

Another potential extension concerns the integration of supply-side factors related to the automotive industry. Manufacturer strategies, model availability, the disruptive market entry of highly competitive foreign EV brands (e.g., Chinese manufacturers), and the subsequent impact of international trade tariffs may play an increasingly important role in shaping EV adoption patterns and price parity. Incorporating these elements into the empirical framework could provide a more comprehensive understanding of the electrification process.

Additionally, future studies could explore the interaction between charging infrastructure expansion and other elements of the energy system, including electricity grid capacity, renewable energy integration, and smart charging technologies. As electric mobility becomes increasingly widespread, these interactions will likely become more relevant for both policymakers and industry stakeholders.

Finally, as the electric vehicle market continues to mature, further research could investigate how consumer preferences, technological innovation, and policy frameworks jointly shape the long-term trajectory of the transition toward zero-emission mobility.

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Appendix

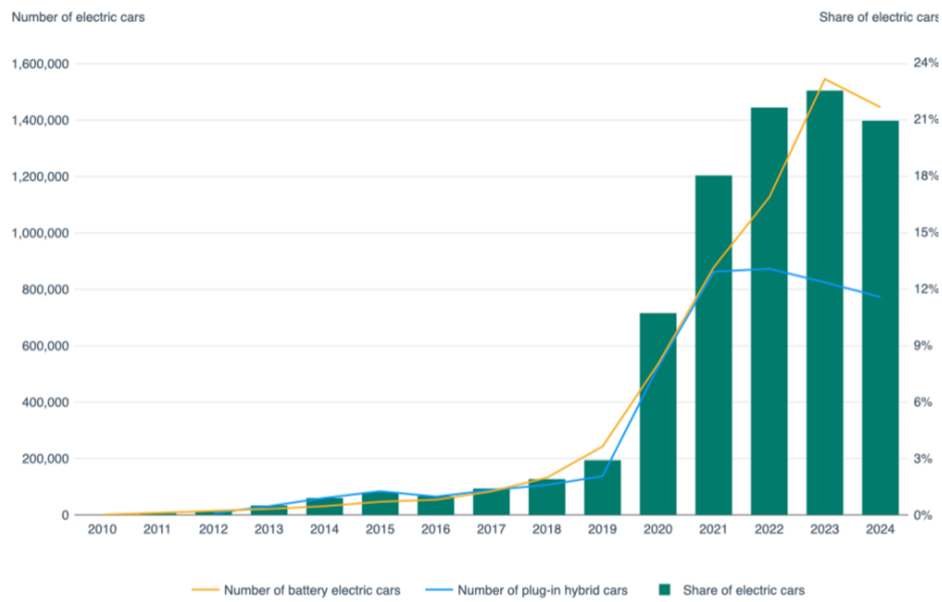

Figure A.1 - Monitoring of CO2 emissions from passenger cars Regulation (EU) 2019/631 (European Environment Agency)

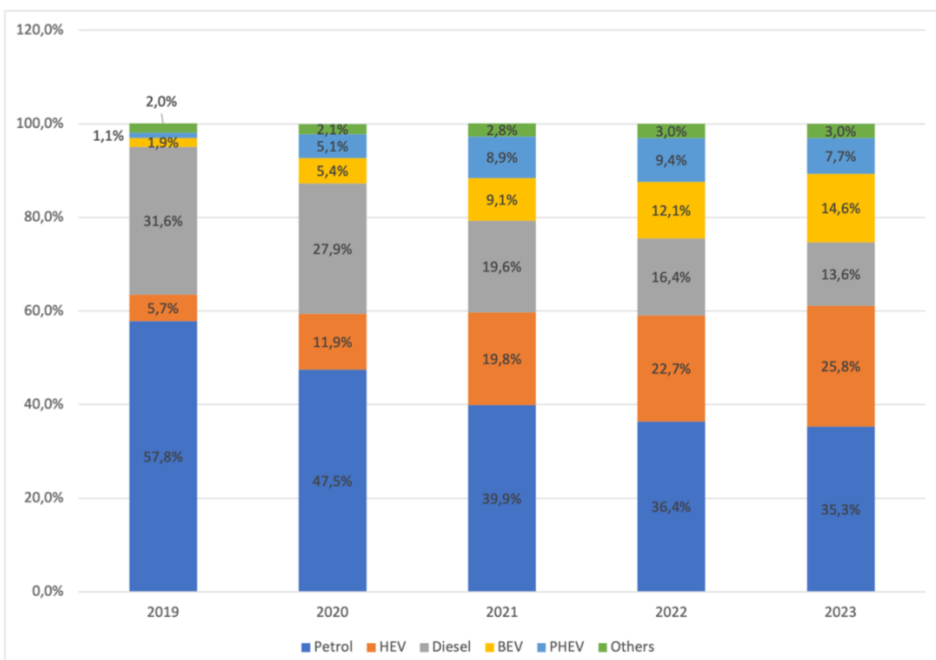

Figure A.2 – New EU cars by power source 2019-2023 (ACEA)