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Cars and Greenhouse Gas Goals: A Big Stone in Europe's Shoes

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Abstract

If new technologies can increase production efficiency and reduce the consumption of natural resources, they can also bring new environmental risks. This dynamic is particularly relevant for the automotive industry, since it is one of the sectors that invests most in R&D, but at the same time also contributes a significant portion of greenhouse gas emissions and consumes a large amount of energy. This article aims to analyze the feasibility of meeting the environmental targets in place within 32 European countries in light of the recent technological trajectory of the automotive industry, namely with regard to the adoption of the propulsion model's alternative to oil and diesel. Using data disaggregated by countries from 2000 up until 2020, in this paper, the estimated regressions aimed to not only verify whether electrical vehicles had a positive impact on CO_2 emissions found in the European market, but to also assess whether they will meet the target set for the next 30 years, with attention to the economy recovery after 2025 and a more robust EV market penetration in replacement of traditional fossil fuels cars.

Keywords: sustainable mobility; decarbonization; electric vehicles; general linear models; cross-section with time series; fixed effects

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1. Introduction

Environmental changes and accelerating technological progress are central aspects of the contemporary global economy. While new technologies can increase production efficiency and reduce the consumption of natural resources, they also bring new environmental risks. This dynamic is particularly relevant for the automotive industry, which is one of the sectors that most heavily invests in research and development (R&D) and also contributes significantly to greenhouse gas (GHG) emissions and final energy consumption.

The European Union's Green Deal, unveiled in 2019, sets out a comprehensive and ambitious roadmap for transforming Europe into the first climate-neutral continent by 2050. It encompasses a wide range of initiatives aimed at reducing greenhouse gas (GHG) emissions, promoting clean energy, enhancing energy efficiency, and fostering sustainable agriculture and industry. A cornerstone of this strategy is the "Fit for 55" package, which establishes legally binding targets to reduce the EU's GHG emissions by at least 55% by 2030 compared to 1990 levels, thereby reinforcing the European Union's commitment to the goals of the Paris Agreement [1]. This package revises and extends several existing climate

and energy frameworks, including the EU Emissions Trading System (EU ETS) (The EU ETS is the world's first and largest carbon market, operating on a "cap-and-trade" principle. It sets an overall limit ("cap") on the total amount of greenhouse gases that can be emitted by sectors within the European Economic Area. Companies receive or purchase emission allowances, which they can trade with one another. The cap is reduced annually, ensuring that total emissions decline over time [1]), the Effort Sharing Regulation (ESR) (The ESR complements the EU ETS by setting binding annual national targets for sectors not covered by the carbon market, including transport. Each Member State is assigned a different target based on its GDP per capita and cost-effectiveness considerations. The regulation aims for an overall EU-wide emissions reduction of 30% below 2005 levels by 2030 in these sectors [1]), the Renewable Energy Directive (RED II) (RED II, on the other hand, sets binding targets for renewable energy consumption across the EU, requiring that at least 32% of final energy consumption comes from renewable sources by 2030. It also establishes sub-targets for sectors like transport (e.g., biofuels, renewable electricity) and promotes cross-border cooperation to achieve cost-effective renewable energy deployment [2]), and the Energy Efficiency Directive (The EED establishes measures to improve energy efficiency across the EU; it mandates national energy saving obligations, energy audits for large enterprises, and promotes efficient renovation of public buildings [3]), to ensure alignment with the updated climate target [1–3]. According to the European Environment Agency (EEA), achieving these targets will require accelerating reductions across all major emitting sectors—energy, transport, buildings, and agriculture—with transport posing one of the most significant challenges [4].

The "Fit for 55" package mandates that emissions from sectors covered by the EU ETS, such as power and heavy industry, must decrease by 61% by 2030, while emissions from non-ETS sectors, including transport, must fall by 40% relative to 2005 levels [1,4]. The EEA reports that although the EU reduced its overall GHG emissions by 30% between 1990 and 2021, transport emissions remain stubbornly high, having increased by approximately 16% over the same period [1,4]. Road transport, which accounts for over 70% of transport emissions, is a particular focus, leading to new policies such as the phase-out of new internal combustion engine vehicles by 2035 and expanded deployment of alternative fuel infrastructure [5,6].

Moreover, the EEA emphasizes that while electrification of passenger vehicles is progressing rapidly—with battery–electric vehicles accounting for 14.6% of new car registrations in the EU in 2022—additional measures are needed to decarbonize freight transport, aviation, and maritime sectors [4]. The Fit for 55 package also introduces the Carbon Border Adjustment Mechanism (CBAM) to prevent carbon leakage and proposes a Social Climate Fund to assist vulnerable households and small businesses in managing the costs of the transition. Together, these initiatives reflect an integrated and ambitious policy architecture aimed not only at achieving the EU's short-term climate goals but also at laying the foundation for deep decarbonization towards climate neutrality by mid-century [4,5].

Achieving these objectives requires systemic change across multiple sectors, with an emphasis on industries responsible for high emission outputs, notably energy and transportation. The latter, indeed, plays a pivotal role in climate mitigation within the European Union, contributing nearly 28% of total GHG emissions—more than any other end-use sector [5,6]. Within this sector, road transport alone is responsible for approximately 72% of emissions, primarily due to the dominance of internal combustion engine vehicles and the continued reliance on fossil fuels. Despite modest improvements in vehicle fuel efficiency standards, overall transport-related emissions have continued to rise slightly, at an average annual rate of about 0.8% [7]. This persistent growth highlights the pressing

need for transformative measures to decarbonize transport systems as part of the EU's climate strategy.

That is the reason why electric vehicle (EV) adoption is widely recognized as one of the primary levers for reducing transport emissions, particularly when coupled with decarbonization of the electricity grid. Supporting strategies include expanding EV charging infrastructure, fostering modal shifts towards public transit and active transportation, and promoting the use of alternative clean fuels such as biofuels. Recent studies indicate that while accelerated EV penetration is critical, it will be insufficient to achieve full decarbonization without simultaneous improvements in the electricity mix, energy storage solutions, and smart grid integration [8,9]. In addition, behavioral and economic factors, such as consumer acceptance, vehicle affordability, and policy incentives like carbon pricing or EV subsidies, play crucial roles in shaping the transition pathway [10].

The European EV market is also increasingly influenced by external factors, particularly the rise of China as a dominant player in EV technology and production. As per the International Energy Agency, Chinese manufacturers, benefiting from significant government support, economies of scale, and technological advancements in battery manufacturing, have driven down EV prices globally, making EVs more accessible but also intensifying competitive pressures on European automakers [11]. Indeed, China continues to dominate battery manufacturing, accounting for over 75% of the world's battery production as of 2024 [11]. Chinese battery producers enjoy significant cost advantages, with battery prices in China falling by nearly 30% in 2024 compared to the previous year (2023), making them more than 30% cheaper than European-produced batteries and over 20% cheaper than batteries produced in North America [11]. This price decline has allowed Chinese electric vehicles (EVs) to achieve cost parity—and in some cases, become cheaper—with their internal combustion engine counterparts [11].

The IEA also emphasizes that China's advantage is not only due to its scale of cell production but also its highly integrated supply chain, especially when it comes to rare minerals. Chinese manufacturers control nearly 90% of global cathode active material capacity and more than 97% of global anode material production [11]. Such vertical integration has made Chinese battery production highly efficient; however, it has also led to significant overcapacity, with cell production utilization rates falling below 40% and even lower in cathode and anode material manufacturing [11]. This surplus creates additional downward pressure on global battery prices, further widening the competitive gap between China with respect to the EU.

On the other side of the Atlantic, the United States has enacted the Inflation Reduction Act (IRA), which includes substantial tax credits and incentives for domestically assembled EVs and battery components [12]. Early evidence indicates these incentives have spurred over USD 50 billion of new investment in North American battery factories and upstream processing facilities [12]. Moreover, American agreements with resource-rich partners—such as recent memoranda of understanding with Ukraine and Australia on lithium and graphite—aim to secure critical mineral supplies, further altering global trade flows and potentially limiting European access to these inputs [12]. Also, in the Imperial Valley and Salton Sea area, California, there is a possible extraction capacity of up to 300,000 mt lithium in the next few years, as per a feasibility study ran [13]. However, under the new administration office which came into power on 8 January, this dynamic might be undermined, given the focus on more fossil fuel technology and also given the decision to leave the Paris Agreement.

While more affordable Chinese-backed EVs may accelerate Europe's transition to zero-emission vehicles (ZEV), they pose economic and industrial challenges that the EU must address. Ensuring long-term competitiveness will require innovation policies to foster

domestic battery technologies, strategic investments in diversified mining and processing capacities—both within Europe and through allied partnerships—and, where appropriate, trade measures to safeguard against unfair market distortions, such as the recent imposition of tariffs stemming from the United States [14]. Moreover, the IEA emphasizes the critical role of recycling and second-life battery applications: in a net-zero pathway, recycled materials could meet up to 30% of future cobalt and copper demand and 15% of lithium and nickel demand, offering a viable buffer against raw-material shortages and price volatility [14].

This has led to concerns within the EU regarding supply chain dependencies, market competitiveness, and strategic autonomy in key green technologies. In response to China's dominance, Europe has launched initiatives aimed at building a resilient and competitive domestic battery industry. These efforts include major investment projects, policy incentives under the European Green Deal Industrial Plan, and the establishment of strategic battery alliances [12,14]. Nevertheless, European battery manufacturers face substantial challenges, including higher production costs, slower economies of scale, and technological competition from established Asian companies. Some European firms are seeking partnerships with Asian manufacturers to acquire technological expertise and improve competitiveness [12,14]. Furthermore, the IEA emphasized that coordinated policy support, strategic partnerships, and substantial investment will be necessary if Europe is to successfully reduce its dependency on Chinese battery imports and develop a secure, efficient, and globally competitive battery value chain [14].

Another study, from McKinsey & Company, says that meeting the 2030 targets is technically feasible and could be accomplished cost-effectively if Europe undertakes large-scale investment in renewable energy technologies, energy storage systems, electric mobility, and carbon capture and storage (CCS) solutions [15]. In the same line of thought from [12,14], the analysis suggests that the transport sector would approach climate neutrality by 2045, provided it implements early adoption of EVs and sets up supply chains to support the switch to 100 percent EV sales, stemming from mining the raw materials for batteries to assembling EVs [15].

However, despite these policy advancements, the pace and scale of decarbonization vary significantly across member states, reflecting differences in technological readiness, infrastructure development, political commitment, and socioeconomic conditions. Some countries, particularly those with well-developed renewable energy sectors and robust infrastructure for electric vehicles (EVs), are progressing more rapidly, while others lag behind due to structural barriers and limited investment capacity, especially Eastern European countries. This uneven progress underscores the need for tailored national strategies within the broader EU framework to ensure that all member states can contribute effectively to the collective climate objectives, avoiding regional disparities in the transition toward a sustainable and resilient Europe [15].

In the next session, we will explore additional challenges that might hamper the evolution of EV production within the EU.

2. Challenges Faced by Electric Vehicles in the EU

According to the IEA newly released report entitled "Global EV Outlook" in 2024, EVs have emerged as the dominant force behind the global demand for critical minerals essential to lithium-ion battery technology. As of 2024, EVs account for approximately 60% of global lithium consumption, 40% of cobalt, 30% of nickel, and a striking 90% of graphite demand. This growing mineral dependency reflects the central role of EVs in the low-carbon transition and their influence on the global commodity landscape. The proliferation of lithium-ion battery technologies—required not only for passenger EVs but

increasingly for buses, trucks, and stationary energy storage—has shifted mineral demand away from traditional industrial uses to mobility applications [14,16].

Looking forward, the convergence of rising EV sales and ambitious climate legislation in the EU, China, and the United States will continue to accelerate mineral intensity. Failure to scale mineral production in parallel with this demand could lead to a bottleneck that slows the global rollout of electric mobility technologies and jeopardizes emissions reduction timelines [17].

The upstream extraction of minerals is similarly concentrated. The Democratic Republic of Congo (DRC) supplies over 70% of the world's cobalt, Australia leads in lithium mining, and Indonesia dominates nickel production [14,16]. Yet the refining of these raw materials is still overwhelmingly dependent on Chinese facilities. Such geographical concentration makes supply chains vulnerable to disruptions from political instability, regulatory changes, or environmental incidents. As global EV ambitions intensify, the need for diversified, transparent, and sustainable mineral supply chains becomes increasingly urgent—not just to mitigate risks, but to ensure equitable and stable access to the foundational materials of the clean energy transition [14,16].

The looming surge in mineral demand is not currently matched by adequate investment in mining and refining capacity. Another core challenge is related to market volatility: for instance, lithium prices collapsed by approximately 75% in 2023, discouraging exploration and delaying new projects [14,16]. These price swings make capital investment riskier and contribute to supply chain uncertainty, even as long-term demand remains strong [14,16,17].

In response to supply concerns, battery recycling and technological innovation offer promising avenues to reduce reliance on virgin materials. Under the IEA's Net Zero Emissions (NZE) Scenario [14], recycled materials could account for 30% of cobalt and copper demand and 20% of lithium and nickel needs by 2040, alleviating pressure on certain minerals [14]. Despite the potential of battery recycling, these solutions remain underdeveloped, with the focus on Asia and limited capacity in Europe and North America, according to [14].

The consequences of mineral supply gaps could be profound. If supply fails to keep pace with demand, battery and EV prices could rise, eroding affordability and slowing adoption—particularly in cost-sensitive markets. This could stall progress toward decarbonization goals and inadvertently extend the lifespan of internal combustion engine (ICE) vehicles, especially in emerging economies, such as in countries from Eastern Europe [14,17–19].

In sum, this article aims to estimate how the new European Green Deal and the advent of new automotive technologies, such as hybrid and electric vehicles, impact GHG emissions in 32 European countries. Additionally, it seeks to predict whether these countries will meet the Nationally Determined Contribution (NDC) goals for 2050, given the ambition for every member to achieve climate neutrality—an economy with net-zero GHG emissions—or if they will fall short. To achieve this objective, we will use a cross-sectional time-series model. We argue that the recent technological trajectory of the automotive industry regarding fleet electrification and its possible impacts on global energy consumption might not align with current environmental goals within the European Union (EU) under the Paris Agreement, especially after COVID-19. The pandemic has underscored the impact of fossil fuel vehicles, particularly in recently admitted EU countries, by increasing CO_2 emissions. The final outcomes of this study will be useful for policymakers in analyzing and formulating sectoral environmental policies and possibly reassessing current climate goals. The transport sector is a major player in new technologies and innovative solutions,

with 28.3% of total European investment in R&D. Significant technological advances in the past decade may affect the sector's overall energy consumption [20].

3. A Systematic Review of the Literature

This systematic review provides an in-depth analysis of the literature, showcasing different strategies to mitigate Europe's transport sector decarbonization efforts. Most of the works are mostly focused on economic and technological impacts, aiming at environmental policy making and future trends.

The systematic review component was developed in accordance with the PRISMA 2020 (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) guidelines. Following the PRISMA methodology, we performed a structured four-stage process involving study identification, screening, eligibility assessment, and final inclusion. This rigorous framework ensures transparency, reproducibility, and minimizes selection bias in synthesizing the existing literature base [21].

As shown in Table 1, the initial database search yielded a total of 14,244 studies that addressed topics related to EV adoption, decarbonization strategies, or GHG emissions trends in the transport sector. Applying our first inclusion criterion—restricting the geographic scope exclusively to the European Union—reduced the dataset to 6775 publications. This focus was necessary to maintain consistency with the policy frameworks (e.g., Fit for 55, European Green Deal) that underpin our study. We then further narrowed down the corpus by selecting only studies employing panel data methodologies, as panel econometric techniques are better suited to capturing both temporal dynamics and cross-country heterogeneity critical for transport emissions analysis. This filtering step resulted in 554 relevant publications.

Table 1. Systematic review.

#	Criteria	# Publications
1	AND (OR (Decarbonization, GHG, CO_2 Emission), AND (Transportation))	14,244
2	AND (OR (Decarbonization, GHG, CO_2 Emission), AND (Transportation)) AND (EUROPE)))	6775
3	AND (OR (Decarbonization, GHG, CO_2 Emission), AND (Transportation)) AND (EUROPE) AND (Panel Data)))	554
4	Restriction Period: 2019 to 2024	407
5	Restriction Publication: Only Articles	382
6	Additional Restriction Geographic Region: Only European Countries	145

Source: Scopus and Web of Science [2024].

For the final inclusion, we applied additional exclusion criteria: limiting the literature to peer-reviewed articles published between 2019 and 2024 and ensuring that the studies pertained directly to empirical or theoretical analyses of EV adoption, decarbonization policies, or transport-related GHG trends within Europe, yielding in 145 studies. This strict temporal and methodological focus ensured that our systematic review reflects the most recent, policy-relevant, and methodologically rigorous contributions to the field. Consequently, the refined corpus of studies provides a robust empirical and theoretical foundation for contextualizing our econometric analysis of transport sector emissions and EV market dynamics in the European Union. We drilled down into six main studies that

give an important overview of GHG reduction in the EU transport sector and that utilized our methodology.

Our bibliometric analysis was conducted using the VOSviewer version 1.6.20 methodology, as proposed by [22]. This approach allows for the visualization of co-occurrence networks, enabling us to systematically map major research trends in the areas of electric vehicle (EV) adoption, transport sector greenhouse gas (GHG) emissions, and policy interventions related to decarbonization. By analyzing keyword co-occurrences, we were able to identify thematic clusters and assess the evolution of scientific attention across different subfields within sustainable transport.

As per Figure 1 below, it becomes evident that the transport sector is relatively isolated from discussions directly addressing carbon dioxide (CO_2) emissions or broader decarbonization efforts. Compared to other sectors, the transport sector appears to be underrepresented in the academic literature surrounding greenhouse gas (GHG) mitigation strategies. This observation highlights a significant gap in the existing research, suggesting that the sector's unique challenges and opportunities for decarbonization have not been sufficiently explored. Consequently, there is both a necessity and an opportunity to undertake a more thorough evaluation of the transport sector's role in GHG emissions. Addressing this gap can meaningfully contribute to advancing the scientific and policy discussions aimed at achieving comprehensive climate goals within the European Union.

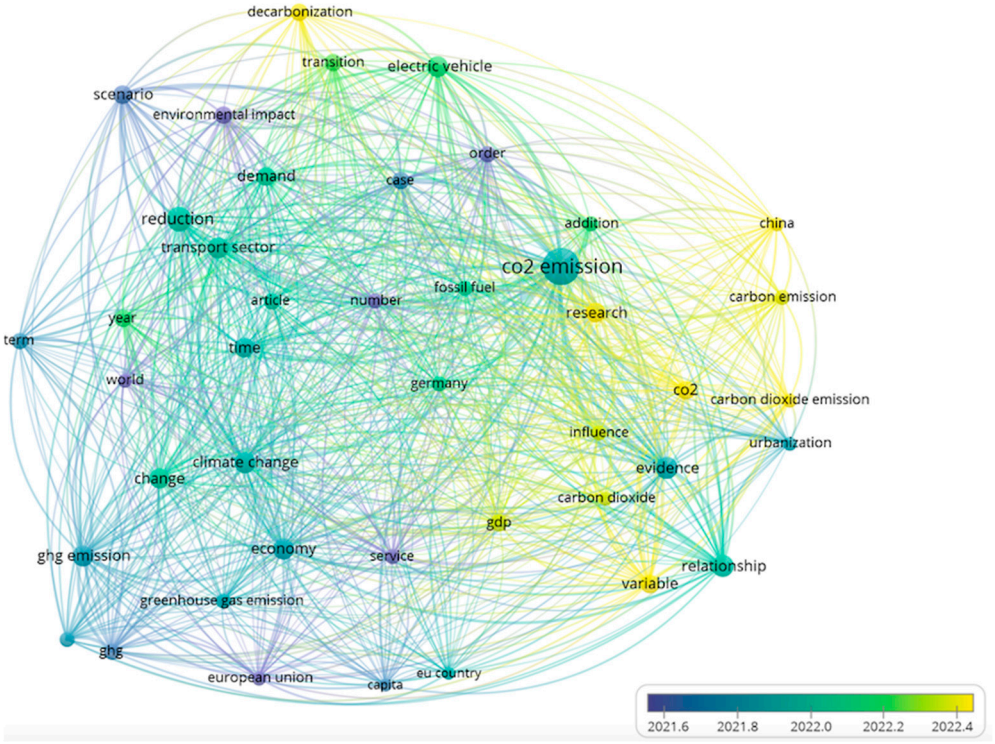


Figure 1. Co-occurrence Vosviewer chart.

It is important to examine six recent studies that underscore the vital contribution of renewable energy and environmental technologies in mitigating CO_2 emissions within the EU transportation sector. These studies provide a comprehensive view of how technological, economic, and policy factors interplay in shaping emission trends.

Beginning with a broader perspective, the study by González et al. [23] analyzed CO_2 emissions from passenger cars in Western Europe, ranging from 1990 to 2015. Their findings indicate that while advancements in technology and improvements in fuel efficiency have helped to curb emissions, this progress has been offset by increases in economic activity

and motorization rates. Utilizing a similar methodology that we use in this article, that is, a dynamic panel data model, the authors investigated how factors such as the dieselization of the vehicle fleet, mobility trends, and economic growth influence CO_2 emissions in the EU-13 countries. Their work highlights the necessity of not only addressing but also understanding the economic growth-related emissions drivers to achieve deeper reductions.

Building on this, the research conducted by [24] focused on 12 European nations between 1994 and 2014 to assess the determinants of transport sector CO_2 emissions. Their analysis explored the impact of environmental policy stringency, investments in transport infrastructure—including roads, railways, and inland waterways—and the role of climate-related technologies. Again, applying a panel data approach, they determined that while strict environmental policies and climate technologies have a clear and positive effect in reducing emissions, infrastructure investments did not demonstrate a statistically significant influence. The findings stress the effectiveness of regulatory measures over physical infrastructure in driving decarbonization.

Similarly, the study conducted by [25] examined whether road transport CO_2 emissions across 22 European countries exhibited any type of convergence between 1990 and 2014. Their results confirmed that emissions levels are indeed converging, primarily influenced by factors such as economic activity and fuel prices. However, this process of convergence has been associated with an undesirable outcome: countries with historically lower emissions are catching up to more polluting counterparts, thereby raising overall emissions levels unless structural reforms are enacted.

In contrast, Ref. [26] analyzed the implications of economic globalization on greenhouse gas emissions in the EU from 2000 to 2019. Their dynamic panel analysis, which segmented countries by GDP per capita, revealed that both trade and financial globalization tend to exacerbate emissions. Specifically, increased trade openness was found to significantly elevate CO_2 levels, particularly in wealthier nations. The study emphasizes the critical role of technology transfer and the widespread deployment of renewable energy to counterbalance the negative environmental impacts associated with globalization.

In another study, Ref. [8] further contributed to this body of work by investigating the effectiveness of electric vehicles (EVs) in reducing emissions. Their study, which covered 29 EU countries from 2010 to 2020, applied panel quantile econometrics to assess the differential impacts of battery–electric vehicles (BEVs) and plug-in hybrid electric vehicles (PHEVs). The results show that BEVs have a substantially stronger effect on lowering CO_2 emissions compared to PHEVs, despite challenges related to the environmental costs of battery manufacturing. This highlights the superior emissions reduction potential of fully electric vehicles in achieving the EU's 2050 carbon neutrality targets.

Lastly, the research carried out by [10] assessed the role of renewable energy adoption in driving emissions reductions between 2007 and 2020. Using panel-corrected standard errors and feasible generalized least squares methods, they identified that the growing share of renewable energy is a key factor in declining transport-related CO_2 emissions. Their analysis, framed through the Environmental Kuznets Curve, suggests that emissions initially decline with early adoption of green technologies but can rise again if economic expansion leads to increased vehicle usage or shifts toward more energy-intensive transport modes. This nuanced relationship underlines the complexity of balancing economic growth with sustainable transport transitions.

Together, these studies underscore the necessity of adopting renewable energy technologies, implementing stringent environmental policies, and addressing economic factors to significantly reduce CO_2 emissions in the EU transportation sector.

4. Materials and Methods

The analysis is underpinned by the economic theory, mainly through the generalized linear model (GLS), since it reflects both country characteristics and cross-section time series. Known also as panel data analysis, it combines cross-sectional and time-series dimensions, and allows us to control for both unobserved heterogeneity across countries and dynamic temporal effects. To appropriately model these complexities, we apply a generalized least squares (GLS) estimator, which corrects for common violations of classical assumptions encountered in macro-panel settings, such as heteroskedasticity and autocorrelation in the error terms [27,28].

$$Y_{it} = \beta^{\top} X_{it} + \mu_i + \varepsilon_{it},\ t \in \{1, 2, \ldots, T\}, i \in \{1, 2, \ldots, N\} \quad (1)$$

where Y_{it} is the dependent variable and X_{it} is the exogenous variable. The (latent) variable μ_i represents the individual contribution of each state, with i being the average value (i.e., the average contribution) specific to each country. Thus, this model represents the sample parameters to be estimated (hence the name fixed effect) and the states are binary variables that will be added (or subtracted) to this sample mean. The error is white noise, that is, $\varepsilon_{it} \sim N(0, \sigma^2)$.

According to [27], ignoring μ_i, using only pooling OLS results in biased and inconsistent estimators because it is likely correlated with X_{it}, a condition known as endogeneity due to omitted (latent) variable bias. To address this, panel econometric models typically use two approaches: fixed-effects (FE) models, which allow μ_i to be arbitrarily correlated with X_{it}, and random-effects (RE) models, which assume that μ_i is uncorrelated with X_{it}.

Given the strong likelihood of correlation between country-specific characteristics (e.g., baseline emissions intensity, historical industrial structure) and transport sector dynamics, we tested a fixed-effects model. The FE estimator removes μ_i, through a "within transformation", subtracting the mean of each variable over time:

$$\left(Y_{it} - \overline{Y_i}\right) = \beta^{\top}\left(X_{it} - \overline{X_i}\right) + \left(\varepsilon_{it} - \overline{\varepsilon_i}\right), t \in \{1, 2, \ldots, T\}, i \in \{1, 2, \ldots, N\} \quad (2)$$

When the error terms are heteroskedastic or autocorrelated, as often occurs in macroeconomic panels, GLS estimation becomes necessary. The GLS estimator adjusts for non-spherical error covariance structures, leading to estimators that are BLUE (Best Linear Unbiased Estimators) under generalized assumptions [28]. Specifically, GLS minimizes the generalized least squares:

$$\min_{\beta} (Y_{it} - X_{it}\beta)' \Omega^{-1} (Y_{it} - X_{it}\beta) \quad (3)$$

where Ω is the variance–covariance matrix of the errors, and if it is unknown, it is estimated via feasible GLS (FGLS) procedures. The properties of the GLS and FE estimators under the assumptions of strict exogeneity, no perfect multicollinearity, and time-invariant unobserved effects are as follows [28]:

1. Consistency: Both FE and GLS produce consistent parameter estimates even in the presence of heteroskedasticity.
2. Efficiency: GLS estimators are asymptotically more efficient than standard FE estimators when heteroskedasticity and autocorrelation are properly modeled.
3. Bias: Bias arises primarily if the strict exogeneity assumption is violated or if time-varying omitted variables correlate with X_{it}.

Given the above theoretical considerations, the panel model applied in this study corrects for country-specific unobserved heterogeneity, heteroskedasticity, and serial corre-

lation, ensuring robust and policy-relevant inferences about the determinants of transport sector GHG emissions across European Union countries, as detailed in the next section.

Empirical Model

This empirical study is carried out using data disaggregated from 1999 up until 2020 on a yearly basis by member countries in the European Union and affiliated countries (Iceland, Norway, Switzerland, and more recently United Kingdom), totaling 32 countries (see Table 2 below). They are interconnected by different means of transport, and therefore, import spillover effects can be seen and then retrieved in our model.

Table 2. The European countries considered in this study.

Country	ID	Country	ID	Country	ID	Country	ID
Austria	AT	France	FR	Luxembourg	LU	Sweden	SE
Belgium	BE	Germany	DE	Netherlands	NL	Iceland	IS
Bulgaria	BG	Greece	EL	Poland	PL	Norway	NO
Croatia	HR	Hungary	HU	Portugal	PT	Switzerland	CH
Czech Republic	CZ	Ireland	IE	Romania	RO	United Kingdom	UK
Denmark	DK	Italy	IT	Slovakia	SK	Liechtenstein	LI
Estonia	EE	Latvia	LV	Slovenia	SI	Malta	MT
Finland	FI	Lithuania	LT	Spain	ES	Cyprus	CY

The problem of missing data was solved by their respective geometric interpolation, and in the case of country-wise unavailability, it was assumed that these variables grow (or shrink) according to the total level of stock of vehicle dynamics, without loss of information. (It is worth highlighting some additional methodological changes: i. The ACEA and Eurostat Dataset refer to the end of the year, except for BE: 1 August (1 July in 2012), CH: 30 September, and LI: 1 July; ii. for some countries, we relied on national statistics (IE, FI, UK, ME, RS) or estimates made by Eurostat; iii. taxis are usually included; iv. HR: from 2009, light vans are included in passenger cars; v. FR: 2013–2019 data were revised, data until 2012 included private cars < 15 years old, and the data are provisional for 2020; vi. the data for Poland were taken from the PZPM (Polish Automotive Industry Association) for vehicle categories > 3.5 t, and for Romania, this refers to sales (APIA)). All data were retrieved from the following agencies: i. the Association des Constructeurs Européens d'Automobiles (ACEA), ii. The National Automobile Manufacturers' Associations, iii. Eurostat, iv. The European Environmental Agency, v. the European Commission Oil Bulletin (non-UK), and vi. BEIS Fuels Survey (UK).

With that in mind, we use the GHG emissions in the transport sector for cars as the dependent variable and vehicle car fleet with different motor technologies, fossil fuel prices (diesel and petrol), and GDP as independent variables. Given the different variables' dimensions, all variables are used as their natural logarithms. In addition, we also considered dummy variables for regulatory interventions within the EU with regards to the New Green Deal, the roadmap for CO_2 emission, and a methodologic approach

from 2012 onwards, since variables were compiled by Eurostat from that date onwards. Therefore, our regression is as follows:

$$\begin{aligned} \text{Ln}(1 + \text{GHG})it = {} & \beta 1^{*}\ln(1 + \text{Passengers.Cars.Petro})\ it + \beta 2^{*}\ln(1 + \\ & \text{Passengers.Cars.Diesel})\ it + \beta 3^{*}\log(1 + \text{Passengers.Cars.Others.Tec})\ it + \\ & \beta 4^{*}\ln(1 + \text{Diesel.Price.with.Taxes})\ it + \beta 5^{*}\ \ln(1 + \text{Petrol.Price.with.Taxes})\ it + \\ & \beta 6^{*}\ln[(1 + \text{Diesel.Price.with.Taxes})^{*}\ (1 + (\ \text{Petrol.Price.with.Taxes})]\ it + \\ & \beta 7^{*}\ln(1 + \text{GDP_AC})\ it + \beta 7^{*}\text{Dr} + \beta 8^{*}\text{Trend} + \varepsilon it \end{aligned} \quad (4)$$

where "*i*" refers to the 32 analyzed countries shown in Table 2, "t" = time period (by year from 1999 to 2020), "*Dr*" = dummy variable for the European Green Deal Goal, "*Trend*" = trend variable, and "ε" is the error term. All variables are stock variables analyzed as their natural logarithms in order to directly calculate the cross elasticities, except for the dummy variables.

There are a few properties worth mentioning with regards to the following model: (1) total rank, which is also called the identification condition, is assumed to have a flexible linear relationship with the dependent and independent variables; (2) the conditional expectation between the dependent variables and the error term is zero (they are orthogonal); (3) the variance–covariance matrix of the errors (given the independent variables) is homoscedastic; (4) the errors are normal and identically distributed, following a Gaussian distribution; (5) we may not want to assume that observations are identically distributed over time. In the next section, we explore more thoroughly the model output as well as the respective statistical tests.

5. Results

In this case, our panel is balanced and has the following dimensions: 32 variables, a time period of 20 years, and 704 lines. Thus, countries have disclosed data from different years and the fleet of vehicles varies among them.

It is worth clarifying that our study aims to verify whether electrical vehicles allied with other types of clean vehicle technologies had an important impact on CO_2 emissions in the transport sector, given the new European Green Deal and their NDC ambitious targets.

It can be seen from Figures 2 and 3 that different countries are in distinct stages in terms of the level of GHG emissions and electric vehicles, with an ascending trend from 2008 onwards for the former, which was a landmark for the Paris Agreement and the European commitment to help decrease the Earth's temperature by 1.5 degrees Celsius. It is important to mention that in March 2020, COVID-19 hit the world and reduced overall GHG emissions, especially from cars, in the transport sector due to the imposed confinements.

It can be seen from Figure 2 below that Western European countries have managed to either stabilize or even marginally decrease their CO_2 emissions in the form of fossil fuel car combustion into the atmosphere, namely Germany (DE), France (FR), the United Kingdom (UK), Spain (ES), and Portugal (PT), among others. However, most of the Baltic Islands, the Balkans, and Eastern European countries are drifting in the opposite direction, which is somewhat worrisome for the current long-term targets for 2030 and 2050.

But these dynamics may converge to more acceptable levels in light of incentives and subsidies favoring electric vehicles and similar technologies (ZEV, PEV, etc.), as well as stricter restrictions on traditional diesel and petrol cars, as shown in Figure 3. It is relevant to highlight that cars are deemed as passenger and light-use vehicles.

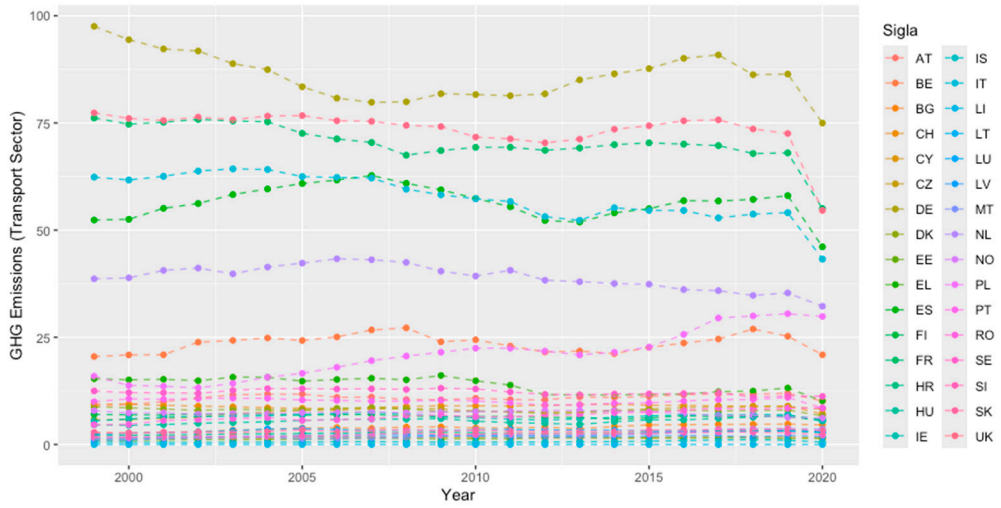


Figure 2. Evolution of GHG emissions in transport sector.

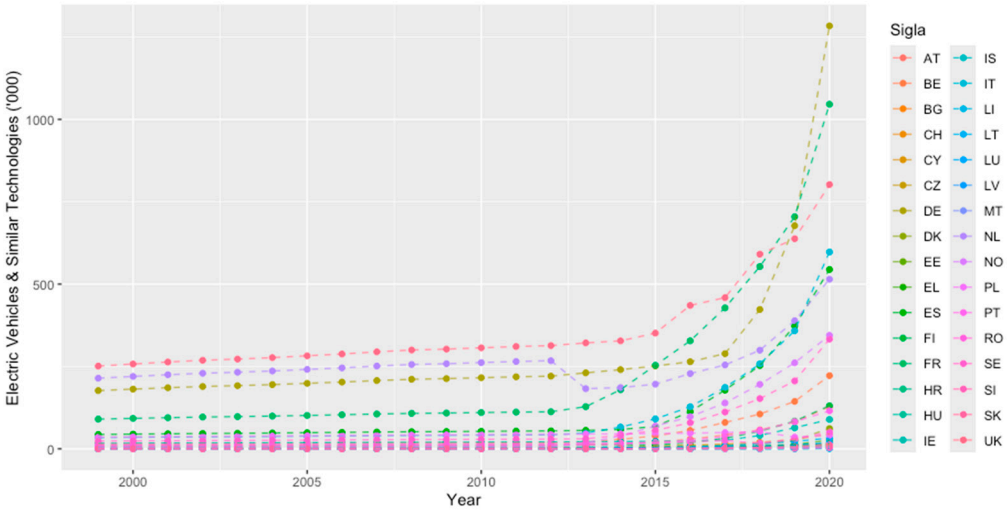


Figure 3. Evolution of electric vehicles and similar technologies.

A primary motivation for using this methodology is to solve the problem of omitted variables coming from μ_i in fixed-effects models, as laid out in Section 3. All variables used in our model are summarized in Table 3 below, which shows their descriptive statistics. We explore in depth these variables in the following paragraph.

Our variables demonstrate thick tails and well-behaved t-Student distributions (which converge asymptotically to a normal distribution). For car fleet vehicles, especially for other motor technologies (which include EV, BEV, ZEV, etc.), it can be pointed out that there is a higher positive skewness and mesokurtic kurtosis, since the data have higher variability in terms of timespan and country. Fuel prices, on the other hand, have a narrower and platykurtic distribution.

As a second step, we applied a Hausman test, which evaluates the consistency of estimators in the context of cross-sectional data regression and specifically determines whether the fixed-effects model (individual-specific effects–country-specific effects; i.e., "i" in Equation (2)) is correlated with the explanatory variables or whether the random-effects model (individual-specific effects are uncorrelated with the explanatory variables) is more appropriate.

Table 3. Descriptive statistics.

Vars	n	Mean	Sd	Median	Skew	Kurtosis	Se
No passengers ('000)	704	465.8	122.1	469.9	−0.1	0.2	4.6
Stock of vehicles ('000)	704	7,692,097.8	11,560,005.5	2,970,599.0	1.9	2.3	435,684.1
New vehicle registrations ('000)	704	462,045.3	799,567.7	131,125.5	2.3	4.2	30,134.8
Passengers cars EV ('000)	704	8697.4	30,498.5	584.9	6.4	50.4	1149.5
Passengers cars petrol ('000)	704	4,341,084.3	6,531,995.3	1,867,233.9	2.3	4.7	246,183.8
Passengers cars diesel ('000)	704	3,063,761.2	4,914,121.9	954,954.1	2.2	3.9	185,207.9
Passengers cars other Tec ('000)	704	55,259.6	122,521.9	9744.3	4.3	26.0	4617.7
Total GHG ('000 tCO_2eq)	704	155.9	222.7	65.1	2.2	4.3	8.4
Total GHG transp car ('000 tCO_2eq)	704	17.4	23.9	7.1	1.7	1.6	0.9
Diesel price wo taxes ('000)	704	0.4	0.1	0.4	0.0	−1.1	0.0
Diesel price with taxes ('000)	704	0.9	0.3	0.9	−0.1	−1.1	0.0
Diesel tax (%)	704	0.5	0.1	0.5	0.2	0.4	0.0
Diesel tax (USD)	704	0.4	0.1	0.5	0.1	−0.7	0.0
Petrol retail prices wo tax	704	0.4	0.1	0.4	0.0	−1.2	0.0
Petrol retail prices with tax	704	0.9	0.3	1.0	−0.1	−1.1	0.0
Petrol tax (%)	704	60.2%	7.7%	60.3%	−0.2	0.1	0.0
Petrol tax ($)	704	0.5	0.2	0.5	−0.1	−0.8	0.0
GDP (%)	704	2.2%	3.7%	2.4%	−0.4	4.8	0.0
GDP_AC (index number year 1999 equals 1)	704	1.31	0.25	1.27	2.17	7.81	0.0

The former model controls for unobserved heterogeneity by allowing each cross-sectional unit (each country) to have its own intercept. This model effectively demeans the data within each cross-sectional unit, removing any time-invariant characteristics. The latter, however, treats the individual-specific effects as random variables drawn from all countries and it includes these random effects in the error term, allowing for both within- and between-variation to be used in the estimation.

In our case, the result rejects the lack of individual effects as the null hypothesis of the Hausman test, given a *p*-value less than 5%, as shown in Table 4 as follows:

Table 4. Fixed-effects statistical test.

Statistic	*p*-Value	Parameter	Method	Alternative
17.58	0.04	7	Hausman test	one model is inconsistent

Source: the authors.

Drawing on the results from Table 5 below, it is not surprising that there is a positive cross-elasticity between petrol and diesel car fleets, 0.28 and 0.23, respectively, since they tend to have a more significant impact on CO_2 emissions into the atmosphere. Electric vehicles and similar technologies had a near-zero cross-elasticity, 0.001. This type of vehicle is expected to hinder increases in GHG emissions, although the effect is minimum and not statistically significant. It is an important variable to account for in the future because EV and hybrid motor technologies reached moderate penetration in the market, hovering around 22%, from 2010 to 2022, according to [10] (https://www.eea.europa.eu/en/analysis/indicators/new-registrations-of-electric-vehicles, accessed on 16 May 2025). Given that new EV registrations will outnumber traditional fossil fuel vehicles, as per the

scope of the European New Green Deal, it suffices to say that GHG emissions will tend to approximate to zero.

Table 5. Fixed-effects model.

Term	Estimate	Std. Error	Statistic	*p*. Value	Significance
log(1 + Passengers.Cars.Petro)	0.28	0.05	5.53	0.00	***
log(1 + Passengers.Cars.Diesel)	0.23	0.04	5.30	0.00	***
log(1 + Passengers.Cars.Others.Tec)	0.00	0.01	−0.01	0.99	
log(1 + Diesel.Price.with.Taxes)	−0.02	0.14	−0.14	0.89	
log(1 + Petrol.Retail.prices.with.Tax)	−0.05	0.16	−0.30	0.77	
log(1 + GDP_AC)	0.84	0.08	10.57	$<2 \times 10^{-16}$	***
Trend	−0.01	0.00	−4.85	0.00	***
Dr	0.02	0.02	1.04	0.30	***
Signif. codes: 0 '***' 0.001 '**' 0.01 '*' 0.05 '.' 0.1 ' ' 1					

Source: the authors.

This effect requires a drilldown in other sectors that might influence this specific fleet dynamic. When it comes to diesel and petrol prices with taxes, there is no substantial impact on emissions, since the former presents a very inelastic and not statistically significant estimate, −0.02% and −0.05%, which means that for every one percent of price increase, there will be a decrease in GHG emissions of 0.02% and 0.05%, respectively. Thus, price dynamics for traditional vehicles running on fossil fuels do not influence the reduction in greenhouse gases.

Interestingly, the Real Gross Domestic Product has the highest impact among all variables, despite being inelastic, because it measures the total level of economic activity, that is, 0.84. That being said, income elasticity will be paramount to achieving a successful zero-emissions transition economy. The 2008 dummy variable was input in this equation as the initial commitment from Europe to reduce GHG emissions. Our assumption of this coefficient is related to the different stages at which each country decided to co-sign the Paris Agreement and also the new European members that came on the scene over the last few decades.

Indeed, the fitted values in Figure 4 below show consistent movement in all analyzed countries, and the result corroborates our assumption that new members, especially from Eastern Europe such as Slovakia (SK), Check Republic (CZ), and Hungary (HU), the Mediterranean, namely Italy (IT) and Greece (EL), the Baltics, including Latvia (LT), and the Balkans, namely Croatia (HK) and Montenegro (MT), are augmenting their GHG emissions contributions, given the different investment stages of implementing net-zero economy principles, as laid out in Sections 1 and 2.

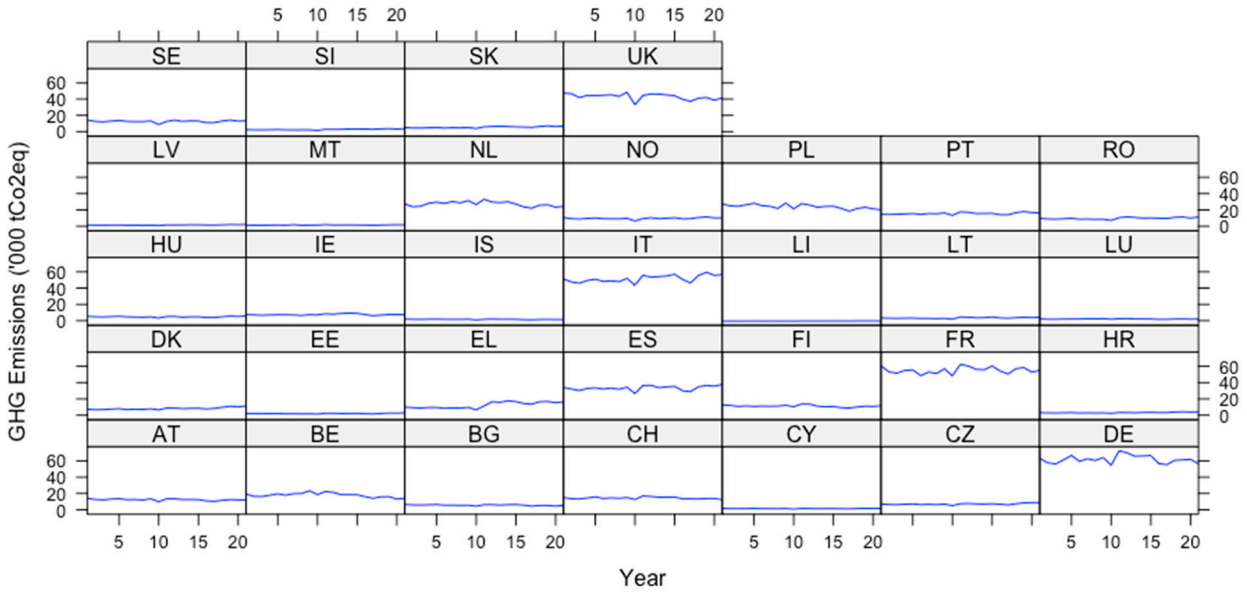


Figure 4. Fitted values from fixed-effects model.

6. Discussion

As said previously, the European Union (EU) has set ambitious climate goals through its New Green Deal, with the "Fit for 55" legislative package mandating a 55% reduction in GHG emissions by 2030 compared to 1990 levels and net-zero emissions by 2050. Within this framework, the transport sector—responsible for nearly 28% of EU GHG emissions—is a critical focus due to its substantial environmental footprint and persistent emissions growth [1].

In practice, this means that all new cars registered from 2035 should be zero-emission, revealing the growing importance of vehicles with electric motors and the development of hydrogen. The current targets for cars and vans are as follows: −15% for both by 2025; −37.5% for cars and −31% for vans by 2030. In the new proposed targets, the 2025 15% goal remains, whereas by 2030, the new targets are −55% for cars and −50% for vans, and by 2035, a total reduction of −100% is expected for both [1,2].

Our empirical findings from Table 5 align with this policy context and suggest that vehicle fleet composition significantly influences emissions. Specifically, both petrol and diesel fleets exhibit a positive and statistically significant elasticity of 0.28 and 0.23, respectively, confirming that internal combustion engine (ICE) vehicles remain strong contributors to CO_2 emissions. In contrast, electric vehicles and hybrid technologies display a near-zero cross-elasticity of 0.001, with no statistically significant effect. While this result may initially appear underwhelming, it reflects the relatively modest market penetration of electric vehicles during the 2010–2022 period—hovering around 22%—as cited by the European Environment Agency [5]. Nevertheless, the trajectory of electric vehicle adoption is deemed to shift dramatically. With new EV registrations expected to outpace fossil fuel vehicles in the coming decade under the New Green Deal, GHG emissions from this source are likely to decline substantially, even if the full effect has yet to manifest statistically.

Supporting this interpretation, we circle back into our recent empirical systematic review, which reinforces the long-term benefits of technological transition, where [23] found that technological progress and fuel efficiency reduced CO_2 emissions from passenger cars in Western Europe, while motorization and economic growth had the opposite effect. Similarly, [8] showed that battery–electric and plug-in hybrid vehicles are effective in mitigating CO_2 emissions, with BEVs having the most significant impact. These findings

align with our current results, underscoring the importance of accelerating EV deployment while acknowledging that their full decarbonization potential is still maturing.

Beyond fleet composition, the analysis also highlights the limited role of fuel prices in curbing emissions. Diesel and petrol prices (inclusive of taxes) exhibited minimal and statistically insignificant elasticities of −0.02 and −0.05, respectively. These results suggest that price mechanisms alone are insufficient to drive meaningful changes in consumer behavior or emissions outcomes—likely due to the inelastic nature of fuel demand and the entrenched reliance on fossil fuel vehicles. This replicates conclusions by [24], who found that infrastructure investments and economic levers alone were inadequate for reducing emissions, whereas environmental policy was more effective.

Perhaps most striking is the elasticity of the Real Gross Domestic Product (RGDP), which, at 0.84, is the most substantial among all variables, despite being technically inelastic. This finding reinforces the strong correlation between economic activity and emissions, in line with the conclusions by [25], who demonstrated that economic growth fueled convergence in transport emissions across EU countries. Our results suggest that income elasticity—defined as the responsiveness of emissions to changes in economic output—will be a pivotal factor in achieving a net-zero transition. As nations grow wealthier, emissions tend to increase unless decoupled through stringent policy, innovation, and behavioral shifts, as highlighted in [24].

To account for structural change, a 2008 dummy variable was included, corresponding to the global financial crisis and the initial commitments toward the Paris Agreement. The coefficient associated with this dummy is interpreted as capturing heterogeneity in policy uptake, particularly among EU countries that joined more recently or adopted climate targets at varying stages. This is supported by findings from [26], who stressed that globalization and delayed policy adoption can exacerbate emissions, especially in economies undergoing integration and liberalization, such as the case of Eastern European countries.

Finally, broader decarbonization trajectories must consider complementary variables such as renewable energy use, technological investment, and sector-wide innovation. Reference [29] pointed out that emissions reductions from 2007 to 2020 were closely tied to renewable adoption and environmental technology diffusion. This aligns with our findings, when it comes to positive EV and other technologies' effects on emission control, since fleet transition, economic dynamics, and structural reforms all interact to determine CO_2 outcomes [29].

This study hopes also to steer the discussion on whether Europe will actually meet these very ambitious non-binding targets and shed some light on possible public policies to mitigate it. In that line of thought and considering the current numbers of fleets, the passenger car fleet in the EU will remain constant in size, as will new car sales, until 2030. The economic lifetime of passenger cars is 15 years, and the utilization of these vehicles will die out smoothly. EVs and other technologies will replace the current fleet via the following bridging scheme seen in Table 6.

Table 6. Out-of-sample model assumption.

Period	Passengers Cars Petro (1)	Passengers Cars Diesel (1)	Passengers Cars Others Technology (2)	Diesel Price with Taxes (3)	Petro Price with Taxes (3)	Real GDP (4)
2021	92%	92%7	0.4%	1.00%	1.00%	4.31%
2025	92%	92%	7.5%	4.06%	4.06%	1.23%
2030	65%	65%	35%	9.37%	9.37%	1.09%

Table 6. *Cont.*

Period	Passengers Cars Petro (1)	Passengers Cars Diesel (1)	Passengers Cars Others Technology (2)	Diesel Price with Taxes (3)	Petro Price with Taxes (3)	Real GDP (4)
2040	35%	35%	70%	20.81%	20.81%	0.94%
2050	0%	0%	100%	33.45%	33.45%	1.02%

Source: Adapted by the authors from [30,31]. Legend: (1) decay velocity, (2) replace velocity, (3) retail price variation accumulated % from 2020, and (4) % yoy.

We analyzed the assumptions from [31] and move forward the targets considered more realistic in that study, given the current state of Europe in this moment and the data available up until now. With that in mind, our model was applied to forecast the out-of-sample results, given by Figure 5 below.

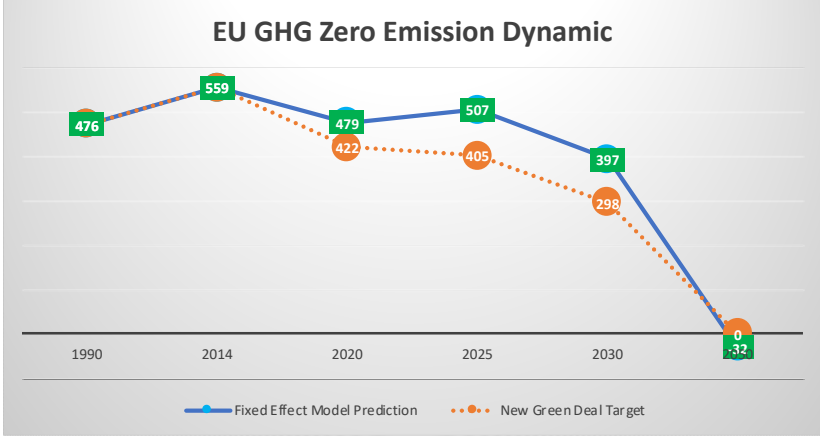


Figure 5. Out-of-sample forecast. Source: the authors [30,32].

Thus, our work indicates that the European Union and aligned members have almost achieved the 2020 climate and energy targets of reducing greenhouse gas emissions by more than 20% compared to 1990 levels and that emissions will increase in 2025 due to economic activity growth right after the end of COVID-19. However, the trajectory by 2030, and from that point onwards, a more aggressive measure will be necessary to zero out the fossil fuel car fleet by the end of 2050.

Indeed, the European Automobile Manufacturers' Association (ACEA) has raised concerns over the declining outlook for battery–electric vehicle (BEV) adoption in the European Union [33,34]. Citing revised forecasts from [35], BEVs are expected to account for only 41% of new car sales in the EU by 2030, a significant decrease from the previously anticipated 51%. This downward revision poses challenges to the EU's goal of achieving a 100% reduction in CO_2 emissions from new cars by 2035 [33–35].

Reference [35] underscores the declines in key markets, such as in Germany, which is projected to have a BEV market share for 2030 plummeting from 51% to 44%, and also in France, with figures ranging from 53% to 48% [35]. Factors contributing to this slowdown include high vehicle prices, insufficient charging infrastructure, reduced consumer incentives, and rising energy costs, particularly in the aftermath of geopolitical events like the war in Ukraine [35]. Additionally, the disparity in EV adoption rates between Western and Eastern EU member states is widening, threatening a cohesive and equitable transition across the region., as seen in Figure 2 [34,35].

The European market is also experiencing increased competition from Chinese EV producers. It has implemented its own set of tariffs on Chinese-made EVs, especially

from BYD, with rates reaching up to 45.3%. These measures aim to level the playing field for European manufacturers and address concerns over unfair subsidies. However, the increased tariffs have also led Chinese companies to adjust their strategies, such as increasing the sale of plug-in hybrid vehicles (PHEVs) in the EU, which are subject to lower tariffs [33–35].

In response to these challenges, the ACEA is advocating urgent and coordinated policy actions, such as increased investment in charging infrastructure, enhanced financial incentives for consumers, and support for local EV supply chains. These measures are deemed essential to revitalize the BEV market and ensure the EU meets its climate and mobility goals, as seen in Figure 6 [33–36].

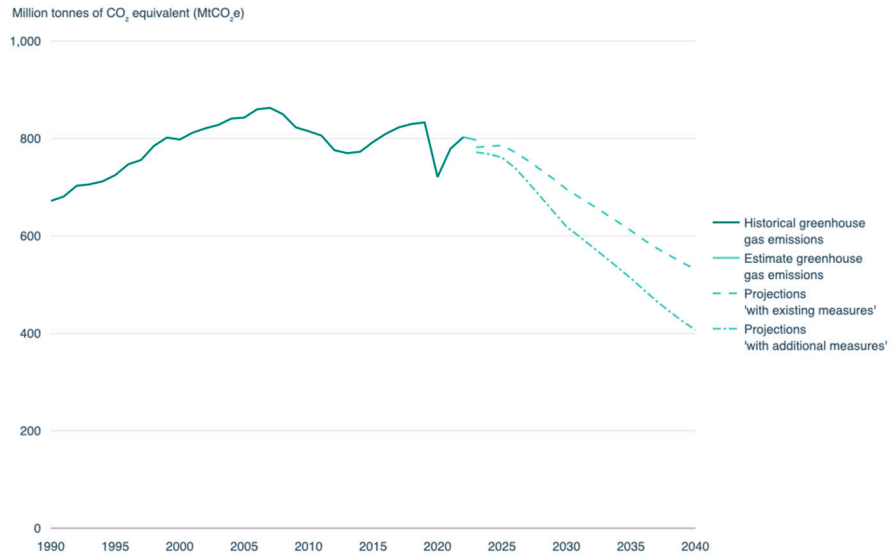


Figure 6. Out-of-sample forecast—European Union. Source: [36].

Those facts may actually catalyze future increments in GHG emissions in the long term. Indeed, new estimates from [13] show a similar path (see Figure 6 below), but start in 2020, while our estimates are after 2025, since COVID-19 is still hampering road activities. This still indicates the robustness of our premises and methodology.

7. Conclusions

The transport sector will play a central role in achieving the climate goals set by the Paris Agreement in the EU. With 28.3% of the total of European investment in R&D, the transport sector is a major player in new technologies and innovative solutions, and in the past decade has seen significant technological advances that might affect the sector's overall energy consumption. This paper aimed to analyze the role that the automotive industry can play in the pursuit of EU climate goals, or even their feasibility, in light of the recent technological trajectory of EVs. It is important to shed some additional light on future public policies and that policy makers follow up on this scenario.

Road transport constitutes the highest proportion of overall transport emissions (in 2019, it emitted 72% of all domestic and international transport GHG emissions). As the majority of existing and planned measures in Member States focus on road transport, this share is expected to decrease as road transport decarbonizes faster than other transport modes. However, in response to supply concerns, battery recycling and technological innovation offer promising avenues to reduce reliance on virgin materials [36]. Under the IEA's Net Zero Emissions (NZE) scenario, recycled materials could account for 30% of cobalt and copper demand and 20% of lithium and nickel needs by 2040. Closed-loop

recycling systems, where end-of-life batteries are processed and materials reused, could play a critical role in moderating demand and stabilizing prices. Innovations in battery chemistry—such as the shift to low- or no-cobalt designs—may also alleviate pressure on certain minerals [14]. These solutions remain underdeveloped. Current recycling rates are low, particularly for lithium and graphite, and many countries lack the policy frameworks or infrastructure needed to scale recovery operations. Most global battery recycling is still focused in Asia, with limited capacity in Europe and North America. Moreover, existing incentives are often insufficient to spur the level of innovation or capital investment required. Without stronger regulatory push, tax incentives, and public–private partnerships, the industry risks missing a vital opportunity to build circularity into the EV value chain [12,14–16,36].

The consequences of mineral supply gaps could be profound. If supply fails to keep pace with demand, battery and EV prices could rise, eroding affordability and slowing adoption—particularly in cost-sensitive markets, such as Eastern European markets [12,14]. This could stall progress toward decarbonization goals and inadvertently extend the lifespan of internal combustion engine (ICE) vehicles.

As the IEA cautions, a sustained "mismatch between demand and supply could undermine the pace of energy transitions" [14]. Without coordinated global action, the electrification of transport may not proceed at the speed necessary to limit warming to 1.5 °C. This means the EU and its partners must accelerate investment in diversified and secure supply chains, enhance collaboration on battery recycling, and embed circular economy principles throughout the EV ecosystem. Closing the mineral gap is not just a matter of industrial policy—it is a precondition for a credible global climate strategy [14,36–39].

To conclude, our results emphasize that while the EU's policy framework is aligned with scientific evidence, implementation must focus on three interdependent levers: (i) accelerating the adoption of zero-emission vehicles, (ii) insulating emissions from economic expansion, and (iii) integrating sectoral and structural reforms beyond pricing tools. This approach is essential to ensure that emissions from the transport sector decline meaningfully and sustainably toward 2050 targets.

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Conflicts of Interest: The authors declare no conflicts of interest.

List of Abbreviations

ACEA	Association des Constructeurs Européens d'Automobiles
AT	Austria
BE	Belgium
BEIS	Department for Business, Energy & Industrial Strategy (UK)
BEV	Battery Electric Vehicle

BG	Bulgaria
CH	Switzerland
CO_2	Carbon Dioxide
CY	Cyprus
CZ	Czech Republic
DE	Germany
DK	Denmark
EAFO	European Alternative Fuels Observatory
EE	Estonia
EEA	European Environmental Agency
EL	Greece
ES	Spain
EU	European Union
EUROSTAT	European Statistical Office
EV	Electric Vehicle
FI	Finland
FR	France
GHG	Greenhouse Gas
GLS	Generalized Linear Model
GDP	Gross Domestic Product
HK	Croatia
HDT	Heavy Duty Truck
HR	Croatia
HU	Hungary
IE	Ireland
IMF	International Monetary Fund
IPCC	Intergovernmental Panel on Climate Change
IS	Iceland
IT	Italy
LD	Light Duty Truck
LI	Liechtenstein
LT	Lithuania
LU	Luxembourg
LV	Latvia
MTR	Mass Transport
MT	Malta
NAMA	National Automobile Manufacturers' Associations
NDC	Nationally Determined Contribution
NL	Netherlands
NO	Norway
PEV	Plug-In Electric Vehicle
PHEV	Plug-In Hybrid Electric Vehicle
PL	Poland
PT	Portugal
R&D	Research and Development
RO	Romania
SE	Sweden
SI	Slovenia
SK	Slovakia
tCO_2eq	Ton of Carbon Dioxide equivalent.
UK	United Kingdom
WB	World Bank
ZEV	Zero-Emissions Vehicle

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