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THE ROLE OF VEHICLE TAXATION IN THE EU TRANSPORT SECTOR'S ENERGY TRANSITION: A SYSTEMATIC LITERATURE REVIEW

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ABSTRACT: This paper synthesises existing knowledge on vehicle taxation and examines its role in supporting the energy transition in the transport sectors of EU member states. To achieve this, a systematic literature review (SLR) was conducted using publications from the Scopus and Web of Science databases, covering 182 peer-reviewed articles published between 2014 and 2025. The review was complemented by a bibliometric analysis using VOSviewer. The study provides both theoretical insights and practical policy recommendations, of which a key contribution is identifying time-sensitive strategies: Fuel taxes remain the most effective tool for reducing emissions in the short term; however, as decarbonisation progresses and fuel tax revenues decline, distance-based taxation becomes increasingly important. In addition, the review emphasises the need for a comprehensive mix of instruments to reduce greenhouse gas emissions, including taxation, subsidies, regulatory measures and support for technological innovation. Promoting public awareness of the negative consequences of environmental degradation is also essential for the successful implementation of sustainable transport policies.

KEYWORDS: environmental tax, vehicle tax, fuel tax, excise, systematic literature review

Introduction

Climate change is one of the most pressing issues of our time. In its Sixth Assessment Report, the United Nations' Intergovernmental Panel on Climate Change (IPCC) highlighted that the rise in greenhouse gas (GHG) levels is undeniably due to human activity. The report warns that if significant reductions in CO₂ and other GHG emissions are not made soon, global temperatures are likely to exceed 1.5°C and 2°C within this century (Intergovernmental Panel on Climate Change, 2023a). It is vital for the well-being of the environment and society to reduce GHG emissions quickly (Intergovernmental Panel on Climate Change, 2023b).

To support the transition to climate neutrality and achieve the desired GHG reductions from freight transport, there is a need for policy tools that promote a shift to green fuels and improve energy efficiency in operations and technology (Brand et al., 2013; Ciccone, 2015; Danesin & Linares, 2015). In this sense, the European Commission has introduced a number of policy measures in the 2019 European Green Deal, with transport sector emissions mainly addressed in the 'Fit for 55' package of proposals. As part of this package, a revision of the EU Emissions Trading Scheme (ETS) was proposed, and a political consensus was reached in December 2022 on the modification of the scheme. The European Union's (EU) climate change legislation sets a binding target for net zero GHG emissions by 2050. It aims to reduce net GHG emissions by at least 55% by 2030 compared to 1990. The European Parliament and EU countries agreed on the final rules in late 2022, which were subsequently approved by the Parliament and the Council in early 2023. The regulations entered into force later that year (European Council & Council of the EU, 2024). Parliament adopted new rules to provide electric car charging stations every 60 km along main roads by 2026 and hydrogen refuelling stations at least every 200 km by 2031. The rules will enter into force once they have been approved by the European Council.

Green taxes, along with subsidies and emissions trading, are examples of market-based environmental policy instruments that operate through market mechanisms and prices. In general, market-based instruments are considered to be more cost effective. If applied uniformly, environmental tax facilitates cost-effective emission reductions by forcing firms to reduce emissions until the tax level equals the marginal cost of reductions (Aldy & Stavins, 2012; Fullerton et al., 2008). In particular, an optimal and cost-effective approach to reducing emissions is recognised as the Pigouvian tax, which is based on the external cost of emissions (Manta et al., 2023; Nellor & McMorran, 1994). Despite the complexity of determining the optimal tax level, uniform taxes are beneficial (Abrell et al., 2018). A stable greenhouse gas tax is technologically neutral and incentivises R&D investment in innovative abatement methods. However, it introduces uncertainty about the total reductions achievable, poses political implementation challenges, especially at the global level, and risks carbon leakage if not offset by border adjustments (Abrell et al., 2018).

Despite theoretical speculation, few studies have attempted to assess the effectiveness and mechanism of environmental taxes on green growth and energy transition across different sectors of the economy. Arbolino and Romano (2014) found that such taxes were instrumental in combating environmental degradation in 26 European economies. A similar conclusion was reached by Freire-González and Ho (2019), who argued that the introduction of environmental tax reforms in Spain played a crucial role in curbing pollutant emissions from 39 major industries. Rodríguez et al. (2019) suggested that environmental tax changes can promote the energy trade balance and energy efficiency. Karydas and Zhang (2017) proved that despite diminishing returns, green taxes can stimulate innovation and long-term growth. Wang et al. (2013) have shown that carbon taxes can reduce GHG emissions by 8.6% in the short term and PM2.5 emissions by 0.9% and 5.7% in the short and long term, respectively. According to Fan et al. (2019), the introduction of environmental tax policies prompts firms to increase their investment in pollution management, because the cost of penalties rises rapidly as environmental tax rates increase. As pollution increasingly interferes with firms' production, the marginal returns on energy use decline.

However, other researchers have not confirmed the positive effects of green taxes. Bovenberg and de Mooij (1994) used a Computable General Equilibrium (CGE) model to argue that in an economically distorted framework, the inclusion of environmental taxes exacerbates factor distortions, reinforces the marginal social damage of pollution and is detrimental to both economic and environmental outcomes. Using an extended Crepon–Duguet–Mairesse (CDM) model, Yuan and Xiang (2018)

examined the impact of environmental regulation on green development and found that the model only increases energy efficiency, while suppressing labour productivity in the long run. Chintrakarn (2008) pointed out that the financial burden of environmental regulation is the main contributor to the decline in technical skills in the manufacturing sector. In addition, Richardson and Chanwai (2003) found that the energy tax implemented in North West England did not trigger substantial investment in energy-efficient technologies or renewable energy sources. The social impact of the tax has been comparatively mild and selective.

Despite efforts to quantify the effectiveness of environmental taxes, the results show considerable heterogeneity and divergence between studies due to variations such as the taxes analysed, the time period of the study, the economic sectors and environmental domains involved and the methodologies used to assess impacts. This lack of consensus on the overall impact of green taxes is particularly evident in the transport sector. Despite the extensive literature on climate policy instruments for the transport sector, their evaluation needs to be more conclusive in order to increase knowledge of their effectiveness and facilitate their continuous refinement and improvement.

From a fiscal perspective, environmental taxes can generate two effects: green dividends (environmental benefits) and blue dividends (non-environmental benefits). Green dividend policies aim to reduce pollution emissions, while blue dividend policies focus on promoting economic growth and transformation. The empirical debate on the double dividend (DD) hypothesis has produced mixed results, reflecting the different economic contexts and methodologies used in relevant studies. For example, Saveyn et al. (2011) found a DD within the EU, which highlights higher private consumption as the main driver. In contrast, research by Ciaschini et al. (2012) found DD exclusively in the north-central districts of Italy, revealing territorial differences in the effectiveness of environmental fiscal measures. Orlov and Grethe (2012) found a DD in Russia and warned of the consequences of distorted competition leading to increased societal expenditure due to environmental taxes, which suggests a potential downside. Finally, Pereira et al. (2016) and Allan et al. (2007) found strong DDs under certain revenue recycling scenarios. This highlights the importance of implementation and recycling strategies to realise potential economic and environmental benefits. The studies finding DDs tend to be more recent and use more sophisticated models. However, the results are sensitive to the assumptions made in the models, such as the elasticity of labour supply and the degree of substitutability between different inputs. Thus, while the empirical debate on the double dividend hypothesis suggests that environmental tax reform can have both environmental and economic benefits, the magnitude of these benefits depends on the specific context and assumptions made in the models.

This paper aims to synthesise and categorise the extant body of knowledge concerning the utilisation of transportation taxation as a mechanism to facilitate energy transition within the transport sector. Existing research yields heterogeneous and sometimes contradictory results on the effects of fiscal instruments on transportation and society. It is contended that environmentally oriented taxation schemes can engender reductions in emissions and stimulate technological innovation. However, there is also a discernible risk that such taxation might precipitate elevated fuel costs and distortions in productivity, potentially exerting detrimental impacts on business performance. Therefore, more research is needed to systematise the literature and clarify how taxation influences the transport sector. To achieve this, a systematic literature review of 182 scholarly papers from the Scopus and Web of Science databases spanning the period of 2014 to 2025 was conducted. The research questions guiding this inquiry are as follows:

- In what manner does the scholarly literature address the impact of varied tax modalities on the energy transition within the transport sector?
- What are the predominant recommendations regarding the overarching criteria for effective tax instruments in the transport domain?

This study makes several contributions. First, this review provides an in-depth understanding of how taxes can support sustainable development goals in the transport sector. Second, it offers evidence of how different fiscal instruments affect transport decarbonisation, focusing on the shift from fuel-based taxation to distance-based approaches. Third, it helps researchers and practitioners understand the concept and potential research frontiers at the intersection of green/sustainable taxation and transport by covering a wide range of representative papers reflecting current research discourse.

Importantly, the novelty of this study lies in its systematic and comprehensive review of peer-reviewed publications using both Scopus and Web of Science and supported by bibliometric analysis and keyword clustering in VOSviewer. While previous studies have explored aspects of green taxation or transport decarbonisation, this review combines quantitative bibliometric techniques with qualitative synthesis to systematically examine how vehicle taxation supports the energy transition in the EU transport sector. In doing so, it provides an integrated understanding of the multifaceted impacts of transport taxes – not only on energy use and GHG emissions but also on the internalisation of environmental and economic externalities, transport prices, public finances and the redistribution of resources. Moreover, this review points to a gap in the literature regarding the timing of tax policy impacts. It shows that while fuel taxes remain relevant in the near term, their effectiveness will diminish with vehicle electrification, making preparing for a transition to mileage-based taxation models essential. Finally, the review proposes a practical framework for policymakers that considers environmental goals, fiscal impact, distributional effects across social groups and implications for technological innovation in the transport sector.

The remainder of the paper is structured as follows. After the introduction, the next section provides an overview of transport taxes in EU member states. The methodology used for the review is then described, followed by a presentation of the results of the published articles and a cluster analysis. All the results are integrated into a comprehensive framework in the discussion. The last section summarises the findings of this study and considers their theoretical and practical implications.

An overview of transport taxes in EU member states

Transport taxes are defined as all taxes directly related to the ownership and use of transport vehicles, including charges on transport infrastructure (Schroten et al., 2019). This definition does not encompass general taxes, such as taxes on profits and wages (e.g., for lorry drivers), as they are only indirectly based on transport activities. Transport charges include all compulsory (non-administrative) payments to governments and public infrastructure operators (such as road and rail authorities, ports and airports). However, payments made for transport services provided by semi-private agents are considered internal transport costs and are therefore excluded.

Tax measures may be directly or indirectly linked to CO₂ emissions from transport. CO₂-differentiated taxes aim to encourage people to buy or drive more fuel-efficient vehicles that have lower CO₂ emissions. This type of tax comprises all energy taxes whose tax base (energy consumption) is directly correlated with carbon emissions. Similarly, vehicle taxes and infrastructure charges can be considered directly related to the level of CO₂ emissions if the tax burden varies with CO₂ outcomes. Conversely, non-CO₂-differentiated transport taxes and charges may only have an indirect effect on CO₂ levels (e.g., by reducing overall transport demand, improving transport efficiency or contributing to a reduction in the number of vehicles in use) (Schroten et al., 2019).

In the EU, transport taxes are set at the national level and driven by different goals; for example, to reflect environmental impacts, increase government revenues, reflect road damage costs and promote alternative fuels and vehicles (Silajdzic & Mehic, 2018). As a result, the policy measures implemented in this sector have been developed in different ways in different EU countries.

Despite the independence of member states in shaping their tax policies, EU law influences transport taxation in these countries. Directive 2003/96/EC for the taxation of energy products and electricity, which introduced minimum excise duty rates on motor fuels (Council Directive, 2003), resulted in limiting the freedom of member states to set their taxation levels. The provisions of this directive allow for the differentiation of tax rates based on factors such as fuel quality and its origin (e.g., alternative fuels), as well as depending on the economic sector. In practice, many countries have used this opportunity to promote lower-emission fuels and low-emission technologies in transport.

Another key document is COM(2020) 562 final (EU Mobility Strategy), which places particular emphasis on the decarbonisation of road transport by promoting low-emission vehicles (including electric ones) (European Commission, 2020). The strategy requires EU member states to take specific actions, including differentiating road taxes depending on the type of vehicle and its environmental impact.

Regulation (EU) 2021/1119 (European Climate Law) does not contain strict tax regulations, but it establishes legally binding targets for achieving climate neutrality by 2050 and for reducing net GHG emissions by at least 55% by 2030 compared to 1990 levels (Regulation, 2021). In response to this regulation, many member states have started introducing and reforming transport taxes to incorporate an environmental component, including differentiating road taxes and registration fees based on CO₂ emission levels.

Recommendations formulated by international organisations (e.g., the IMF and OECD) also, to some extent, determine the principles of transport taxation. The IMF emphasises that the tax policy pursued by governments can play a crucial role in reducing the negative environmental impact of transport (Parry et al., 2019). It also recommends implementing emissions charges and subsidies for low-emission technologies in transport, as well as reforms in energy taxes aimed at promoting sustainable transport (Parry et al., 2014; OECD, 2021). Similar recommendations are made by the OECD (OECD, 2019; van Dender, 2019), which advocates for tax structures aimed at reducing the number of vehicles emitting large amounts of CO₂ and promoting electric and low-emission vehicles. The OECD also promotes the idea of internalising the external costs associated with transport, such as air pollution, noise and health costs (van Dender, 2019).

In general, transport taxes and charges applied in member states can be classified in two ways. The first identifies three types of taxes, depending on the tax base used (Schroten et al., 2019): (a) energy taxes (including CO₂ taxes), (b) vehicle taxes and (c) infrastructure charges. The second way is through fixed or variable taxes/charges, depending on how much the level of taxes/charges depends on actual transport movements.

Regarding energy taxation, fuel taxes are levied in all countries, mainly in the form of excise duties. In some countries, such as Denmark, Finland, France, Ireland, Luxembourg, Portugal, Slovenia and Sweden, specific carbon or CO₂ taxes are included in fuel excise duties and electricity taxes for road transport.

With the increasing market share of electric vehicles (EV), electricity taxation is becoming essential in the transport sector. Most EU countries apply electricity taxes, although significant differences exist in applied tax rates (European Commission, 2023). Generally, electricity taxes are significantly lower than taxes on petrol and diesel (in EUR/MJ), which means that widespread adoption of electric vehicles will lead to lower tax revenues (if tax rates are not changed).

Principal vehicle taxes implemented within the EU encompass initial purchase/registration levies and recurring ownership/circulation taxes (European Automobile Manufacturers Association (European Automobile Manufacturers Association, 2022, 2023). Almost all EU countries impose purchase/registration taxes on passenger vehicles, as illustrated in Table 1. These taxes are also prevalent for light commercial vehicles (LCVs) across numerous EU countries, albeit less extensively than for passenger cars (Schroten et al., 2022). Conversely, a limited array of EU member states impose these taxes on heavy-duty vehicles (HGVs), including buses and coaches, with only France, Greece, Ireland and Italy applying such charges (Schroten et al., 2022).

Approximately half of the EU countries employ a CO₂ emission-based differentiation in their purchase/registration taxes for passenger cars (Schroten et al., 2019). This differentiation is executed through various mechanisms, such as employing CO₂ emissions as the primary tax basis or implementing a bonus/malus system contingent on CO₂ emission levels.

The imposition of taxes on HGVs is not directly contingent on CO₂ emissions; nevertheless, a close relationship exists between the tax rate and CO₂ emission levels. This association is due to the variation in the tax rate based on vehicle weight, which subsequently influences the vehicle's average fuel consumption.

Beyond CO₂ emissions, the criteria for determining purchase/registration tax rates frequently include factors such as the type of fuel used, the vehicle's purchase or list price and the engine size. For LCVs and HGVs, attributes such as vehicle weight and the number of axles play pivotal roles in the tax differentiation process (Schroten et al., 2022). In numerous EU countries, EVs or, more broadly, zero-emission vehicles are exempt from any form of purchase taxation.

Table 1. Overview of transport taxes and charges applied in EU member states

Type of tax/charge (energy, vehicle or infrastructure)	Fixed or variable tax/charge	Tax/charge name	Description	Countries
Energy	Variable	Fuel tax	Consumption (excise) tax on fuels used for transport (including CO ₂ taxes, where applicable)	Fuel taxes: All EU member states Carbon/CO ₂ taxes on fuels: Denmark, Germany, Ireland and Sweden
Energy	Variable	Electricity tax	Consumption (excise) tax on electricity charged to vehicles (including CO ₂ taxes where applicable)	All EU member states
Vehicle	Fixed	Vehicle purchase or registration tax	One-off tax on the purchase or registration of a new vehicle	All EU member states (except Sweden) and in 13 countries based on CO ₂ emissions (Austria, Belgium, Croatia, Finland, France, Greece, Ireland, Italy, Malta, the Netherlands, Portugal, Slovenia and Spain)
Vehicle	Fixed	Vehicle ownership or circulation tax	Periodic tax on the ownership of a vehicle (e.g., annual)	Tax from passenger cars: All EU Member States (except Estonia, Lithuania, Poland, Slovenia and Slovak Republic) and in 14 countries based on CO ₂ emissions (Austria, Belgium, Cyprus, Denmark, Finland, France, Germany, Greece, Ireland, Luxembourg, Malta, the Netherlands, Portugal and Sweden) Tax from commercial vehicles: All EU member states (except Slovenia) and in Cyprus, Finland and Malta based on CO ₂ emissions
Energy, vehicle or infrastructure	Fixed/variable	VAT on transport taxes/charges	Indirect tax levied on taxes/charges levied on road transport (e.g., fuel tax). This tax is only relevant for private passenger transport, as companies can reclaim VAT.	All EU member states
Distance-based road charges (tolls)	Variable	Infrastructure	Charge for the passage along the road network	Charge from passenger cars: Portugal, Spain, France, Ireland, Italy, Poland, Croatia, Greece, Cyprus and Malta Charge from commercial vehicles: Portugal, Spain, France, Ireland, Italy, Poland, Croatia, Greece, Belgium, Czech Republic, Slovak Republic, Austria, Hungary, Slovenia, Croatia, Bulgaria, Cyprus and Malta
Time-based road charges (vignettes)	Variable	Infrastructure	Charge for access to road network for a specific period	Charge from passenger cars: Czech Republic, Slovak Republic, Austria, Hungary, Slovenia, Bulgaria and Romania Charge from commercial vehicles: Romania, the Netherlands, Luxembourg, Denmark, Sweden, Estonia, Lithuania and Latvia

Source: authors' work based on Schrotten et al. (2019), European Commission (2023) and Schrotten et al. (2022).

The rates for purchase/registration taxes vary considerably across member states, with Denmark imposing high rates on fuel-inefficient passenger cars, while Poland has relatively elevated rates for HGVs.

In addition to purchase/registration taxes, ownership taxes, also known as circulation taxes, are implemented in the majority of EU member states, as depicted in Table 1. Ownership taxes for passenger cars are levied in almost all EU27 nations, with Estonia, Lithuania, Poland, Slovenia and the Slovak Republic being notable exceptions (Schrotten et al., 2019). The Eurovignette Directive (European Parliament and Council of the EU, 2022) mandates applying an ownership tax on HGVs in all member states. Similarly, most EU countries impose an ownership tax on LCVs, although Slovenia is an exception. Over half of these nations incorporate a CO₂ emission-based differentiation in the ownership tax for passenger vehicles. The extent of this differentiation varies, ranging from systems entirely predicated on CO₂ emissions (e.g., in Germany) to those imposing a malus on vehicles exceed-

ing specific CO₂ emission thresholds (e.g., in France) (European Automobile Manufacturers Association, 2022, 2023).

However, no member state applies CO₂ differentiation for HGVs, partly due to the unavailability of CO₂ emission data for older trucks. For LCVs, CO₂ emissions are a differentiation criterion in a few countries, including Cyprus, Finland and Malta. Ownership taxes are also differentiated based on fuel type, Euro emission standards, vehicle weight and engine power. As some of these factors, such as engine size and vehicle weight, are indirectly associated with CO₂ emissions, they offer a subtle incentive for the usage of fuel-efficient vehicles.

The majority of EU nations implement some form of infrastructure charge. Among these, 17 member states levy such charges on passenger cars, with 10 countries adopting a distance-based approach and 7 opting for a time-based method. Distance-based road charging is executed either through physical barriers, as observed in France, Spain, Italy and Poland, or via a (electronic) network-wide system, exemplified by Portugal. Generally, LCVs are subjected to the same charging criteria as passenger cars. In the case of HGVs, they are employed in 26 countries. Over the past decade, a shift has been observed in many countries (16 in total) towards adopting distance-based schemes, often replacing the previous vignette systems. However, several countries continue using a time-based HGV scheme (European Commission, 2023). Thus, CO₂ emissions are not a differentiating factor in any European road charging scheme.

Research methods

A systematic literature review (SLR) was used to investigate different aspects of the impact of fiscal instruments on the transport sector and society in general (Mariano et al., 2017). The SLR is a reliable scientific procedure used to decrease study bias (de Menezes & Kelliher, 2011). This systematic review was conducted in accordance with the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 guidelines (Page et al., 2021). This framework has several benefits: Research questions can be clearly defined through a systematic search, necessary criteria and inclusions and exclusions can be identified, and multiple literature databases can be simultaneously examined (Page et al., 2021). Using PRISMA makes it possible to describe the review process in an objective way, as well as coordinate and arrange the data collection process accurately (Petticrew & Roberts, 2008).

The papers used in this analysis were selected from Scopus and Web of Science, two of the world's leading and most respected citation databases. The inclusion of reputable scientific journals in this compilation provides a high level of confidence in the veracity and reliability of the findings presented in the published papers. The last literature search was conducted on 11 June 2025 to ensure that the findings were as current as possible.

Before our literature search was carried out, we first identified keywords. The search terms could be categorised into two groups: (1) different types of transportation taxes (transport tax, vehicle tax, motor tax, fuel tax, excise or VAT) and (2) some environmental aspects (sustainable development, sustainability, CO₂ emissions, greening tax system, clean energy, environmental effect). The defined terms were searched using the keywords, titles and abstracts of scientific works.

In this study, only advanced research techniques were employed. The authors used the phrase search function and the Boolean operators 'OR' and 'AND' to combine the abovementioned words. The symbols and coding used in the search procedure were as follows: TITLE-ABS-KEY ('transport tax' OR 'vehicle tax' OR 'motor tax' OR 'fuel tax' OR excise OR 'vat') AND ('sustainable development' OR 'co2 emissions' OR 'greening tax system' OR 'clean energy' OR 'environmental effect').

Following the described procedure, 515 potential documents were identified. The study selection process is summarised in the PRISMA flow diagram in Figure 2. Papers matching our search criteria have been published since 1995, although growing interest can be observed after 2013, as seen in Figure 1. That being said, research studies published from 2014 to 2025 were included in the search. By narrowing the time frame, the number of articles was reduced to 368. Then, some duplicate records were removed.

The next stage involved screening. A total of 357 documents had to be screened, and four criteria for this SLR study excluded 59 documents. First, the search was limited to English-language scientific

works, because, according to Linares-Espinos et al. (2018), language standardisation is crucial to avoid confusion and prevent lengthy and costly investigations. We did not set any limitations on geographical variables. Most searched documents come from China, the United States, the United Kingdom, Germany, Sweden, Norway and Australia. Second, only articles in their final published form were included. Third, only journal articles were selected because they are highly reliable. Documents such as conference papers, reviews, book chapters, conference reviews and others were excluded. Finally, as the subject area determines the research direction of the study, we chose the following areas: environmental science, energy, engineering, social sciences, economics, econometrics and finance, business, management and accounting. After delimitating the results by the abovementioned criteria, 298 potential documents were identified.

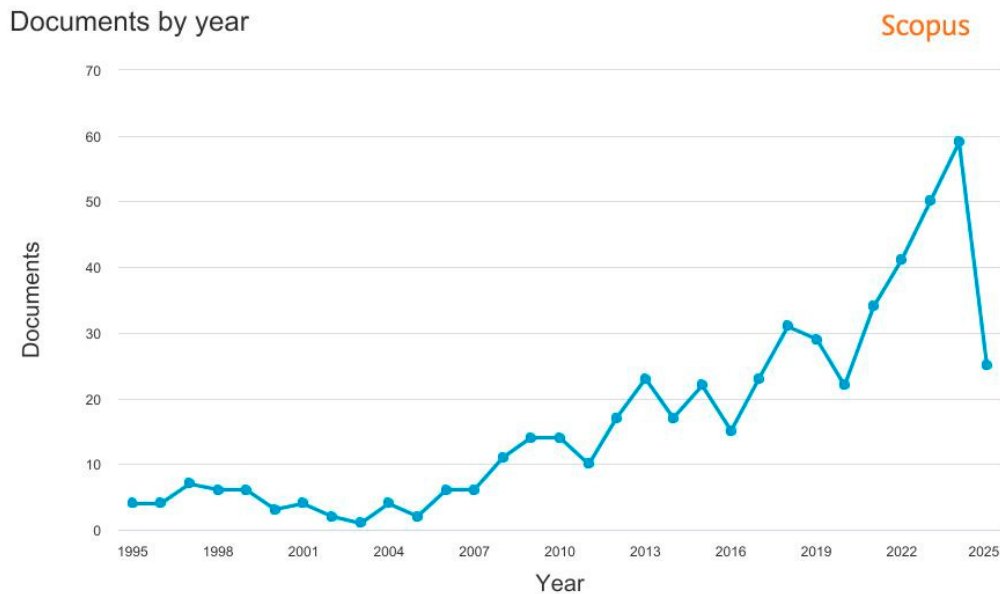


Figure 1. The search results by year

The designed sample was then inserted into Zotero citation management software.

In the next stage, two researchers independently screened the titles, keywords, abstracts and conclusions of the selected papers. Publications were chosen based on their suitability to the review objectives and research question. As a result, articles that did not fit the study's objectives were eliminated. We also removed papers that were not quantitative in nature.

In the final phase, a descriptive analysis of the collected materials was conducted to provide an overview of the documents. At the end of the process, 182 studies were selected for further review and analysis.

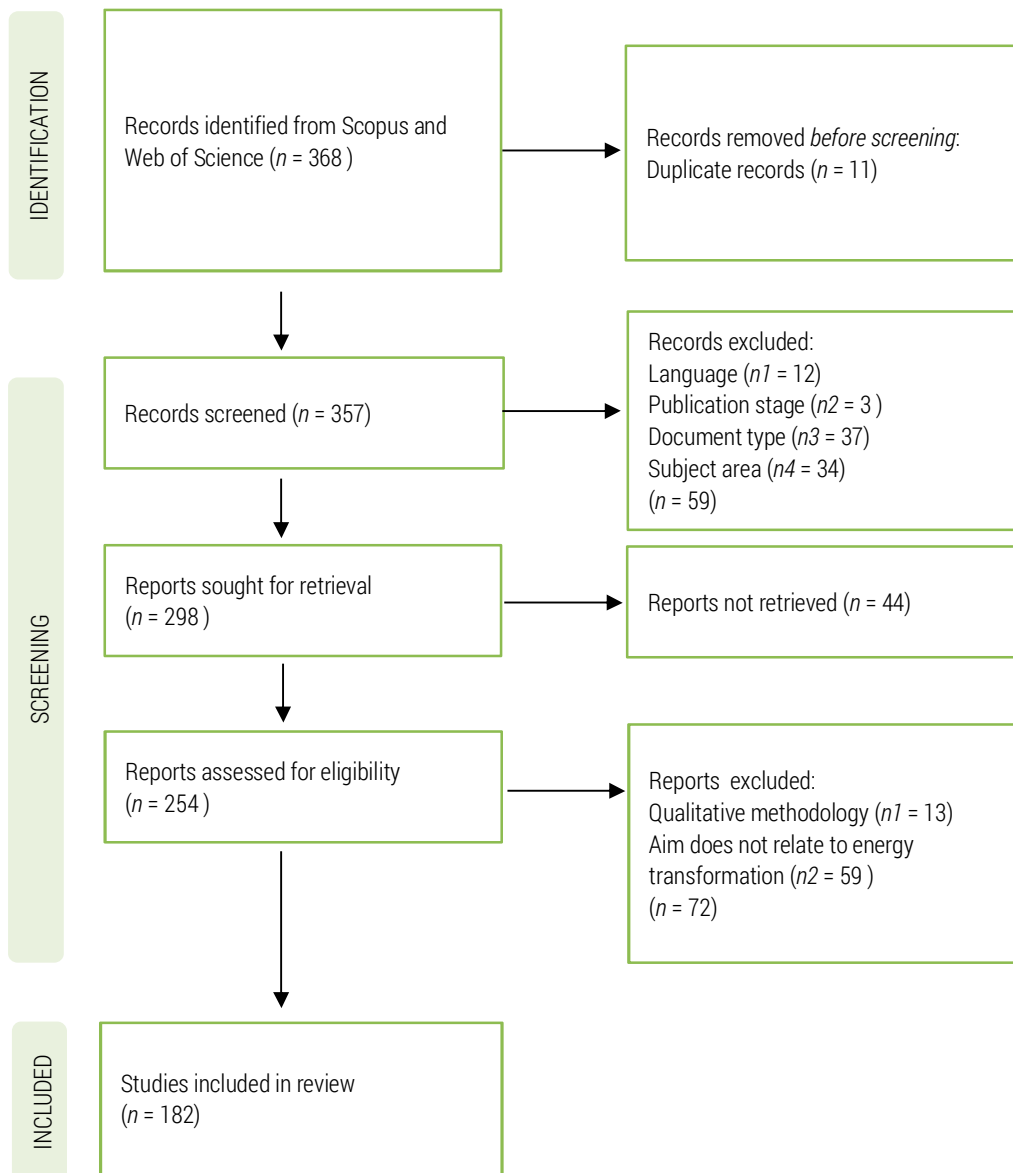


Figure 2. PRISMA flow diagram of literature selection and inclusion

Results

The territorial scope of most examined studies is limited to selected EU or EFTA countries, especially in Western Europe (Ajanovic & Haas, 2017; Borjesson & Ahlgren, 2012; Ciccone, 2015; Danesin & Linares, 2015; Hennessy & Tol, 2010; Mabit, 2014; Nygrén et al., 2012; Rogan et al., 2011; Shafei et al., 2018). There are also some studies on Central and Eastern European countries – individually (e.g., Latvia) (Barisa et al., 2015; Brizga et al., 2022; Māris & Jānis, 2017) or as groups (Silajdzic & Mehic, 2018). The reason for intensified interest in the topic in this part of the world is that the EU is a leading region in the fight against climate change. All member states have ratified the Paris Agreement and taken steps to implement its provisions. Moreover, in December 2020, the European Council agreed to achieve a climate-neutral EU by 2050. The target is to reach a net domestic reduction of at least 55% in GHG emissions by 2030 compared to 1990 (Council of the European Union, 2024).

It can be observed that out of the non-European states, several studies focus on countries that exhibit higher per capita pollution intensities. Some research has been conducted in China (Wang et al., 2013), Turkey (Onat et al., 2015), Australia (Stanley et al., 2018) and Columbia (Soto et al., 2018).

We categorised the examined papers into two groups in terms of the analysis period. The first includes retrospective research devoted to the assessment of current transportation tax policy

(Danesin & Linares, 2015; Mabit, 2014; Māris & Jānis, 2017; Nygrén et al., 2012; Rogan et al., 2011; Santos, 2017; Silajdzic & Mehic, 2018; Soto et al., 2018). The second group covers articles that contain projections for the future, developed using the scenario approach (Ajanovic & Haas, 2017; Barisa et al., 2015; Borjesson & Ahlgren, 2012; Brand et al., 2013; Hennessy & Tol, 2010; Onat et al., 2015; Stanley et al., 2018; Shafiei et al., 2018). The work of Wang et al. (2013) integrates both retrospective and prospective perspectives.

The aims of the selected scientific papers are diverse, although their common feature is that most concentrate on finding the most effective policy strategies for achieving GHG reduction targets. However, a smaller number of publications address other issues related to the impact of vehicle taxation, including its economic or distributional effects (Hussain et al., 2022; Missbach, 2023). The mentioned strategies are based on some tax policy actions – alone or as a part of broader reforms.

A hybrid approach involving systematic and content analysis was employed to enhance the comprehension of the pertinent literature and provide precise insights. In alignment with the recent investigations conducted by Khan et al. (2020) and Paltrinieri et al. (2019), a bibliometric analysis was performed on the 182 selected articles using VOSviewer. An analysis of word co-occurrence was performed, and the research clusters were determined. A linkage map was developed using VOSviewer. A total of 1384 keywords were identified in the database, of which 41 occurred at least five times. A map of the connections between keywords was used to determine the main research clusters, as presented in Figure 3.

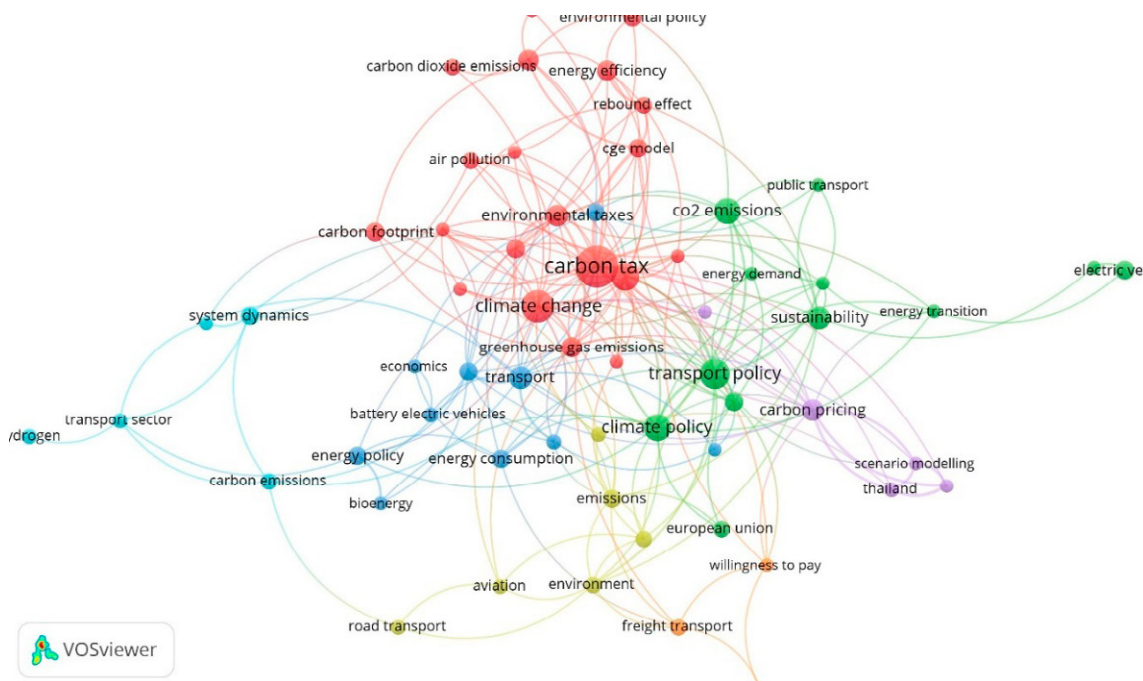


Figure 3. Author keyword co-occurrence map

Source: authors' work based on VOSviewer.

The analysis of the co-occurrence of keywords allowed us to determine seven main areas. Two areas refer to current problems and challenges and cover keywords such as air pollution, carbon footprint, greenhouse emissions and climate change (cluster 1), as well as emissions, road transport and global warming (cluster 4). Others concern the process of energy transformation and the transformation of the transport sector:

- Increased transport efficiency: energy transition, sustainability, public transport, transport policy, climate policy and social welfare (cluster 2),
- Transition to low-emission energy carriers and more fuel-efficient vehicles: battery electric vehicles, bioenergy and biofuel (cluster 3); hydrogen (cluster 6); and alternative fuel vehicles (cluster 7),
- Technologies of the future: autonomous vehicles (cluster 5).

Discussion: The influence of different types of taxes on energy transition in the transport sector

According to the SLR findings, transport taxes have a multitude of impacts on both the transportation industry and the greater society. These outcomes can be classified into five main categories: the effects on the transportation sector's energy use and resulting GHG emissions, the internalisation of external economic and environmental costs associated with transportation, transportation prices, public finances and the redistribution of resources.

Energy use and GHG emissions in transport

Many studies have found that CO₂-based fuel taxes and registration taxes encourage the use of renewable energy sources for electricity generation, which aligns with environmental sustainability goals (Ajanovic & Haas, 2020). Implementing CO₂-based registration taxes enhances the attractiveness of battery electric vehicles (BEVs) in the passenger car segment by reducing the tax burden on low-carbon technologies. These tax measures are designed to stimulate the BEV market and drive technological advancements, which encourages the shift towards more sustainable and environmentally friendly transportation options (Ajanovic & Haas, 2020).

Bilan et al.'s (2022) study highlights the positive impact of environmental taxes (especially transport and energy) on using biofuels. In this way, these taxes can indirectly reduce energy consumption and GHG emissions, with energy taxes having an immediate effect and transport taxes showing medium-term effectiveness. The study recommends using taxes to encourage biofuel production and consumption, but also suggests exploring the combined effects of taxes and government support on bio-energy.

In the study by Al Shammre et al. (2023), the results of the GMM estimator show a mixed impact of transport taxes on CO₂ emissions in OECD countries. The dynamic panel threshold procedure suggests that a minimum of 0.434% of GDP from transport tax revenue is required to reduce CO₂ emissions effectively. However, other studies indicate that transport taxes do not significantly influence CO₂ emissions. While these taxes help generate revenue for the government, they need to be more effective in addressing environmental degradation.

Interesting conclusions also come from the study by Alola and Nwulu (2022), who tried to confirm the double dividend effect of some environmental taxes, such as energy, pollution, resource and transport taxes. The existence of green dividends was tested by determining the impact of the above taxes on GHG emissions. In contrast, the effect of the blue dividend was confirmed by examining the influence of taxes on energy intensity. The results show that the energy tax leads to lower GHG emissions and energy intensity and is the only environmental tax that consistently supports the DD hypothesis in the broader panel case. Transport taxes show some potential to reduce GHG emissions, but this effect is not statistically significant. However, only in Sweden does transport tax policy contribute to achieving favourable results regarding the DD hypothesis. This research suggests that increasing pollution and resource taxes worsens GHG emissions and increases energy intensity, so the authors did not confirm the DD effect (Alola & Nwulu, 2022).

Finally, some authors showed that introducing a tax on the purchase of diesel cars may significantly reduce NO_x emissions, with a moderate impact on CO₂ emissions. In the short term, this tax will only slightly increase overall energy consumption and lead to a shift from diesel to petrol vehicles (Brand, 2016). However, over the longer term, fuel shifting and reduced energy consumption have been observed due to the adoption of more energy-efficient powertrains, including plug-in hybrid vehicles (PHEVs) and BEVs. However, the greatest effects can be achieved by combining tax on purchasing diesel cars with high electrification (Brand, 2016). Similarly, according to Campisi et al. (2021), it is necessary to provide road users with an adequate network of public recharging infrastructures and to facilitate the set-up of private recharging stations through shared and participatory development plans between stakeholders and all the institutions involved.

Internalisation of external economic and environmental costs

Road transport generates various externalities, such as pollution, congestion, accidents, noise and climate change. Fuel taxes are perceived as an attractive economic instrument for correcting these negative phenomena. As a result, they are widely used by policymakers. As proved by Li et al. (2014), consumers respond more strongly to fuel tax changes than to changes in tax-inclusive prices. According to some studies, excise duties on fuel are more efficient than fuel economy standards and subsidies on vehicles (Li et al., 2014; Saltee, 2010). This makes fuel taxes an efficient corrective instrument.

Such fiscal duties are known as corrective or Pigouvian taxes. The idea behind these constructions is to internalise the externality by increasing the price (in this case of fuel), so that its marginal private cost is equal to its marginal social cost. Imposing a Pigouvian tax leads economic agents to take the whole cost of their actions (not only their private costs) into account when buying fuel and thus to change their behaviour in order to reach a socially optimal outcome. The corrective tax could take the form of an excise tax; in other words, a tax imposed on the seller, assuming that they would shift the burden on to consumers.

There is consensus that fuel taxes (or carbon taxes embedded in the fuel tax) constitute well-suited instruments to internalise the external costs of CO₂ emissions. The undeniable fact that CO₂ emissions are causing climate change has emerged as a politically acceptable reason for the wide use of these taxes. Indeed, fuel tax would be adequate to internalise the climate change externality and, to some extent, air pollution. However, according to estimates made by Santos (2017), in many countries, road transport externalities are not currently fully internalised.

Furthermore, some authors emphasised that fuel taxes are not perfect instruments to internalise noise, congestion and accidents. According to Santos (2017), fuel taxes can serve as a temporary measure until better designed measures can be implemented. The above-mentioned externalities would be better internalised with specifically targeted, more sophisticated instruments, such as congestion charges and pay-as-you-drive insurance. Similarly, Hysing et al. (2014) discuss congestion charging as an effective policy measure to regulate and reduce car traffic demand and associated environmental and health problems in cities. They used a specific case – the Gothenburg congestion tax introduced in 2013. The funds collected were used to co-finance infrastructure investments. This can be perceived as a compromise with powerful political and economic interests that can lead to more profound long-term effects.

Transportation prices

Fuel taxes (especially in the form of excise duties) are widely used as fuel price leverages, which can be directly related to fuel prices (Wang et al., 2013). They are easy, quick and inexpensive to collect. In Europe, they represent almost half of the net fuel price (Santos, 2017). As was emphasised by Sterner (2007), fuel taxes have played a significant role in consumer fuel prices during the last 20 to 30 years.

Public finance

As mentioned above, fuel taxes are widely used as fuel price leverages (Wang et al., 2013). Due to the fact that they are paid at the point of fuel purchase, their collection is easy, quick and inexpensive. Another advantage is that they are an instrument for raising fiscal revenues in an effective way. According to Eurostat (2024a), their share in total tax revenues (including social security contributions) is, on average, 5.4% at the EU level. A considerable portion of the 2020 EU environmental tax revenue (77%) comes from energy taxes. Transport taxes account for 19.3%, and the share of taxes on pollution and resources is still minimal (3.7%) in the EU (Eurostat, 2024b).

Some authors (e.g., Brizga et al., 2022) emphasised that existing environmental taxes reduce transport emissions and at the same time have a significant fiscal impact. Other researchers have explored the financial implications of autonomous, connected, electric shared vehicles (ACES), both directly and indirectly (Adler et al., 2019). The adoption of ACES is expected to result in a significant decline in tax revenue from fossil fuels, as these vehicles are more efficient and run on electricity. This shift towards EVs will also increase electricity consumption, but the increase in tax revenue from

electricity is likely to be minimal compared to the decrease in fuel tax revenues (Adler et al., 2019). Furthermore, the rise of car-sharing and ride-sharing models could result in a decrease in vehicle registration and circulation taxes. The integration of ACES will require significant investment in public infrastructure and may also lead to changes in road maintenance expenses and public transportation funding.

Redistributional effects of transport taxes

The functioning of transport taxes has always raised concerns about their fairness. These public duties, especially fuel taxes, are accused of having a regressive impact on national income distribution.

In high-income countries, heterogeneous households show differences in their consumption patterns. Lower income households allocate a relatively larger share of their total expenditures to the consumption of some essential goods (i.e., fuel or electricity), while well-off households spend more money (relative to total expenditures) on other goods and services. Poor households acquire relatively more carbon-intensive goods and services than richer ones, and as a result, they bear proportionally high additional economic costs of transportation taxes.

Many researchers have presented studies on the distributional impacts of carbon pricing reforms and confirmed that it is often regressive (Hussain et al., 2022; Missbach, 2023). Moreover, they have proved that differences within income groups can be meaningful, possibly exceeding differences between income groups (Missbach, 2023). Özmen and Mutascu (2025) estimated various distributional effects of transport tax and energy tax by comparing two groups of countries: those with relatively high per capita income and those with predominantly low-income populations.

The uneven distribution of the tax burden can diminish public support for environmental policies and subsequently hinder their effectiveness. For this reason, it is essential to mitigate the adverse impacts of transportation taxes on vulnerable segments of the population (i.e., through increasing green spending or implementing targeted transfer schemes). Governments could, for instance, use (part of) carbon pricing public revenues to compensate households (e.g., by subsidising electricity consumption) (Büchs et al., 2021). Such policies can sustain a more equitable distribution of income and thus facilitate just and socially balanced sustainability transitions; however, they may also contribute to the reduction of the incentive for households to lower the consumption of carbon-intensive products.

Policy implications

Alola and Nwulu (2022) emphasise that a combination of different cost-effective policies promoting environmentally sustainable consumer behaviours might be more effective than solely relying on pollution, resource or transport tax measures. High rates of environmental taxes could increase productivity costs, which should be offset by government incentives or subsidies that promote ecological innovation. To prevent environmental taxes from disproportionately impacting households, effective awareness programmes and incentives for adopting innovative environmental practices are crucial.

According to the majority of examined studies (e.g., Ajanovic & Haas, 2017; Silajdzic & Mehic, 2018; Stanley et al., 2018; Shafiei et al., 2018; Soto et al., 2018; Wang et al., 2013), there is no single measure or technology that could solve all problems in passenger car transport. When used in isolation, these instruments do not appear to have a large effect at an aggregate level. Only the implementation of a broad portfolio of different policy instruments and actions can reduce energy consumption and meaningfully contribute to GHG emissions.

Brizga et al. (2022) emphasise that in order to achieve a decarbonisation target, a significant reduction in fossil fuel consumption is required. This can be realised by increasing taxes on fuel, supporting environmentally friendly infrastructure and increasing motivation for electric car use and social innovation (e.g., modal shift, car-pooling, teleconferencing). Stanley et al. (2018) and Shafiei et al. (2018) point out that significant results can be achieved by implementing a combination of 'sticks' (i.e., higher fuel taxes/excise) and 'carrots' (i.e., lower public transport fare and subsidies). Similarly, Barisa et al. (2015) prove that a significant boost in the production of biodiesel can be reached only by involving subsidies in at least two sectors of the identified dynamic structure (i.e., biodiesel producers, feedstock suppliers, rapeseed producers and end-users).

When it comes to public transport, another strategic step to reduce GHG emissions is making it more attractive by improving service levels (Wang et al., 2013). There are also some administrative measures, such as standards or quotas, that can be enacted (Ajanovic & Haas, 2017). Another effective instrument can take the form of banning older vehicles. Onat et al. (2015) developed scenarios assuming such bans for cars produced before 2000, 1996 and 1990 and showed that the reduction rate of CO₂ emissions would be 48%, 36% and 26%, respectively.

These policy actions should be accompanied by systematic efforts to induce technological progress, especially alternative energy use, and support for the use of renewable energy and its production (Silajdzic & Mehic, 2018). Extensive efforts should be made to change behaviour towards increased use of low-emission modes of transport as well as to drive culture change towards less emission-intensive travel behaviours (Stanley et al., 2018). The analysis conducted by Soto et al. (2018) suggests that in an environmentally conscious market, people prefer alternative technologies and fuels. According to these authors, policy actions should not only be directed at infrastructure and vehicles but should also focus on user awareness and acceptance of alternative fuel vehicles. Barisa et al. (2015) confirmed that promoting biofuel acceptance among end users is the primary key issue. Their model simulations prove that a significant boost in the production of biodiesel can be reached only by involving subsidies in at least two sectors of the identified dynamic structure (i.e., biodiesel producers, feedstock suppliers, rapeseed producers and end-users). Anguralia and Singh (2024) postulate the implementation of a whole set of policies – the development of advanced clean and sustainable transportation technologies (such as EVs, hydrogen fuel cells and alternative fuels), support for R&D initiatives and the promotion of innovation in the automotive industry (such as grants, tax credits and other incentives).

Conclusion

This paper employed a systematic literature review to analyse academic publications retrieved from the Scopus and Web of Science databases using a dedicated search query. The initial query was subsequently expanded with the support of keyword co-occurrence analysis in VOSviewer.

Based on the reviewed literature, we propose several policy recommendations essential for the development of an environmentally sustainable transport taxation system.

First, it is important to incorporate different temporal perspectives when designing sustainable transport policies. In the short term, tax systems should primarily rely on fuel taxes, which remain the most effective tool for promoting decarbonisation. These should be complemented by vehicle-related taxes linked to CO₂ emissions – particularly purchase taxes – to accelerate the adoption of low- and zero-emission vehicles. In the longer term, as transport decarbonisation advances and fuel tax revenues decline, a gradual shift towards distance-based taxation mechanisms will be necessary.

Second, policymakers should adopt a comprehensive mix of policy instruments to reduce energy consumption and significantly curb GHG emissions. Taxation must be complemented by subsidies, emissions quotas, regulatory standards and support for technological innovation (e.g., alternative energy development). Equally important is raising public awareness of the negative consequences of environmental degradation and fostering societal acceptance of clean energy solutions.

Third, externalities beyond CO₂ emissions – such as air pollution, traffic noise, accidents and congestion – must also be reflected in the overall tax burden. Given the increasing social costs of congestion, especially in urban areas, we advocate for the broader implementation of congestion charging schemes.

Fourth, transport taxes tend to be regressive. Therefore, it is vital to introduce compensatory measures to alleviate their unequal social impact. This may involve earmarking part of the tax revenues for redistribution through mechanisms such as the Social Climate Fund at the national or EU level.

Fifth, the structure of transport-related taxes and fees should be regularly updated to reflect changes in the automotive industry and evolving consumer preferences, particularly regarding vehicle emissions and electrification trends.

Finally, transportation tax revenues should be reinvested in developing sustainable transport infrastructure. This includes funding for low-emission vehicles, alternative fuel networks (such as EV charging stations) and support for public transport systems.

The findings of this review are relevant not only in academic terms but also from a practical policy perspective. By synthesising the effects of various transport taxation instruments, the study provides public authorities with a structured evidence base to help them align fiscal tools with sustainability goals. In the short term, local governments can use the findings to design and implement urban-level policies, such as congestion charges, low-emission zones and differentiated parking fees, particularly in densely populated metropolitan areas. They can also adjust local vehicle taxation schemes to favour low- and zero-emission vehicles, support improvements to public transport through targeted subsidies, invest in alternative fuel infrastructure and use earmarked revenues from transport taxes to fund socially inclusive mobility programmes. Furthermore, local authorities can launch awareness campaigns to encourage behavioural change and boost public acceptance of sustainable transport policies. In the medium and long term, national and EU-level policymakers may use these findings to inform adjustments to the structure of fuel and vehicle taxation in response to the electrification of vehicle fleets and evolving mobility patterns. They can also gradually introduce distance-based road user charges to compensate for declining fuel tax revenues, reform tax expenditures to better target hard-to-decarbonise sectors (such as heavy-duty vehicles and vans) and regularly update fiscal instruments in line with technological progress and changing consumer preferences. Finally, policymakers can use these insights to address concerns about regressivity by reallocating revenues through climate social funds or targeted subsidies and promote coherent, multi-level strategies by integrating tax instruments with vehicle standards, renewable energy incentives and infrastructure investments.

While this review offers novel insights into the role of transport taxation in supporting the energy transition, several limitations must be acknowledged. First, the analysed literature reveals a geographical bias towards Western European countries, with relatively limited coverage of non-EU or non-European economies. This restricts the global generalisability of the findings. Second, although the review draws on two comprehensive databases (Scopus and Web of Science), the scope remains limited to peer-reviewed academic publications that may underrepresent policy experiences from certain regions. Third, while bibliometric mapping tools such as VOSviewer offer valuable support for visualising keyword co-occurrence and thematic clusters, they cannot fully capture individual studies' contextual nuances or methodological diversity. Future research could expand the geographic and methodological scope by complementing systematic reviews with targeted regional case studies or mixed-methods approaches.

Acknowledgements

Project financed from the state budget granted by the Minister of Science under the program "Excellent Science II – Support for Scientific Conferences".



The contribution of the authors

Conceptualisation, K.W.; methodology, M.M.Ch.; formal analysis, K.W. and M.M.Ch.; writing, K.W. and M.M.Ch.; conclusions and discussion, K.W. and M.M.Ch.

The authors have read and agreed to the published version of the manuscript.

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ROLA PODATKÓW OD POJAZDÓW MECHANICZNYCH W TRANSFORMACJI ENERGETYCZNEJ W SEKTORZE TRANSPORTU – SYSTEMATYCZNY PRZEGĄD LITERATURY

STRESZCZENIE: Celem artykułu jest dokonanie syntezy wyników dotychczasowych badań na temat wpływu podatków od pojazdów silnikowych na przebieg transformacji energetycznej w sektorze transportu. W tym celu oparto się o metodę Systematycznego Przeglądu Literatury (SPL), który przeprowadzono w oparciu o publikacje zgromadzone w bazach Scopus i Web of Science. Kwerendą objęto 182 artykuły naukowe, opublikowane w latach 2014-2025. Wyniki te zostały wzbogacone o rezultaty analizy przeprowadzonej z wykorzystaniem programu the VOSviewer. Opracowanie dostarcza szeregu teoretycznych i praktycznych rekomendacji. Podkreślono, że aby zapewnić zrównoważony rozwój sektora transportu, konieczne jest uwzględnienie różnych perspektyw czasowych – w krótkim okresie system podatków ekologicznych powinien bazować na podatkach paliwowych, podczas gdy na zaawansowanym etapie dekarbonizacji konieczne będzie przesunięcie ciężaru opodatkowania w kierunku danin, których wysokość zależy od przebytego dystansu. Aby ograniczyć emisję gazów cieplarnianych konieczne jest użycie, obok podatków, szerokiego katalogu innych instrumentów (np. subsydiów czy instrumentów prawnych), jak również wspieranie rozwoju nowych technologii i podnoszenie społecznej świadomości na temat negatywnego wpływu zanieczyszczenia powietrza na kondycję środowiska naturalnego i społeczeństwa.

SŁOWA KLUCZOWE: podatek ekologiczny, podatek od pojazdów silnikowych, podatek paliwowy, akcyza, systematyczny przegląd literatury