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Research Paper

Global trends in electric vehicle adoption and the impact of environmental awareness, user attributes, and barriers

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ABSTRACT

Electric vehicles, powered by one or more electric motors, offer numerous advantages, such as reduced noise pollution, a cleaner environment, and lower operating costs. The selection of electric cars could be influenced by various drivers including environmental awareness, user attributes, barriers, incentives, and user awareness. Accordingly, this paper aimed to explore the impacts of those influential drivers on adopting kinds of electric vehicles by considering spatiotemporal patterns. In this paper, the meta-regression approach was run to combine the findings of 38 primary articles from 1990 to 2023. In this context, the effects of main drivers on adopting electric vehicles were assessed in Battery Electric Vehicles (BEVs), Plug-in Hybrid Electric Vehicles (PHEVs), and Hybrid Electric Vehicles (HEVs). The findings indicate that the main drivers influence the selection of electric cars. The meta-regression results showed that achieving electric vehicle adoption can be globally influenced by environmental awareness (β= 0.23), user attributes (β= 0.17), barriers (β= −0.07), and user awareness (β= 0.12). The highest spatial effect is related to the adoption of BEVs (β= 0.17) by European countries. Accordingly, the use of electric cars is recommended, especially in large countries that emit greenhouse gases such as China and India. The expansion of electric vehicles, especially renewable energy, is suggested to reduce fuel imports and reduce vulnerability to fuel price fluctuations, especially in countries dependent on fossil fuels such as Middle Eastern countries. In this context, policymakers are advised to use incentive tools, like free parking and tax exemptions, to accelerate the selection of electric cars in areas with slower uptake.

1. Introduction

While developing countries are leading the automobile markets, they rely on unsustainable fossil fuel-based transport methods (Jajja et al., 2021; Mohideen et al., 2023). One of the challenges of the transport sector is the emission of carbon dioxide gas, which has raised concerns about the increase in global temperature (Kovacikova et al., 2021; Liu et al., 2023). The considerable increase in the global emission of carbon dioxide gas in recent years has had many destructive consequences such as droughts, storms, and floods (Akaev and Davydova, 2022; Rayer et al., 2021). The five countries that emit the most global carbon dioxide gas are China, the United States, India, Japan, and Russia (Su et al., 2019; Zhang et al., 2022a). The future perspective is aimed at about 30 % mitigation of carbon dioxide emissions in 2030 (Fang et al., 2019; He and Zhang, 2020). Developing countries are among the major consumers of global oil, and oil consumption in those regions is expected to increase in the future (Ahmad and Zhang, 2020; Wang et al., 2021). In this regard, initiatives to shift towards sustainable mobility and thereby reduce fossil fuel consumption globally have been introduced by some countries such as China and India (Palit et al., 2022; Umar et al., 2020). Electric mobility and ensuring renewable sources of electricity can notably reduce carbon dioxide emissions (Filote et al., 2020; Sobol and Dyjakon, 2020). In this context, the significant shift towards electric mobility is evident (Krishnan and Koshy, 2021; Tarei et al., 2021) and highlighted by initiatives such as Europe's Green Deal, which aims to generate the area climate-neutral by 2050 (Fetting, 2020).

Since the infrastructure and market structure required for emission-free vehicles are unique, these vehicles are still considered an emerging technology in developing countries (Mali et al., 2022; Verma et al., 2020). In this context, infrastructure is the integrated structures, machinery, and equipment to support an electric vehicle, including battery chargers, fast chargers, and battery swapping stations (Singh et al.,

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2024). Regional disparities in infrastructure and economic development affect the adoption of electric cars, with low-income developing countries experiencing slow growth in electric vehicle adoption due to lack of necessary infrastructure (Rajper and Albrecht, 2020). However, electric vehicles have a much higher purchase cost than conventional vehicles because they have expensive batteries (Goetzel and Hasanuzzaman, 2022; Liu et al., 2021b). Norway has the largest electric car market in the world because it has extensive incentive packages such as free parking and tax exemptions for these types of cars (Aasness and Odeck, 2023; Penmetsa et al., 2023). Norway continues to lead in battery-electric vehicle (BEV) sales, with BEVs accounting for approximately 90 % of all new vehicle sales since the beginning of this year. The country is also set to become the first to ban the outlet of novel petrol and diesel vehicles by 2025. In addition to reducing the cost difference between electric and conventional vehicles, users are only willing to buy this novel technology if they understand its benefits (Featherman et al., 2021; Krishna, 2021). Thus, the users' correct understanding of the benefits of electric vehicles has an important role in the success of their market (Chamberlain and Al-Majeed, 2021; Ziegler and Abdelkafi, 2022). During the 1880s, experimental electric cars had been made, yet the initial actual BEVs occurred in the 1890s. Hence, commercially available, practical electric cars appeared during the 1890s (Ajanovic et al., 2021). An electric car bore the car land rate record up to around 1900 (Martyushev et al., 2023). The idea of electric car chargers can be traced back to the early 1900s when automobiles were first being developed. Battery vehicle milk floats expanded in 1931, and by 1967, gave Britain the largest electric vehicle fleet in the world. Electric car markets are witnessing strong growth with nearly 15 million sales in 2023. The share of electric vehicles in total sales has risen from about 4 % in 2020 to 18 % in 2023. Sales of electric cars are expected to be strong in 2024 (Khaleel et al., 2024).

More than half of the world's electric car users are in China and the United States (Ou et al., 2019; Sovacool et al., 2019). After that, European countries occupy the second place with about 20 % of the global electric vehicle market share (Borge-Diez et al., 2021; Münzel et al., 2019). Six countries (i.e., Norway, the Netherlands, Sweden, France, China, and Japan) have larger electric vehicle market shares than passenger cars (Macioszek, 2020). However, electric cars have gained less popularity in developing regions than in developed nations (Rajper and Albrecht, 2020; Sun et al., 2019). Accordingly, India has less than one percent of electric vehicles in terms of car ownership (Hu et al., 2021; Lin and Wu, 2021). When it comes to electric vehicles, persons normally believe in electric vehicles, nevertheless, in the case of appearing nations, i.e., Vietnam, a significant number of electric two-wheeled vehicles are sold. The ease of mobility and the reasonable price of buying two-wheeled electric vehicles have made them gain market share in the sale of these vehicles (Jain et al., 2024; Kashyap et al., 2023). The electric two-wheeler market share in other Asian countries is also growing slowly, such as India and Taiwan. This is notable for the development of electric vehicles that match the electric power organization in developing nations (Aznar et al., 2021). The use of hybrid electric cars is suggested for nations with a mainly heat-based electricity mix due to high energy performance and reduced emissions (Mneimneh et al., 2023). Another issue is the affordability of electric vehicles for citizens to purchase. Since electric four-wheeled vehicles have a high price, developing countries have switched to electric two-wheeled vehicles (Eccarius and Lu, 2020). In this context, China is a clear example that in this country two-wheeled electric vehicles have been directed towards an exponential number (Patil, 2009; Shahbaz et al., 2023).

A major driver for the decision to purchase electric vehicles is environmental concerns (Ahmadi, 2019; Pevec et al., 2020). Users' awareness of environmental issues leads to an increase in their willingness to accept emission-free vehicles (Butt and Singh, 2023; Cruz-Jesus et al., 2023). In addition, the decision to buy electric vehicles is influenced by user attributes such as age and education level (Chen et al., 2020; Mukherjee and Ryan, 2020). Furthermore, electric vehicles' relative advantage (i.e., the degree of understanding that this new technology is better than the traditional one) can be an effective factor in the decision to adopt (Mukherjee and Ryan, 2020; Hardman and Tal, 2021). In this context, the high purchase cost, expensive batteries, limited charging infrastructure, and battery range are some of the obstacles to the selection of electric cars (Alotaibi et al., 2022; Ruoso and Ribeiro, 2022). However, financial incentives including tax exemptions and non-financial ones such as free parking and access to bus routes have been identified to encourage the selection of electric cars (Hardman, 2019; Xue et al., 2021). The knowledge and awareness of users about electric vehicles have a high correlation with the adoption of new technology (Tanwir and Hamzah, 2020; Tiwari et al., 2020). In contrast, threats (e.g., targeted malware attacks, key spoofing, remote vehicle control, and acceleration and braking control) perceived by users often limit the adoption of electric vehicles (Featherman et al., 2021; Xu et al., 2020). The main argument or hypothesis of the study is that increasing users' awareness of environmental issues, improving their attributes, and pursuing financial incentives lead to the selection of electric cars.

The drivers for the adoption of electric vehicles are different depending on various regions, and extensive studies (such as Almeida Neves et al., 2019; Singh et al., 2020; Wu et al., 2020) have been conducted in this field. The results of those studies indicated that policies should be set for each type of technology separately, rather than a single policy for all-electric vehicles. Identifying the psychological, social, economic, environmental, and technical determinates of the selection of electric cars can determine future directions for electric vehicle researchers and experts and assist states and the car industry to add the share of electric car use. In this regard, it is necessary to study the understanding of user preferences for urban areas worldwide. The research gap in previous studies is the failure to integrate all the drivers influencing the adoption of electric cars around the world. The novelty of the present study is in quantifying the effect of all drivers influencing the selection of electric cars at the global level. We conducted an extensive literature review to identify potential drivers of electric vehicle purchases worldwide. This study contributes to policymakers and industry stakeholders in identifying key motivating and inhibiting factors for the selection of electric cars. Thus, this study could be a proper guide for adjusting sustainable policies that lead travelers to use electric vehicles and abandon their conventional vehicles. The aim is to review the primary articles on the drivers influencing the adoption of electric cars in the world applying meta-analysis. In this regard, the research questions are designed as follows:

1) What are the global effects of environmental awareness on adopting electric vehicles?
2) What are the global effects of user attributes on adopting electric vehicles?
3) What are the global effects of barriers to adopting electric vehicles?
4) What are the global effects of incentives on adopting electric vehicles?
5) What are the global effects of user awareness on adopting electric vehicles?
6) What are the regional effects of the adoption of electric vehicles in the world?

2. Literature review

The current study reviewed the original articles in which the theoretical framework was based on the technology adoption theory. The life cycle of technology adoption is a sociological model that examines the adoption of innovation according to the demographic and psychological characteristics of the adopter groups. In some models, adoption is not only the choice to adopt an innovation but also the degree to which that innovation is integrated into the appropriate context (Stornelli et al., 2021).

2.1. Main drivers of adopting electric vehicles

Several researchers (e.g., Asadi et al., 2021; Kumar and Alok, 2020) have studied the impact of environmental awareness on adopting electric cars. The results of the studies mainly show the low understanding of the users towards improving the stability of electric vehicles (Sanguesa et al., 2021; Zhang et al., 2022b). Upgrading users' awareness of the environmental advantages of these vehicles can increase the motivation to adopt emission-free cars (Singh and Paul, 2023; Ramachandaramurthy et al., 2023). Understanding the environmental advantages of electric vehicles can even convince users to pay the high cost of these cars caused by expensive batteries (Krishna, 2021; Shi et al., 2023). In other words, users' decisions can be influenced by the perceived negative effects of conventional vehicles such as noise pollution, air pollution, and climate change (Lashari et al., 2021). In this context, user attributes can also influence the decision to buy electric vehicles. Some researchers (e.g., Adhikari et al., 2020; Goel et al., 2021; Pamidimukkala et al., 2024) stated that the increasing education level of users is a barrier to the selection of electric cars as educated users are aware of some disadvantages of electric cars. In addition, the improvement of users' income has not shown an effective role in the selection of electric cars (Higueras-Castillo et al., 2021). Scholars (e.g., Lai et al., 2022; Zhang et al., 2024) continued to create more efficient, safer, and longer-lasting batteries than lithium-ion batteries. One of the latest technologies includes graphene batteries, which engage faster charging, longer lifespans, and more safety. Additionally, charging infrastructure has improved. Researchers (such as Roy and Law, 2022; Shern et al., 2024) using artificial intelligence models on electric vehicle survey data have discovered the point that charging stations have an average reliability score of 78 percent, meaning one in five is not working.

2.2. Barriers and incentives

Another group of researchers has focused on barriers to electric vehicle adoption, including high purchase cost (Giansoldati et al., 2020; Tarei et al., 2021), expensive batteries (Alotaibi et al., 2022; Kongklaew et al., 2021), and limited charging infrastructure (Kongklaew et al., 2021; Kumar et al., 2021). Electric vehicle purchase and operating costs differ in different countries (Costa et al., 2021; Noll et al., 2022). Sweden has kept the cost of new technology relatively lower than traditional vehicles (Costa et al., 2021), while France has followed a different approach (Noll et al., 2022). Thus, researchers have emphasized reducing the costs of these new vehicles in recent years (Deng et al., 2020; Sanguesa et al., 2021). Moreover, the driving range and lack of sufficient charging stations for electric vehicles are known to be the inhibiting factors that can be improved by creating a sufficient number of charging infrastructures to adopt this technology (Mahdavian et al., 2021). Thus, a barrier determinator has been considered, synthesizing studies on economic and infrastructure barriers including high purchase costs, expensive batteries, limited charging infrastructure, battery range, driving range, and charging stations. The results of studies have shown financial incentives including tax exemptions (Liu et al., 2021a; Wu et al., 2021) and non-financial incentives (e.g., free parking and access to bus routes) (Ogunkunbi et al., 2021). These incentives were suggested to cheer the use of electric cars. In this context, financial incentives are more effective than non-financial incentives. However, non-financial incentives make users feel supported and appreciated by supporting social and emotional well-being (Chi et al., 2023). In this regard, an incentive determinator has been incorporated, synthesizing studies on various incentives.

2.3. Strengths and weakness of previous studies

Finally, the researchers acknowledged that the majority of users who have experience driving electric vehicles tend to use this technology in the future (Krishna, 2021; Mahdavian et al., 2021). In contrast, threats, for example, targeted malware attacks, key spoofing, remote control of the vehicle, and control of acceleration and braking often limit the selection of electric cars (Laraib and Ujjan, 2024). Presenting the quantitative coefficients of factors affecting the probability of adopting electric cars based on regression estimation is appropriate although there are also deficiencies that this study has taken steps to resolve. While developed countries have made considerable progress in adopting electric vehicles (Zhuge and Shao, 2019), he selection of electric cars in developing nations can be promising. The selection of electric cars in developing nations depends on addressing critical challenges and creating the right policies, infrastructure, and systems (Rajper and Albrecht, 2020). According to our knowledge, previous studies have not considered the factors affecting all types of electric vehicles, while this study includes different types of electric ones. In addition, previous studies did not consider all of the influencing factors, but this study tried to include all the influencing factors. Although previous studies have been conducted regionally or nationally, this study can be interpreted by synthesizing the effect coefficients of the primary articles at the global level.

3. Methodology

This study is a systematic review and meta-analysis that used the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) standards (Parums, 2021). This study has used meta-regressions to provide information in different functions to synthesize the effects of drivers affecting the adoption of electric vehicles. Various advantages of these regressions include assessing the effects of different influential factors, generating new hypotheses to obtain spatial and temporal patterns, and assessing the quality of primary articles. The advantage of meta-regression analysis is a reliable method for identifying variables that affect the topic. The process of performing a meta-regression allows confidently determine which factors matter most, which factors can be ignored, and how these factors influence each other.

3.1. Probing plan

This study directed a comprehensive keyword probing to collect all relevant articles in Google Scholar, Science Direct, Springer, Scopus, ProQuest, Oxford University Press, and SID for English language publications from 1990 to 2023. Probing keywords included "environmental awareness", "user attribute", "perceived advantage", "barrier", "incentive", "knowledge and awareness of users", "age", "education", "high purchase cost", "expensive batteries", "limited charging infrastructure", "battery range", "driving range", "charging station", "tax exemption", "free parking", "access to bus routes", "technical feature", "fuel-saving advantage", "Battery Electric Vehicles (BEVs)", "Plug-in Hybrid Electric Vehicles (PHEVs)", and "Hybrid Electric Vehicles (HEVs)". After the first search, the retaken records were attentively concealed applying predefined inclusion and exclusion criteria. If there are subsequent publications, this is great to consider that the present study performed a complete review of the reference lists of relevant articles identified during the probing process, along with articles that met the predefined inclusion criteria. Thus, a thorough and comprehensive review of all relevant literature is ensured using this rigorous approach.

3.2. Choosing articles

According to PRISMA guidelines, the original articles were selected through a rigorous process by two independent reviewers. First, the primary reviewer performed the prob based on the predefined keywords above. In the next step, duplicate articles were carefully removed and the number of original articles was equal to 3654. Two independent reviewers thoroughly screened the article titles and abstracts according to the inclusion criteria. Complete contents of articles that could not be decided based on the title and abstract alone were downloaded and reviewed by two autonomous reviewers. To ensure accuracy and precision in the article selection process, consultation with a third researcher was employed. The PRISMA process is shown graphically in Fig. 1.

3.3. Inclusion criteria

To consider original articles, the following criteria must be met: 1) focus on the main drivers of the adoption of electric vehicles, 2) the unit of measurement (i.e., Likert scale) should be considered the same for the effective drivers, 3) report quantitative findings that evaluate the impact of the main drivers on the adoption of electric vehicles, (i.e., BEVs, PHEVs, and HEVs) 4) should be printed in peer-reviewed journals in English before September 2023.

Selected articles were excluded from the review process when they met one of the following criteria. Firstly, statistical inaccuracies reduce the accuracy of meta-regressions. Secondly, qualitative methods didn't assess the effect of influential drivers (e.g., environmental awareness, user attributes, barriers, incentives, user awareness) on the adoption of electric vehicles. Thirdly, the effect sizes were measured based on units other than the percentage differences to avoid heterogeneity in the meta-regression. Fourthly, studies printed both as journal articles and as dissertations to make sure no data duplication.

3.4. Inclusion articles

Initial screening was performed to exclude duplicate or irrelevant articles, and this caused to a total of 3654 articles. In the next step, the abstracts of these articles were carefully reviewed and 2970 articles were excluded as they were not mainly related to the main drivers of adopting electric cars. This study determined that an additional 582 articles on electric vehicles adoption framework without quantitative effect estimates should be excluded after a full-text review of the remaining 684 articles. After the mentioned screening, just 102 articles entered the next step of selection. However, 64 studies that suggested adopting electric vehicles from influential drivers, but did not estimate quantitative effects, were excluded. Finally, the remaining 38 primary articles addressed all criteria and were imported in the analysis (Appendix A).

3.5. Quality control

Two reviewers apart controlled the quality of the literature by applying the Cochrane risk of bias method (Minozzi et al., 2022). In this regard, the normal log of the fixed amounts of the impact was applied to decrease the possible heterogeneity. This can ensure that a strong basis for meta-analysis is built. The sample size is implicitly considered in this study and affects the dependent variable's weight. In this way, the results of meta-regressions can be generalized to the global level.

3.6. Coding manner

The methodology included the extraction of key elements regarding the selection of electric cars and its underlying motivators from each source, in preparation for a comprehensive meta-analysis. The elements gathered from the included articles encompass the following categories: 1) primary motivators for electric vehicle adoption, 2) temporal considerations, 3) spatial variables, 4) publication characteristics, and 5) methodology specifics.

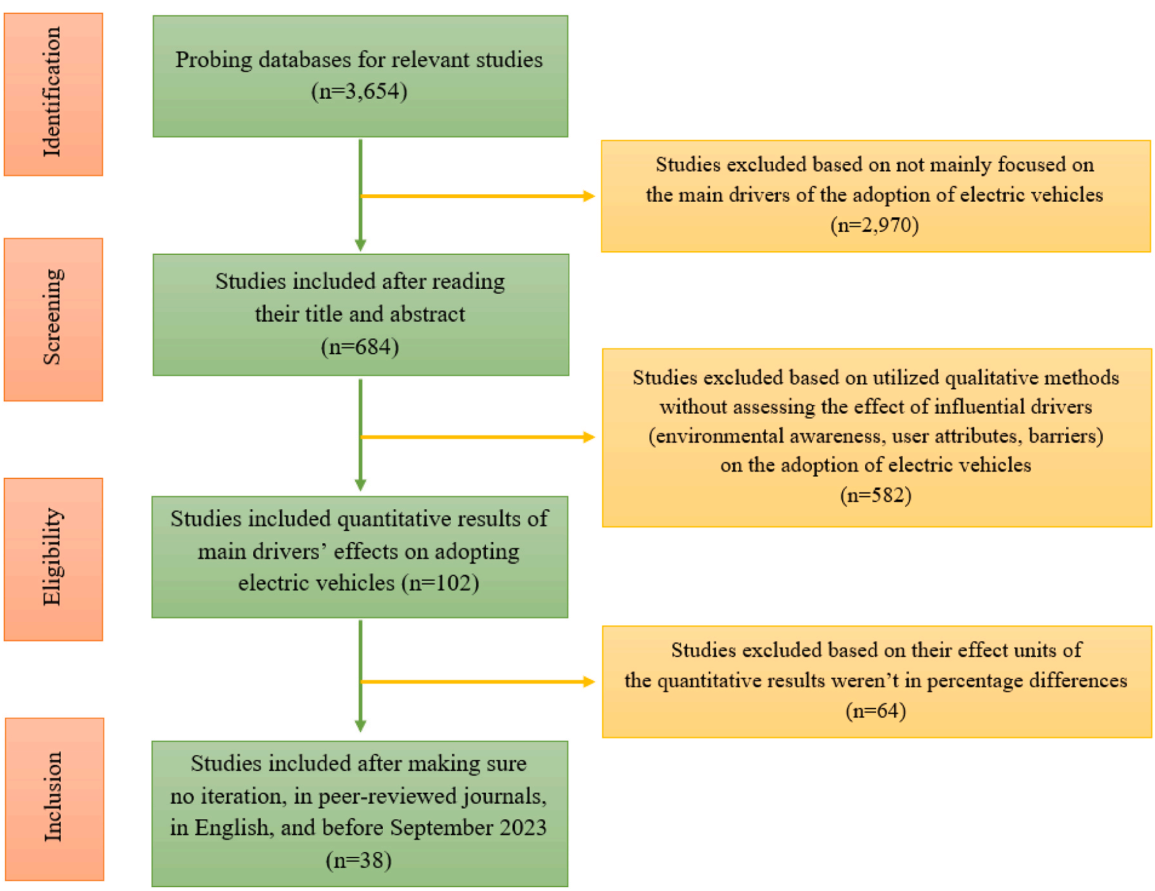

Fig. 1. The PRISMA process.
Source: Study finding.

3.7. Analysis

The mean effect and median effect were applied to operate the meta-analysis. The median effect is a better measure compared to the mean effect because it is not skewed by extremely high or low characteristic values. The usual form of the model is:

$$M_{ij} = \alpha_0 + \sum \beta_k E_{ij,k} + \mu_j + \varepsilon_{ij} \quad (1)$$

where M_{ij} mentions the dependent variable i of the estimate of electric vehicle adoption in a certain article j, $E_{ij,k}$ shows the regressor k and β_k indicates the related parameter. α_0 is the constant, μ_i is an article-certain impact, and ε_{ij} is a residual error. This study determined the effect size of influential drivers, and 95 % confidence intervals (CI) for adopting electric vehicles. P value and I^2 tests were used to evaluate statistical heterogeneity. Heterogeneity was considered to be heterogeneous when P is less than 0.05 or I^2 is more than 50 %, and hence, random effects models were applied. Otherwise, the fixed effects models were used. This rigorous approach contributed to retaining the entirety of the analysis. The Stata17 was applied to estimate the models.

4. Results

4.1. Meta-regressions in previous research

The frequency of original studies is shown in Table 1. An overview of explanatory variables detects those primary articles centralized on various drivers (i.e., environmental awareness, user attributes, barriers, incentives, and user awareness). About 29 % and 34 % of primary articles comprised environmental awareness and user attributes drivers. Those main drivers deal with environment-friendly technology, age, and education. In contrast, 21 % of primary articles included barriers that deal with high purchase costs, expensive batteries, limited charging infrastructure, battery range, driving range, and charging stations. In addition, around 10 % and 5 % of primary articles comprised incentives and user awareness drivers. Those main drivers deal with tax exemption, free parking, access to bus routes, technical features, and fuel-saving advantages. It is expected that main drivers, like environmental awareness, user attributes, barriers, incentives, and user awareness can improve the adoption of electric vehicles (i.e., BEVs, PHEVs, and HEVs). Initial data were gathered on main drivers in 28 various countries from 1990 to 2023. Respectively, 2.6, 10.5, 31.6, 34.2, and 21.1 percent of primary articles were conducted in Africa, America, Asia, Europe, and Oceania. Thus, the sample of selected articles can represent global research on electric vehicle adoption. The spatiotemporal effects of main drivers on adopting electric vehicles are expected to be significant. According to publication type, a substantial 76.3 % of the primary articles were disseminated through ISI Journals. It is worth noting that papers published in these journals undergo a rigorous review process, which enhances the scientific credibility and validity of the articles. The current review focused on the effect of the main drivers and other drivers listed (see Table 1) on adopting electric vehicles.

Table 2 shows the findings of this study. Accordingly, the Adjusted R^2 obtained was from 0.53 to 0.76, which means the considerable percentages of dependent variables changes were described by the independent variables considered in the analysis. The results show that the main drivers have significant effects on all types of electric vehicles, namely BEVs, PHEVs, and HEVs at 1 %, 5 %, and 10 % levels. The findings indicate that the main drivers have significant effects on all types of electric vehicles, namely BEVs, PHEVs, and HEVs at 1 %, 5 %, and 10 % levels. In other words, there is a 1 %, 5 %, and 10 % chance that electric vehicle adoption will not occur or that it just happened by chance alone. In the following parts, the descriptions are introduced in detail. The temporal effects (i.e., data gathering year) have positive influences on the global adoption of electric vehicles. The temporal effects show an increase in adopting BEVs by 16 % and a rise in adopting PHEVs by 7 %. Moreover, the temporal effect increases the adoption of HEVs by 9 %. Given the spatial effects, Asia, Europe, and Oceania have significantly positive influences on adopting BEVs (8 %, 17 %, and 11 %, respectively), adopting PHEVs (6 %, 14 %, and 9 %, respectively), and adopting HEVs (10 %, 15 %, and 13 %, respectively). Several goals and policies have prevailed in the selection of electric cars in various regions of the world. For example, the Indian government has aligned its new electric vehicle policy with climate goals to reduce emissions intensity by 45 percent by 2030 and achieve net zero emissions by 2070. However, China has enacted policies to boost the selection of electric cars and reduce dependence on oil. Beijing only issues 10,000 permits per

Table 1
The frequency of original studies.

Factor	Variable	Kind	Definition	Frequency (%)
Main driver	Environmental awareness	Dummy	When the main driver deals with environment-friendly technology.	28.9
	User attributes	Dummy	When the main driver deals with age and education.	34.2
	Barriers	Dummy	When the main driver deals with high purchase costs, expensive batteries, limited charging infrastructure, battery range, driving range, and charging station.	21.1
	Incentives	Dummy	When the main driver deals with tax exemption, free parking, and access to bus routes.	10.5
	User awareness	Dummy	When the main driver deals with technical features and fuel-saving advantages.	5.3
Temporal factor	Year of data	Continuous	The paper collected its data from 1990 to 2023.	100
Spatial factor	Africa	Dummy	When the study area deals with Africa.	2.6
	America	Dummy	When the study area deals with America.	10.5
	Asia	Dummy	When the study area deals with Asia.	31.6
	Europe	Dummy	When the study area deals with Europe.	34.2
	Oceania	Dummy	When the study area deals with Oceania.	21.1
Publication type	ISI publication	Dummy	When the printed type deals with ISI Journal.	76.3
Methodology type	Method	Dummy	When the method captures heterogeneity.	2.6

Source: Study finding.

Table 2
Factors affecting meta-regressions.

Factor	Variable	Electric cars					
		Battery Electric Vehicles (BEVs)		Plug-in Hybrid Electric Vehicles (PHEVs)		Hybrid Electric Vehicles (HEVs)	
		Coefficient	Standard error	Coefficient	Standard error	Coefficient	Standard error
Main driver	Environmental awareness	0.23**	0.11	0.17*	0.09	0.15**	0.07
	User attributes	0.16***	0.05	0.14***	0.06	0.17**	0.08
	Barriers	−0.07***	0.03	−0.05***	0.02	−0.07***	0.03
	Incentives	0.14	0.12	0.11	0.08	0.17***	0.07
	User awareness	0.12***	0.03	0.09***	0.03	0.11**	0.05
Temporal factor	Data gathering year	0.16***	0.05	0.07**	0.03	0.09**	0.04
Spatial factor	Africa	0.06	0.05	0.04	0.03	0.07	0.05
	America	0.15	0.18	0.09	0.14	0.10	0.13
	Asia	0.08***	0.02	0.06***	0.02	0.10**	0.05
	Europe	0.17***	0.06	0.14***	0.06	0.15***	0.06
	Oceania	0.11***	0.04	0.09**	0.04	0.13**	0.06
Publication type	ISI publication	0.15***	0.04	0.23**	0.12	0.18**	0.09
Methodology type	Method	0.06	0.13	0.02	0.03	0.04	0.06
Number of observations		28		18		32	
Adjusted R^2		0.67		0.53		0.76	

Source: Study finding
* , * *, and * ** show significant effects at 10 %, 5 %, and 1 %, respectively.

month for gasoline vehicles as a way to adopt electric vehicles. Vietnam reduced import duties for electric vehicles and exempted electric vehicle investment projects from corporate income tax. The preferential and supportive policies applied by the government played a significant role in promoting the adoption of these types of cars in Vietnam. In addition to creating incentives for electric vehicles, Norway invested in world-class charging infrastructure to support the transition to more sustainable vehicles. Moreover, when the original study is printed in an ISI publication, the adoption of BEVs, adoption of PHEVs, and adoption of HEVs will increase by 15 %, 23 %, and 18 %, respectively. This paper calculated the mean and median effects to check the main drivers' effects on adopting electric vehicles in the next sections.

4.2. Battery Electric Vehicles (BEVs)

According to Table 2, the main drivers show significant influences on mean adoption BEVs. In this regard, environmental awareness, user attributes, barriers, and user awareness have significant influences on adopting BEVs, but incentives do not have any significant influences on adopting BEVs. The main driver in terms of environmental awareness, user attributes, barriers, and user awareness resulted in variation in the average adoption of electric vehicles by 23 %, 16 %, −7 %, and 12 %, respectively. Therefore, it is concluded that those main drivers lead to improvement in the global adoption of BEVs consisting of a kind of electric car that solely utilizes chemic energy kept in rechargeable battery loads.

The median effects of main drivers on adopting BEVs are illustrated in Fig. 2. The median effect of environmental awareness, user attributes, barriers, and user awareness drivers on adopting BEVs are 0.21, 0.12, −0.05, and 0.09, respectively, and the effects were significant (Fig. 2). Actually, the results demonstrated that median adoption of BEVs for environmental awareness driver is about 42.8 %, 123.8 %, and 57.1 % more than the median adoption of BEVs for user attributes, barriers, and user awareness, respectively. The findings show that the impact on the median adoption of BEVs for incentives is insignificant and negligible (Fig. 2).

4.3. Plug-in Hybrid Electric Vehicles (PHEVs)

According to Table 2, the main drivers show significant influences on the mean adoption of PHEVs. In this regard, environmental awareness, user attributes, barriers, and user awareness have significant influences on adopting PHEVs, but incentives do not have any significant influences on adopting PHEVs. The main driver deals with environmental

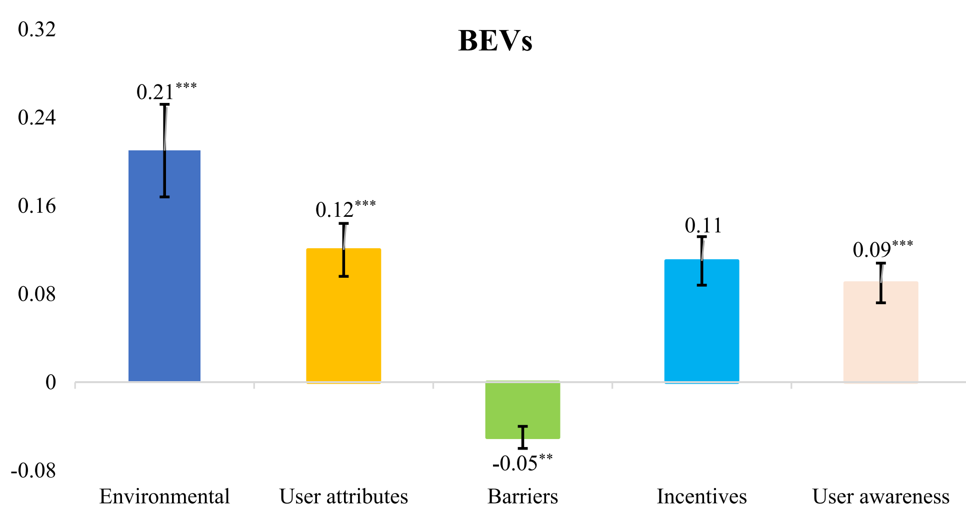

Fig. 2. Median effects of main drivers on adopting BEVs. * *, and * ** show significant effects at 5 %, and 1 %, respectively.
Source: Study finding.

awareness, user attributes, barriers, incentives, and user awareness resulting in respectively 15 %, 17 %, −7 %, 17 %, and 11 % variation in the average adoption of electric vehicles. Therefore, those main drivers lead to improvement in the global adoption of PHEVs consisting of a hybrid electric car whose battery load could be recharged by plugging a charging cable to an outer electric power source.

The median effects of main drivers on adopting PHEVs are illustrated in Fig. 3. The median effect of environmental awareness, user attributes, barriers, and user awareness drivers on adopting PHEVs are 0.14, 0.11, −0.03, and 0.07, respectively, and the effects were significant (Fig. 3). Actually, the results demonstrated that the median adoption of PHEVs for environmental awareness driver is about 21.4 %, 121.4 %, and 50 % more than the median adoption of PHEVs for user attributes, barriers, and user awareness, respectively. The findings show that the impact on the median adoption of PHEVs for incentives is insignificant and negligible (Fig. 3).

4.4. Hybrid Electric Vehicles (HEVs)

According to Table 2, the main drivers show significant influences on the mean adoption of HEVs. In this regard, environmental awareness, user attributes, barriers, incentives, and user awareness have significant influences on adopting HEVs. The main driver deals with environmental awareness, user attributes, barriers, incentives, and user awareness resulting in respectively 15 %, 17 %, −7 %, 17 %, and 11 % variation in the average selection of electric cars. Therefore, it is concluded that the main drivers lead to improvement in the global adoption of HEVs consisting of a kind of hybrid car that merges a normal inner fuel motor system with an electric thrust system. The existence of the electric powertrain is intended to attain finer fuel economy than a normal one.

The median effects of main drivers on adopting HEVs are illustrated in Fig. 4. The median effect of environmental awareness, user attributes, barriers, incentives, and user awareness drivers on adopting HEVs are 0.13, 0.15, −0.06, 0.13, and 0.08, respectively, and the effects were significant (Fig. 4). Actually, the results demonstrated that the median adoption of HEVs for user attributes driver is about 13.3 %, 140 %, 13.3 %, and 46.7 % more than the median adoption of HEVs for environmental awareness, barriers, incentives, and user awareness, respectively.

The regional effects of the main drivers on adopting electric cars are illustrated in Fig. 5. The continental effects of environmental awareness, user attributes, barriers, incentives, and user awareness drivers on adopting electric cars in developed countries are 0.25, 0.21, −0.03, 0.13, and 0.11, respectively, and the effects were significant (Fig. 5). Actually, the results demonstrated that the regional adoption of electric cars for environmental awareness driver is about 16 %, 112 %, 48 %, and 56 % more than the adoption of electric cars for user attributes, barriers, incentives, and user awareness, respectively.

5. Discussion

As the findings of this study show, the temporal effects are significant in adopting electric vehicles (i.e., BEVs, PHEVs, and HEVs). The main factors influencing the adoption of electric cars in a region can be explained by continental areas, in a way that European countries show the most spatial effects on adopting electric vehicles (i.e., all types of electric cars). Thus, the spatiotemporal effects on the adoption of electric vehicles are significant. Although Asian countries, such as China, India, and Singapore have favorable conditions and infrastructure for electric vehicle adoption, its adoption rates in Asia are lower than in Europe and Oceania. In this context, this is recommended to investigate the factors influencing electric vehicle adoption in Asia. The results of the main drivers' contribution to the selection of electric cars are discussed in detail below.

5.1. Environmental awareness

The outputs of the synthesis indicate that environmental awareness can impact the median selection of electric cars, including BEVs (21 %), PHEVs (14 %), and HEVs (13 %). Therefore, the selection of electric cars are improved via environmental awareness of environmentally friendly technology. Moreover, according to the meta-regression findings, environmental awareness has a significantly positive impact on the average adoption of all types of electric vehicles. Thus, according to the median and mean effects, environmental awareness could have a significant effect on adopting electric vehicles. Accordingly, this part addressed the first research question about the global effects of environmental awareness on adopting electric vehicles. The results of other studies such as those by Shalender and Sharma and Singh et al. (2020), aligned with the findings of the current study. In this regard, Shalender and Sharma predicted the intention to accept the purchase of electric cars in India. Their results showed that environmental concerns along with other psycho-behavioral factors has a positive impact on buyers' acceptance intention. Singh et al. (2020) investigated the factors influencing consumer intention to adopt an electric vehicle. Their results showed that environmental concern is an understudied factor in electric vehicle

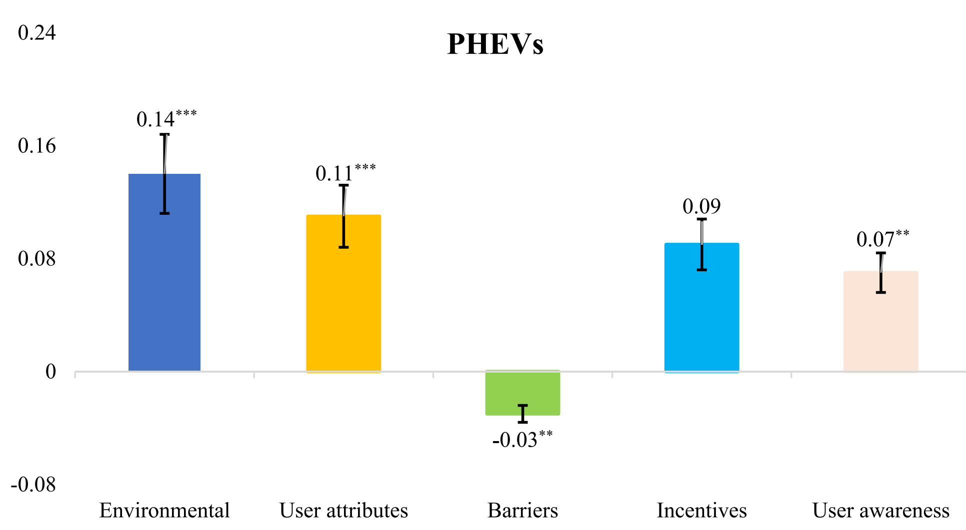

Fig. 3. Median effects of main drivers on adopting PHEVs. **, and *** show significant effects at 5 %, and 1 %, respectively.
Source: Study finding.

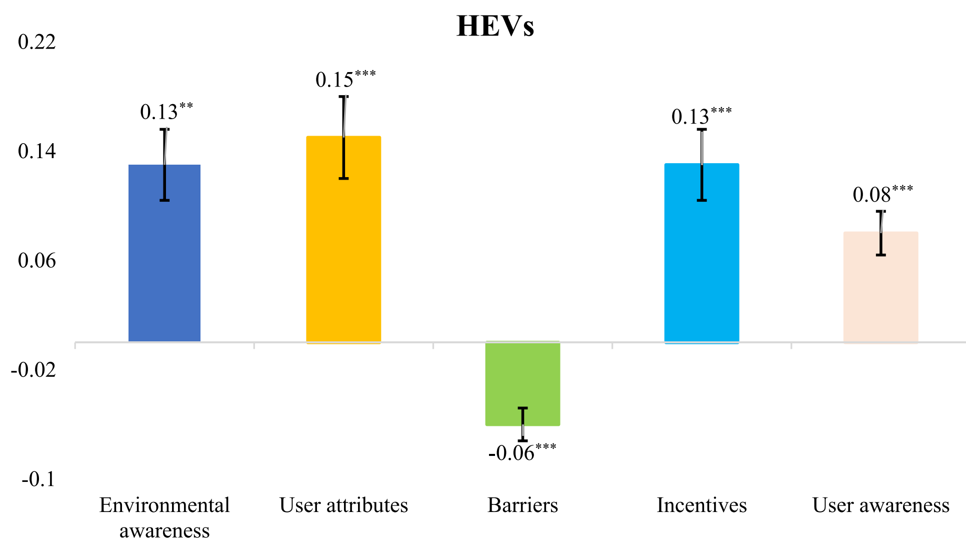

Fig. 4. Median effects of main drivers on adopting HEVs. * *, and * ** show significant effects at 5 %, and 1 %, respectively.
Source: Study finding.

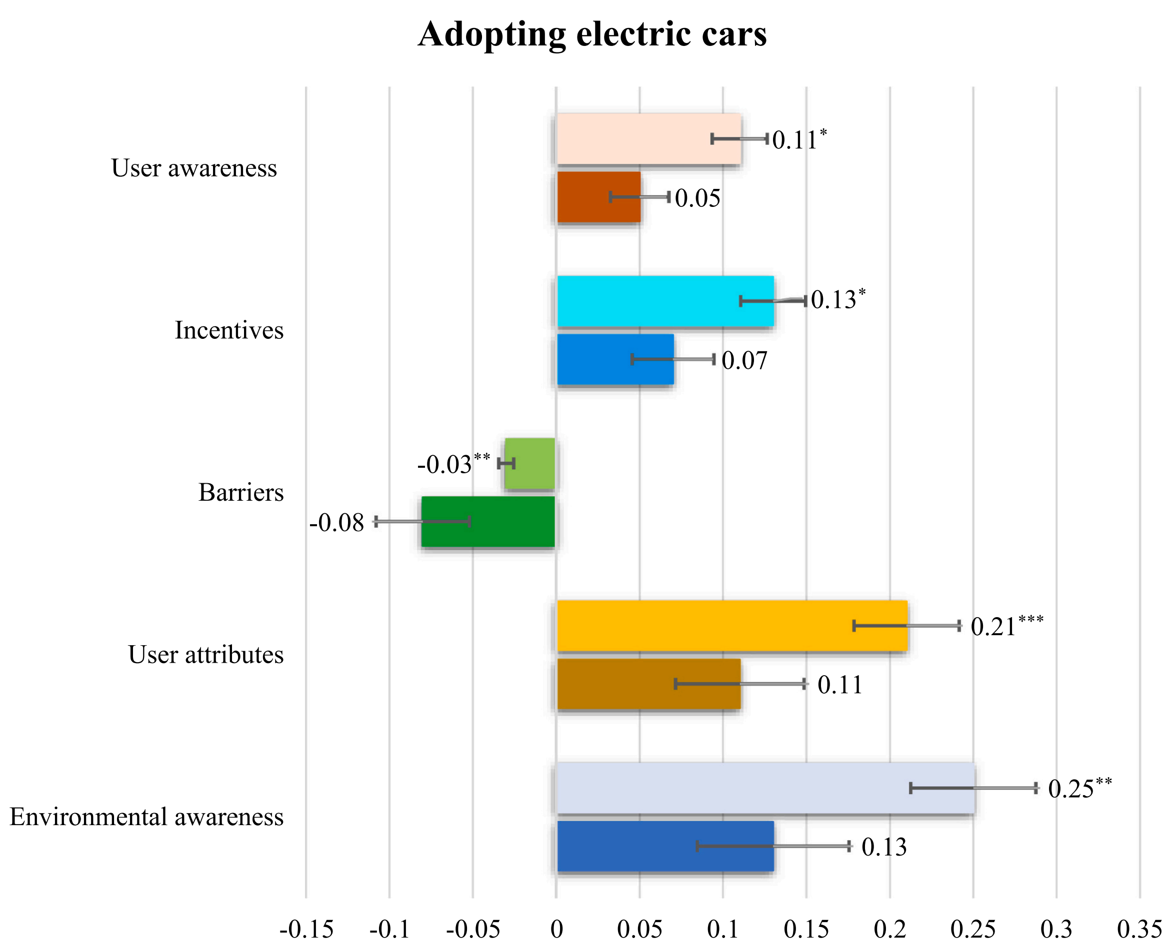

Fig. 5. Regional effects of main drivers on adopting electric cars. *, **, and *** show significant effects at 10 %, 5 %, and 1 %, respectively. Dark colors show developing countries and light colors indicate developed countries.
Source: Study finding.

adoption.

5.2. *User attributes*

The outputs of the synthesis indicate that user attributes can affect the median selection of electric vehicles (i.e., BEVs (12 %), PHEVs (11 %), and HEVs (15 %)). Therefore, user attributes, such as age and education, can improve electric vehicle adoption. Moreover, according to the meta-regression findings, user attributes have significantly positive impacts on the average adoption of all types of electric vehicles.

Thus, according to the median and mean effects, user attributes could have a significant effect on adopting electric vehicles. In this way, the second research question has been met about the global impacts of user attributes on adopting electric vehicles. The outcomes of the research by Yang et al. (2019) and Zhao et al. (2022) were in line with the results of this paper. In this regard, Yang et al. (2019) identified drivers that could encourage users to select electric vehicles from inner and outer views in China. Their results showed that the adoption of electric cars and the understanding of incentive policies were different in various demographic groups. Zhao et al. (2022) investigated the demographic characteristics impacting the selection of electric cars in Shanghai, China. Their results showed that younger but educated individuals were more likely to choose electric cars.

5.3. Barriers

The results indicate that the main driver of barriers could affect the median adoption of BEVs, PHEVs, and HEVs, respectively by −5 %, −3 %, and −6 %. Therefore, barriers, like high purchase costs, expensive batteries, limited charging infrastructure, battery range, driving range, and charging stations could decrease the selection of electric cars. Moreover, according to the meta-regression findings, barriers have significantly negative impacts on the average adoption of all types of electric vehicles. Thus, according to the median and mean effects, barriers could have a significant effect on adopting electric vehicles. Active user education can overcome the challenges of marketing electric vehicles, such as range anxiety, regulatory and policy concerns, charging infrastructure concerns, and safety concerns. For example, concerns about how far an electric car can travel on a single charge has been a common challenge that can be addressed through user education campaigns. Accordingly, the third research question about the global impacts of barriers to adopting electric vehicles has been met. The results of other studies such as Krishna (2021) and Tarei et al. (2021) were in line with the results of this paper. In this regard, Krishna (2021) examined the usual understanding of electric cars between users and the barriers to their general selection. Qualitative analysis revealed a clearer understanding of the barriers and provided contextual data to understand the barriers. Tarei et al. (2021) focused on technological, infrastructural, financial, behavioral, and external barriers for the Indian electric vehicle context. Their findings showed that the main barriers to electric vehicle adoption include efficiency and span, total expense of ownership, and lack of charging foundation.

5.4. Incentives

The results indicate that the main driver of incentives can contribute to the median adoption of HEVs by 13 %. Therefore, incentives such as tax exemption, free parking, and access to bus routes can improve the adoption of electric vehicles in the type of HEVs. However, the median effect of incentives on the selection of BEVs and PHEVs is insignificant. In addition, based on the meta-regression results, incentives have a significantly positive effect on the average selection of HEVs. Thus, according to the median and mean effects, incentives could have a significant effect on adopting HEVs. In this way, the fourth research question about the global impacts of incentives on adopting electric vehicles have been met. The findings of other research such as Ogunkunbi et al. (2022) and Wang et al. (2018) were in line with the results of this paper. In this regard, Ogunkunbi et al. (2022) examined the range of incentives adopted in 15 countries and their impact in the electric vehicle market among other drivers. Their results identified the availability of manufacturing facilities, income, access to quick charging foundation, and value-added tax exclusion as positive and statistically significant drivers for electric vehicle market share. Wang et al. (2018) investigated the relationship between incentive policies and socioeconomic factors and national electric vehicle market shares. Their results showed that charging density and fuel price are significant positive factors in electric vehicle market shares.

5.5. User awareness

The outputs of the synthesis indicate that user awareness can affect the median selection of electric vehicles (i.e., BEVs (9 %), PHEVs (7 %), and HEVs (8 %)). Therefore, user awareness about technical features and fuel-saving advantages can improve the adoption of electric vehicles. Moreover, according to the meta-regression findings, user awareness had significantly positive impacts on the average adoption of all types of electric vehicles. Thus, according to the median and mean effects, user awareness could have a significant effect on adopting electric vehicles. Accordingly, the fifth research question about the global impacts of user awareness on adopting electric vehicles has been met. The findings of other research such as Asadi et al. (2021) and Wang et al. (2021) were in line with the results of this paper. In this regard, Asadi et al. (2021) identified factors affecting consumers' willingness to use electric vehicles in Malaysia. Based on the results, the consumer's perceived effectiveness and awareness of the consequences had a positive and significant effect on consumers' intention to purchase electric cars.

Since this review synthesized quantitative results from original articles, the meta-regression outcomes could be lower or higher than the effects reported in those articles. The limitation of this study is there are no original articles considering all kinds of adaptation motivations of electric vehicles and each study just takes into account a few motivations. Furthermore, not enough studies in the dataset in certain areas, such as Africa, may bias meta-regression outcomes at the world level.

6. Conclusion and policy implications

The findings showed that the main drivers would lead to adopting electric vehicles. In response to the first research question, it is important to note that environmental awareness, user attributes, barriers, and user awareness have a significant effect on the adoption of electric cars, including BEVs, PHEVs, and HEVs. Therefore, some main drivers (i.e., environmental awareness, user attributes, barriers, and user awareness) can change the selection of electric cars. The second research question has been met by the spatiotemporal effects on different adopting electric vehicles. Among the temporal effects of different types of electric cars, there is the greatest positive impact on the adoption of BEVs. Besides, among the spatial effects for different continental regions, European countries seem to have the largest positive impact of the main drivers on the adoption of BEVs. Thus, the findings of this study are completely in line with the current market trends in the field of the emergence of autonomous electric vehicles, in which countries such as Norway, the Netherlands, Iceland, and Germany are the drivers in this market. Norway's policy of combining tax breaks as a financial incentive and free parking for electric vehicles as a non-financial incentive has caused this country to become the largest electric vehicle market in the world.

In summary, influencing factors can be effective in electric vehicle adoption. Policy-makers must consider the perspectives for future global electric vehicle adoption based on their benefits (e.g., not emitting pollutants, increasing energy security, decreasing fuel price fluctuations, and better performance).

Various recommendations can be made to policy-makers. Due to the non-emission of environmental pollutants, the use of electric cars is recommended, especially in large countries that emit greenhouse gases such as China and India. The expansion of electric vehicles, especially the use of renewable energy, is suggested to reduce fuel dependency. It is recommended that policymakers use the promotion of electric vehicles to reduce fuel imports and reduce vulnerability to fuel price fluctuations, especially in countries dependent on fossil fuels such as Middle Eastern countries. To reduce economic barriers such as high battery costs in developing countries, it is recommended to make policies to schedule car charging during off-peak hours, usually late at night or early in the morning. In this context, increased environmental awareness is recommended to accelerate the adoption of electric vehicles, and tax exemptions are suggested to counter the resistance of the entrenched automotive and fossil fuel industries. In summary, to provide direction for forthcoming research endeavors, it is recommended that future studies investigate the psychological factors that impact the adoption of electric vehicles. Furthermore, it is essential for future research to explore diverse approaches for evaluating individuals' satisfaction with electric vehicle usage to ultimately bolster future adoption rates. Consumer behavior models to better predict the adoption of emerging technologies such as electric vehicles must evolve through improving the level of user awareness, and the results of this study have also shown that increasing the level of user awareness has the greatest role in the adoption of electric vehicles. In this way, electric cars can replace conventional cars as vehicles by improving fuel consumption, reducing fuel costs, and reducing pollutants. In addition, it is an interesting topic for future research to quantify the impact of electric vehicle adoption on environmental quality, i.e. CO2 savings, especially considering regional effects.

CRediT authorship contribution statement

Frank Witlox: Writing – original draft, Supervision, Methodology, Conceptualization. **Yuanzhi Wang:** Writing – original draft, Investigation, Formal analysis.

Declaration of Competing Interest

Regarding our paper "Driving Change: Global Trends in Electric Vehicle Adoption and the Impact of Environmental Awareness, User Attributes, and Barriers" submitted to your journal we state that we have no interest to declare.

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Appendix A

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Data availability

No data was used for the research described in the article.

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