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Review

State-of-the-Art Review of the Key Factors Affecting Electric Vehicle Adoption by Consumers

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Abstract: The dependence of road transport on fossil fuels and its contribution to greenhouse gas (GHG) and pollutant emissions are main concerns leading to the need for shifting toward alternative energy sources and, namely, electromobility. The current paper aims to identify the key determinants affecting the consumer adoption of electric vehicles (EVs), focusing on private passenger cars. Toward this purpose, a systematic review of recent international literature is conducted in order to identify motivators and barriers, which are then categorized following the PESTLE (Political–Economic–Social–Technological–Legal–Environmental) approach. Based on the review results, main policy implications and recommendations are discussed. A main conclusion is that the recent literature highlights a wide array of determinants, without converging as to which ones are the most influential regarding EV adoption by consumers. Another conclusion is that the environmental aspects are less important for consumers than anticipated, despite the concerns about climate change and renewable energy transition.

Keywords: electric vehicles; EV adoption; consumer; determinants; factors; PESTLE; literature review

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1. Introduction

The reliance of transport in fossil fuels is higher than any other end-use sector. According to the most recent available data for 2022, the transport sector's share of CO_2 emissions has reached approximately 37%, presenting an increasing trend after lifting mobility restrictions due to the COVID-19 pandemic [1]. Road transport is responsible for the majority of greenhouse gas (GHG) emitted by transport. In Europe, for example, road transport GHG emissions correspond to more than 70% of total domestic and international transport GHG emissions [2]. In addition, road transport is responsible for pollutant emissions, such as NOx and particulate matter, as well as for unacceptable noise levels. The need to reduce the negative external impacts from road transport is even more crucial in the urban context, with cities being responsible for consuming 78% of energy resources and producing more than 60% of GHG emissions globally [3]. Approximately 68% of the world's population is expected to reside in cities by 2050 [4]. Taking the above into account, the shift to carbon-neutral, environmentally friendly and overall sustainable transport for all is timelier than ever.

The promotion of electromobility (e-mobility) is considered one of the main policies to achieve sustainable road transport [5]. A main advantage of electric vehicles compared to conventional vehicles with internal combustion engine (ICE) refers to energy efficiency. The reduction in energy use of a battery electric vehicle (BEV) compared to an ICE vehicle is estimated to exceed 75% [6]. On the other hand, the lifecycle performance of electric vehicles regarding GHG emissions depends mainly on the energy mix to produce electricity and the developments in battery manufacturing and recycling technologies [7–10]. Electric

vehicles (EVs) also have a strong potential for reducing pollutant emissions, including noise pollution [10–12].

Following the promotion policies and the industrial and technological advancements in the field of electromobility, the market of electric vehicles has been rapidly growing. In 2021, one out of ten car sales globally were electric, corresponding to a four-fold rise compared to 2019 and leading to a total number of 16.5 million electric cars worldwide [13]. However, the share of electric vehicles to the total number of circulating cars in the world is still relatively small, while great differences are observed in the adoption of electromobility between different regions and countries [14]. For example, studies argue that some countries, such as the Scandinavian countries and northern Europe, are pioneers in electromobility advancements, and others, such as China, are investing in smaller vehicles and lower manufacturing costs to bridge the price gap between electric and conventional vehicles, while many countries are still lagging behind in electric car adoption [15–17].

In the above context, the scope of the current paper is to contribute to the international research on the main determinants that affect the adoption of electric passenger cars by consumers (end-users) in different geographic areas of the world. These determinants are characterized either as motivators, i.e., aspects that positively affect end-users into selecting an electric vehicle over a conventional one, or as barriers, i.e., aspects that hinder the selection of electric vehicles by end-users. Moreover, the current research brings forward determinants that are perceived in a different way by different samples of end-users in different geographical areas, leading sometimes to contradictory results. The comprehensive and comparative presentation of these determinants can enhance the understanding of policymakers, private bodies and citizens regarding the benefits and drawbacks of electromobility. This understanding will enhance the capacity to develop appropriate policies that will improve the efficiency of the market by addressing the real needs and expectations of consumers. A main research objective of the current study is the identification of the main determinants of EV adoption by consumers and their comparative analysis in terms of the importance attributed by consumers in the international literature. Moreover, the study attempts to assess the importance of the current climate crisis as a determinant of consumers' EV adoption in comparison to other determinants, such as personal costs, range anxiety and charging infrastructure availability.

The vast majority of recent research papers in the field of EV adoption refer to the assessment of the determinants that affect consumers' choices and/or perceptions. There are also few papers that review the international literature on EV adoption determinants [18–21]. In particular, Singh et al. [18] categorized the factors influencing consumers' intention to adopt an EV into four main categories (demographic, situational, contextual, psychological), in order to examine their influence on consumers' intention to adopt an EV. Kumar and Alok [19] studied the mechanisms of EV adoption, by categorizing the main mediators and moderators into five main categories (technical and product features, government policy, sociodemographic factors, social influence, consumer behavior). Stockkamp et al. [20] adopted the above-mentioned categorization in order to study the factors associated with EV adoption by consumers. Austmann [21] examined the influence of relevant determinants on the EV market. The added value of the current paper on the existing literature stems from the collection and comprehensive analysis of the most recent, highly influential research papers and the categorization of the determinants of EV consumer adoption based on the PESTLE (Political–Economic–Social/Sociodemographic–Technological/Technical–Legal-Environmental) analysis [22]. This categorization allows for the systematic review and the comparative analysis among broader categories of determinants. More specifically, the current paper is based on the systematic review of recent international literature in order to identify the aspects that affect the adoption of electric passenger cars by end-users and to organize them into main determinants, following the PESTLE analysis.

After the Introduction, the terms "electric vehicle" and "electromobility" are defined, and the categories of electric vehicles are briefly presented. Next, the methodology of the current research is described, followed by the organized presentation of results. The results

include the brief presentation of the bibliographic metrics and the publication details, methodological approach and location of the study area of each of the examined papers. They also include the comprehensive analysis of the motivators and barriers that derive from these papers, as key determinants of EV adoption. In the final part of the paper, the identified determinants related to EV adoption are summarized, and the main results are discussed, while conclusions, managerial and policy implications and prospects for future research are also included.

2. Definitions and Categorization of Electric Vehicles

Prior to the in-depth examination of the determinants affecting the adoption of electric passenger cars, it is important to provide a definition of the corresponding terms. According to the European Union Science Hub [23], electromobility "refers to clean and efficient transport, using electric vehicles, powered either by batteries or by hydrogen fuel cells". According to the EU Directive on the deployment of alternative fuels infrastructure [24], an electric vehicle refers to "a motor vehicle equipped with a powertrain containing at least one non-peripheral electric machine as energy converter with an electric rechargeable energy storage system, which can be recharged externally". Currently, there are four main categories of electric vehicles that are electrically chargeable [25–27]:

a. Battery electric vehicles (BEVs), fully powered by an electric motor using on-board battery that can be charged through the electric grid;
b. Plug-in hybrid electric vehicles (PHEV), powered by a battery-powered electric motor that can be charged through the grid and which is supported by an internal combustion engine;
c. Fuel cell electric vehicles (FCEV), powered by an electric motor using fuel cell instead of battery or in combination with a battery or a supercapacitor;
d. Range extender electric vehicles (REEV), having an on-board liquid fuel converter to produce electrical energy and to extend the mileage of the vehicle;

Furthermore, hybrid electric vehicles (HEVs) are not electrically chargeable but are powered by an internal combustion engine and an electric motor that uses energy from a battery that is recharged through the vehicle's braking system.

3. Materials and Methods

3.1. Categorization of the Key Determinants

In order to systematically analyze the aspects that affect the adoption of electric vehicles, an approach for the categorization of key determinants is proposed, based on the implementation of PESTLE analysis. This approach is suggested as an outcome from the synthetic overview of other literature reviews, analyses of case studies and consultant reports. More specifically, Kumar and Alok [19] categorized the main factors associated with the adoption of electric vehicles by consumers into: (a) technical and product features (ownership costs, vehicle performance, product perception, environmental benefits); (b) government policy (charging infrastructure, incentives); (c) sociodemographic factors (gender, age, income, education, living and family conditions); (d) social influence; (e) consumer behavior (environmental awareness, innovativeness, emotions and consumer intention). Stockkamp et al. [20] adopted this categorization. The International Transport Forum (ITF) argues that the main factors for the deployment of "clean" vehicles refer to the categories of policy (to support innovation and enhance awareness) and technology (to reduce cost and improve productivity) [28]. Schlosser et al. [15] identified, as main factors for the customer readiness to adopt electric vehicles, the economic factors (namely personal costs), the technical factors (such as the availability of charging points), the social and personal perceptions and the predominant socio-economic conditions. Ruoso and Ribeiro [29] identified the categories: (a) social; (b) environmental; (c) economic; (d) technical; and (e) political, which are weighted differently regarding the adoption of electromobility by each of the examined stakeholder groups (automotive industry, energy distributors, researchers and academics, etc.). Based on the above findings and in order to formulate

a categorization that will be widely accepted by the international research community, the categorization used in the current research comprises the following categories of key determinants: political; economic; social/sociodemographic; technological/technical; legal; and environmental.

3.2. Methodological Approach

Over the last decade, a significant number of research papers have been published related to the adoption of electromobility from the perspective of policymakers, manufacturers and commercial organizations and, mostly, of end-users. In the last category, the available research is focusing on either the actual selection of electric vehicles from consumers or their intention to select these vehicles in hypothetical situations. There are three main considerations when setting up the current paper's literature review approach: (i) The review aims at identifying the key determinants affecting the adoption of private, passenger electric vehicles by end-users, as the choice of an electric vehicle is determined by different aspects according to the use of the vehicle as private or shared passenger car, public transport, light duty van, etc. (ii) The available number of papers in the literature is high enough to include all the key determinants but is manageable to allow for a thorough analysis. (iii) The period of analysis covers the last 3 years, based on the fact that the market share of electric vehicles has grown four times in the period 2019–2021, with increasing trends thus far in 2022 [13], and on the assumption that this is directly related to a shift in end-users' choice over this period.

In the above context, the main features of the methodological approach of the literature review are described below:

1. "Scopus" database was used as the main source for the primary extraction of research papers. The use of appropriate combinations of terms ("electric" AND "vehicles" AND "adoption") was selected to identify relevant papers. The search led to a total of 3537 documents.
2. The period of publication was defined between 2020 and 2022. The last update was conducted on 4 October 2022. From the above documents, the ones written in the English language were selected, and then, the ones that are articles published in scientific journals were chosen. Using the above filters, a total of 989 documents were extracted.
3. The research domain that was selected refers to the broader scientific fields of "Engineering, Social Sciences, Energy and Environmental Science", while the terms "electric vehicle(s)" or "EV(s)" were selected as keywords to exclude any remaining irrelevant documentation. Using the above filters, a total of 350 documents were extracted.
4. Within these documents, only peer-reviewed articles from Q1 journals, according to Scimago list of 2022, were selected manually, leading to a total of 303 documents. The selection of articles published only in Q1 journals was used to maximize the internal validity of the review, given that the content of the articles published in such journals is widely considered to be reliable and valid.
5. A first review of the documents, based on title and abstract screening, was conducted to exclude those that do not refer to private cars, i.e., public transport, shared vehicles, micromobility, freight and commercial vehicles, etc. After this process, a total of 73 documents was selected for further analysis. Based on access rights of these documents, a total of 61 documents was finally selected for further analysis.

The workflow of the literature review methodology, incorporating searching criteria and filters, is shown in Figure 1.

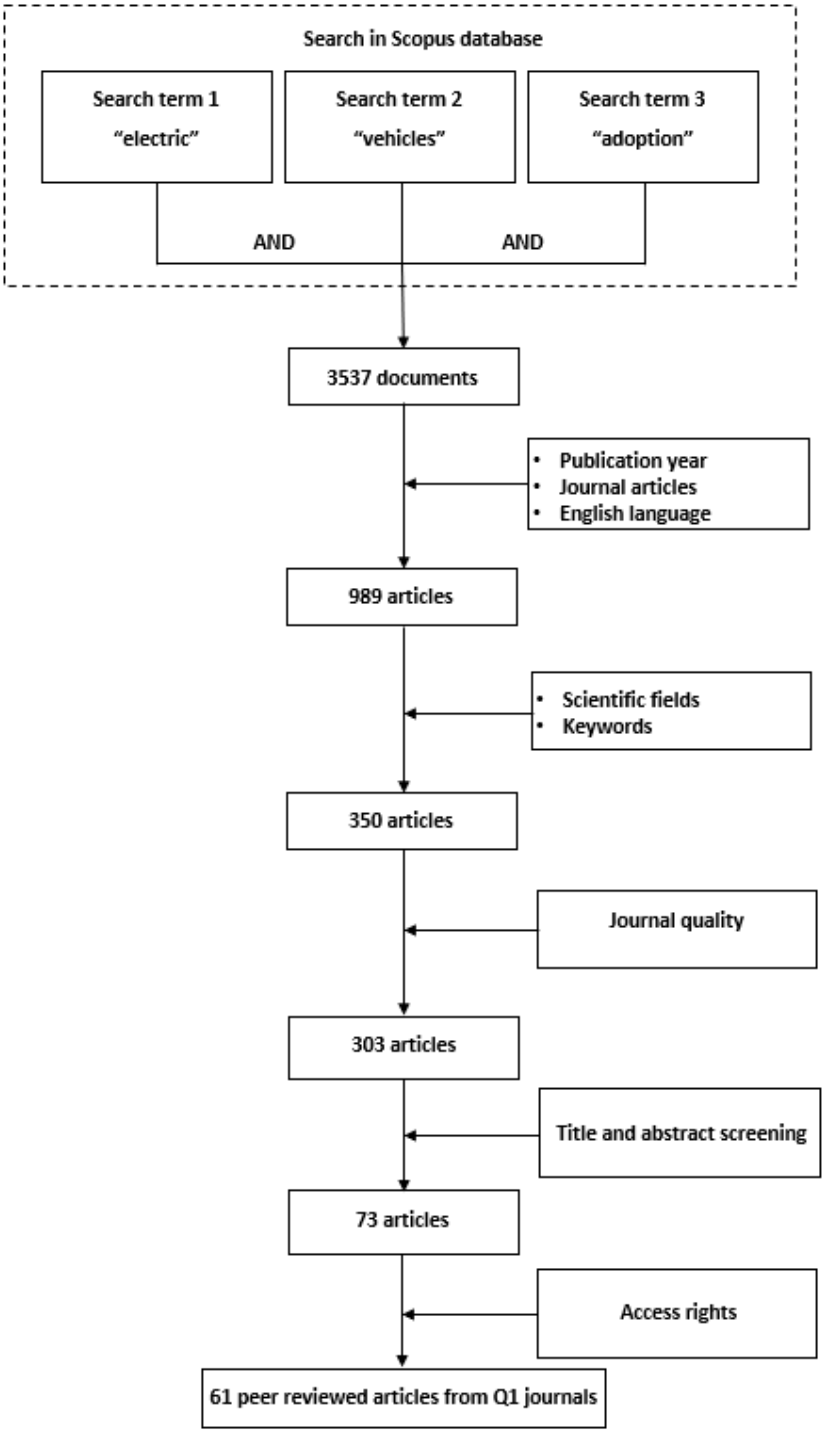

Figure 1. Workflow of the literature review methodology incorporating searching criteria and filters.

The above database of articles was analyzed in view of:

- The analysis of the number of documents per year by source and by country/territory, as well as the share of documents by subject area, according to the classification of the "Scopus" database and manual configuration.
- The brief description of the type of research methods adopted and presented by each document to derive the determinants of EV adoption.
- The identification of the main determinants affecting electric vehicle adoption and the discussion of common and contradictory results from the international literature.

The results of the analysis are presented in the following section.

4. Results

4.1. Distribution of Papers by Leading Journal, Country and Subject Area

Figures 2–4 refer to all articles that were published in scientific journals in the period 2020–2022 and refer to the adoption of any type of electric vehicle (i.e., 989 documents), regardless of the research domain of the article or the ranking and access rights of the journal. The purpose of this representation is to give a cumulative overview and to present the general trends during the last 3 years. On the other hand, Figures 5–7 refer to the documents selected for further analysis in the current study by applying the appropriate filters and manual selection processes, as presented in Section 3.2 (i.e., 61 documents).

Figure 2 presents the number of documents in the initial list of papers (i.e., 989 documents) per year and by source (leading sources only). "Energies" was found in the first place regarding the number of publications, followed by "Transportation Research Part D", "Transport and Environment", "Sustainability Switzerland", "Applied Energy" and "Energy policy".

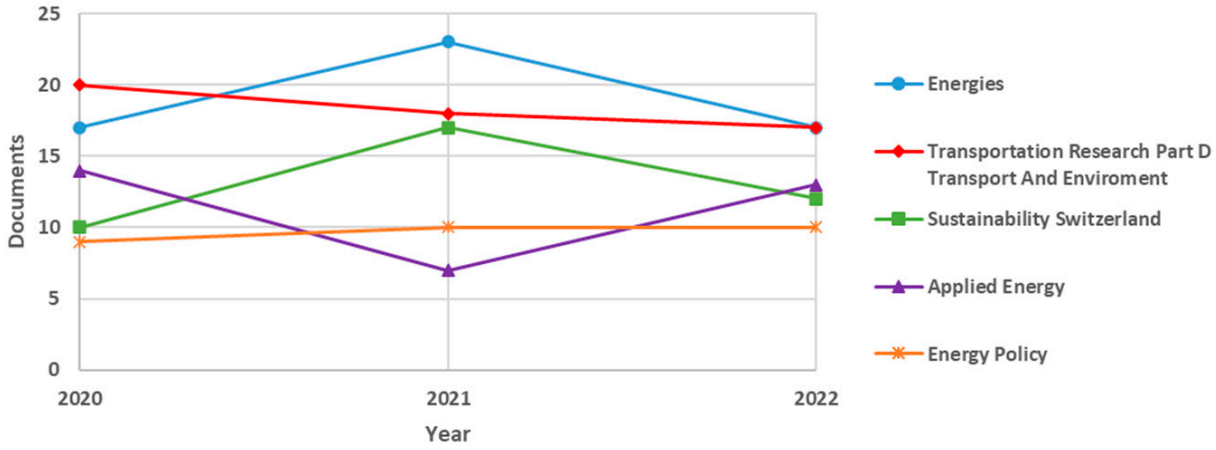

Figure 2. Documents per year by source.

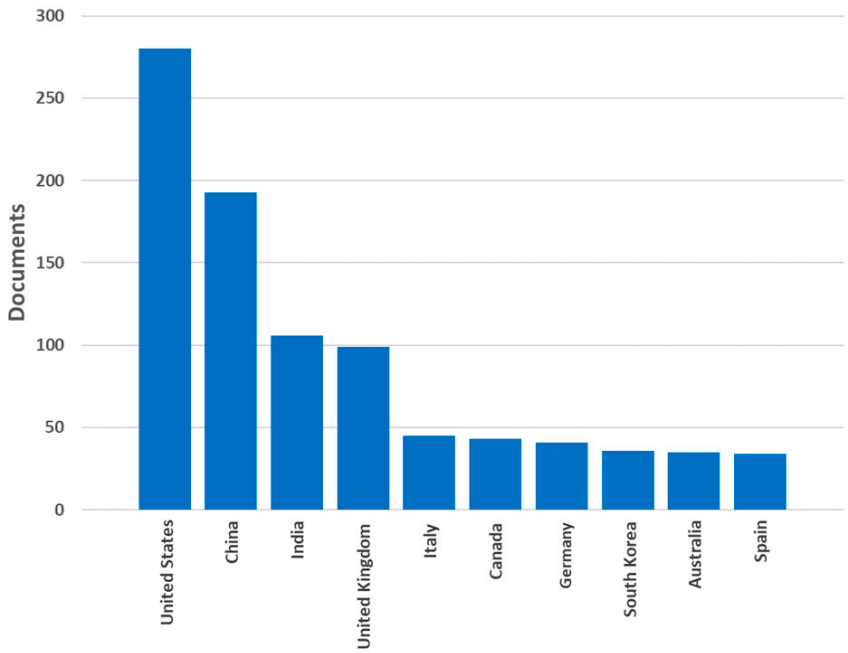

Figure 3. Documents by country/territory.

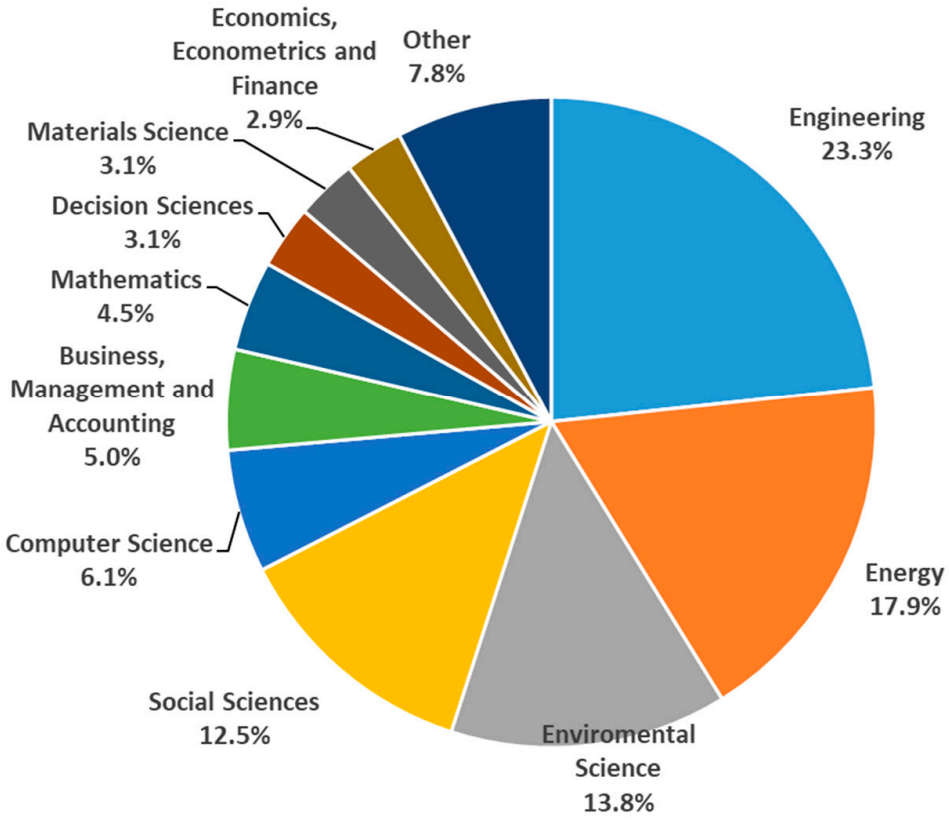

Figure 4. Documents by subject area.

Regarding the initial list of papers (i.e., 989 documents), the number of documents by country/territory (leading countries/territories only), for the years 2020–2022, is shown in Figure 3. United States was found in first place, with China, India, United Kingdom, Italy, Canada, Germany, South Korea, Australia and Spain following.

The share of papers in the initial list of papers (i.e., 989 documents) by subject area, for the years 2020–2022, is shown in Figure 4. The highest share corresponds to "Engineering", while "Energy", "Environmental science", "Social sciences", "Computer science", "Business, management and accounting", "Mathematics", "Decision sciences", "Material science" and "Economics, econometrics and finance" follow, with the rest of the articles belonging to other subject areas.

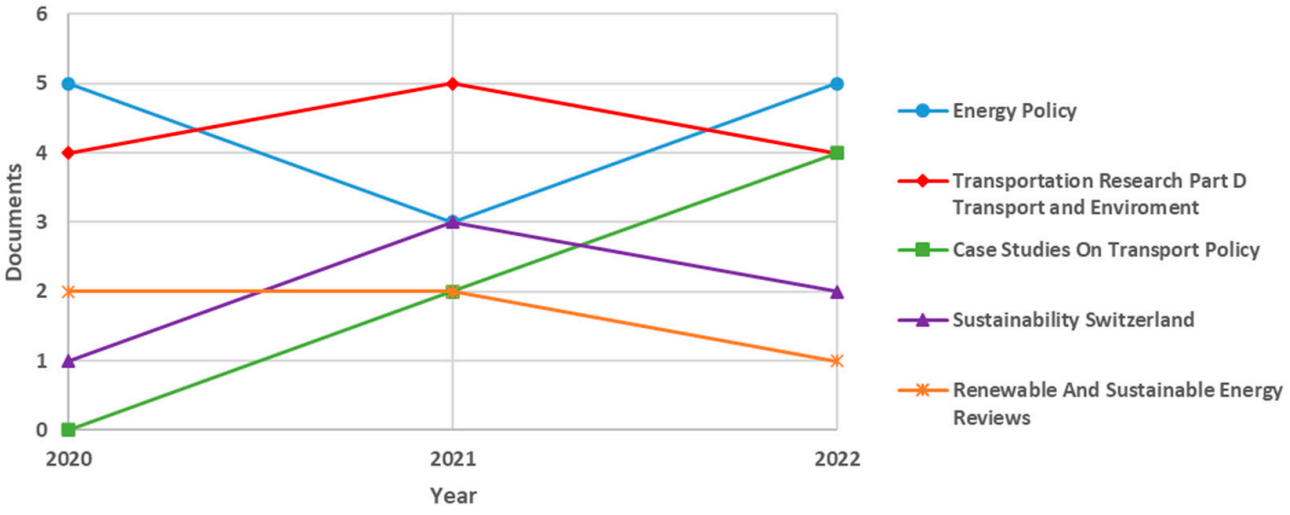

Figure 5. Analyzed documents per year by source.

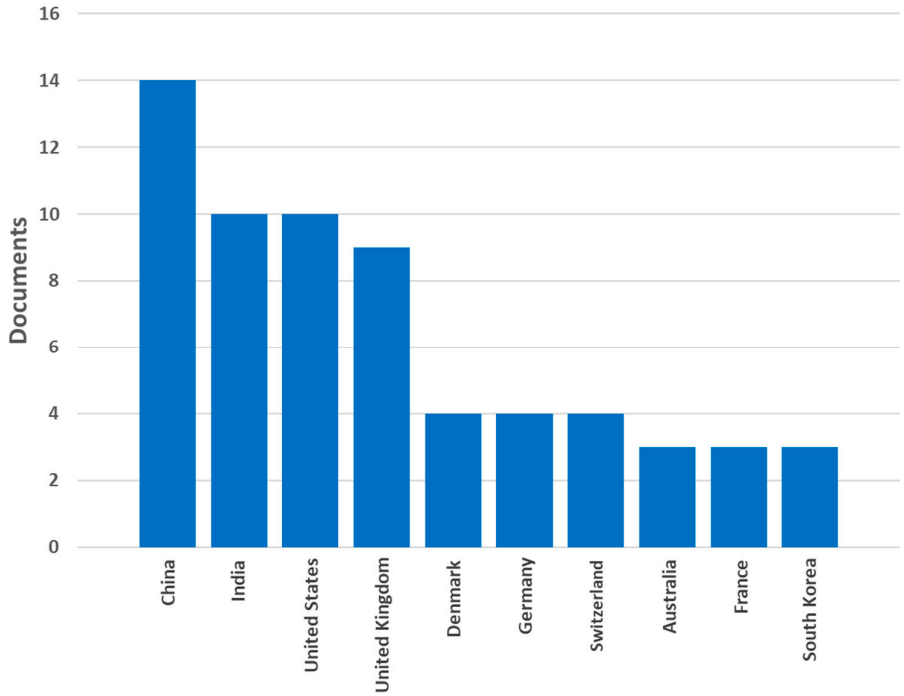

Figure 6. Analyzed documents by country/territory.

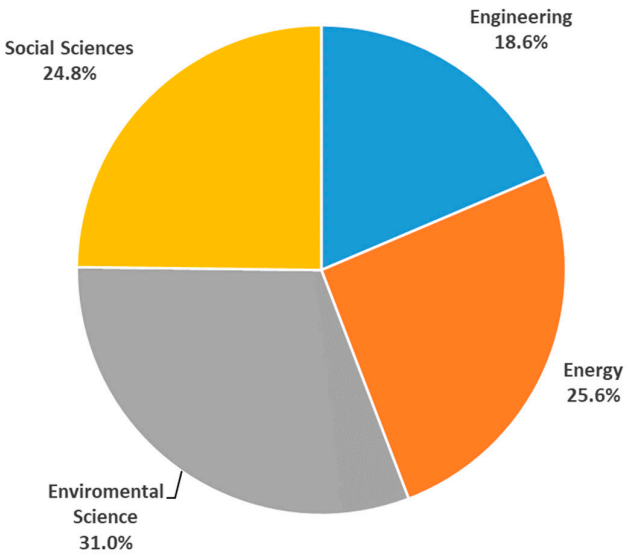

Figure 7. Analyzed documents by subject area.

Figure 5 presents the documents that were further analyzed by the current review (i.e., 61 documents) per year and by source (leading sources only). "Energy policy" was found in the first place, followed by "Transportation Research Part D", "Transport and Environment", "Case studies On Transport Policy", "Sustainability Switzerland" and "Renewable and Sustainable Energy Reviews".

In Figure 6, the number of analyzed documents (i.e., 61 documents) by country/territory (leading countries/territories only), for the years 2020–2022 is shown. China was found in first place, with India, USA, UK, Denmark, Germany, Switzerland, Australia, France and South Korea following.

The share of analyzed papers (i.e., 61 documents) by subject area, for the years 2020–2022, is shown in Figure 7. The higher share corresponds to "Environmental science", while "Energy", "Social sciences" and "Engineering" follow.

4.2. Research Methods and Study Areas

The research method adopted by each of the analyzed studies, along with the study area (country, region, city(ies) or area) in each case, are shown in Table 1. A variety of qualitative and quantitative methods are applied, either separately or in combination, to obtain the actual adoption or the intention to adopt EVs. Quantitative methods are applied in the majority of the papers, with the questionnaire survey being predominant. The study areas are located in Europe, Asia, America and Oceania. Certain documents do not refer to a specific area, while others refer to more than one area, as shown in Table 1.

Table 1. Research methods in the existing studies.

Publication	Research Method	Study Area
Ruoso and Ribeiro, 2022 [29]	Interviews, literature review	Brazil
Mohammadzadeh et al., 2022 [30]	Stackelberg game model, Nash equilibrium game	-
Ramesan et al., 2022 [31]	Literature review, focus group discussion	Delhi, India
Li et al., 2022 [32]	Online reviews and market reports, fuzzy set qualitative comparative analysis	China
Ju and Hun Kim, 2022 [33]	Online panel, structural equation model	USA, Korea
Munshi et al., 2022 [34]	Stated preference survey, discrete choice models	Hyderabad, India
Brückmann, 2022 [35]	Online and "pen-and-paper" survey, test-driving, intention to treat, local average treatment effects	Switzerland (Aargau, Schwyz, Zug, Zurich)
Singh and Singh, 2022 [36]	Mix-integer non-linear programming (MINLP) optimization model	-
Künle and Minke, 2022 [37]	Literature review, interviews, comparative empirical analysis, STEPE (socio-cultural, technological, economic, political, environmental) analysis	France, Germany, Norway
White et al., 2022 [38]	Online survey, multiple regression with ordinary least squares, multiple mediation analysis	USA (Los Angeles, Dallas/Fort Worth, Atlanta)
Sahoo et al., 2022 [39]	Online questionnaire survey, structural equation modelling technique	India
Murugan and Marisamynathan, 2022a [40]	Interview-based questionnaire survey, Quality Function Deployment (QFD) method and Analytical Hierarchy Process (AHP)	Ahmedabad, India
Ledna et al., 2022 [41]	Automotive Deployment Options Projection Tool (ADOPT)	California, USA
Murugan and Marisamynathan, 2022b [42]	Fuzzy Decision-Making Trial and Evaluation of Laboratory (DEMATEL)	Ahmedabad, India
Xia et al., 2022 [43]	Diffusion of Innovation (DOI) theory, offline questionnaire survey, partial least-squares-based structural equation modeling (PLS-SEM) technique,	Wuhan, China
Ogunkunbi et al., 2022 [44]	Socioeconomic and socio-demographic data and incentives from relevant reports, Generalized Linear Model (GLM)	15 European countries (Norway, Germany, the United Kingdom, France, Sweden, Belgium, Netherlands, Switzerland, Spain, Austria, Italy, Portugal, Finland, Hungary, Poland)
Sheng et al., 2022 [45]	Spatial negative binomial regression models	Auckland, New Zealand
Liu et al., 2022 [46]	Paper-based questionnaire survey, agent-based model	Beijing, China
Ali and Naushad, 2022 [47]	Questionnaire survey, Structural Equation Modeling (SEM) and Confirmatory Factor Analysis (CFA)	Delhi and the National Capital Region, India

Table 1. *Cont.*

Publication	Research Method	Study Area
Pillai et al., 2022 [48]	Literature review and scenario analysis	Ireland
Plananska and Gamma, 2022 [49]	Online survey, between-subject design experiment, choice experiment, Hierarchical Bayes analysis	Switzerland
Zhang et al., 2022 [50]	Questionnaire survey (printed)	10 EV pilot Chinese cities
Schulz and Rode, 2022 [51]	Data collection from various Norwegian sources	356 (mainly rural) Norwegian municipalities
Rodrigues et al., 2021 [52]	Web-based questionnaire surveys	Portugal
Broadbent et al., 2021 [53]	Desktop survey (print media review), online questionnaire survey, interviews	New Zealand
Dutta and Hwang, 2021 [54]	Convenience sampling methodology, structural equation modeling, confirmatory factor analysis	Taiwan
Chhikara et al., 2021 [55]	Interviews	India
Debnath et al., 2021 [56]	Analysis of Facebook public posts on EVs, PESTLE (Political, Economic, Social, Technological, Legal, Environmental) analysis, topic modeling through Latent Dirichlet Allocation algorithm	USA
Irfan and Ahmad, 2021 [57]	Questionnaire survey, big five trait theory, structural equation modeling	7 Indian cities (Mumbai, Delhi, Bangalore, Ahmadabad, Chennai, Kolkata, and Hyderabad)
Huang et al., 2021 [58]	Scenario-response method, agent-based modeling	Virtual study area for the simulation, based on Chongqing, China
Goel et al., 2021 [59]	Literature review, meetings with experts and stakeholders, Decision-Making Trial and Evaluation Laboratory (DEMATEL) approach	India
Jang and Choi, 2021 [60]	Personal discrete choice surveys, logit model	7 Korean cities
Krishnan and Koshy, 2021 [61]	Face-to-face questionnaire survey, Structural Equation Modeling	Kottayam, India
Lashari et al., 2021 [62]	Questionnaire survey, binary logistic regression, regression tree	Korean cities
Geronikolos and Potoglou, 2021 [63]	Interviews with stakeholders	Athens, Greece
Stauch, 2021 [64]	Experimental online survey	Germany
Mandys, 2021 [65]	Data from previous state preferences survey, adaptive Lasso technique, binomial and ordered logit regressions	United Kingdom
Pradeep et al., 2021 [66]	Online and paper questionnaire survey, exploratory factor analysis, multiple regression model, mediation analysis	Nagpur and Hyderabad, India
Jia and Chen, 2021 [67]	Web-based stated preference survey, real-world data analysis (related to EV ownership)	Virginia, USA
Cui et al., 2021 [68]	Online questionnaire survey, multiple regression analysis	China
Ullah et al., 2021 [69]	Web-based questionnaire survey, partial least square- based structural equation modeling	-
Xue et al., 2021 [70]	Data collection from published reports and online resources, random effects model analysis	20 countries (Norway, Iceland, Sweden, The Netherlands, Finland, China, Portugal, Switzerland, Austria, Belgium, United Kingdom, Denmark, Canada, France, United State, Germany, Ireland, Hungary, Japan, Spain)
Haustein et al., 2021 [71]	Online questionnaire surveys	Denmark, Sweden

Table 1. *Cont.*

Publication	Research Method	Study Area
Brückmann et al., 2021 [72]	Online and on print questionnaire survey (revealed preference survey), mixed-effects logistic maximum-likelihood model	(Aargau, Schwyz, Zug, and Zurich) Switzerland
Wood and Jain, 2021 [73]	Questionnaire survey with the participation of officials	Major USA cities
Hsu and Fingerman, 2021 [74]	Analysis of data from American Community Survey and Census Block Group	California, USA
Ma and Fan, 2020 [75]	Panel vector auto-regression model	20 Chinese provinces
Li et al., 2020a [76]	Online questionnaire survey, theory of planned behavior	China
Illmann and Kluge, 2020 [77]	Data from official German sources, cross-sectional augmented autoregressive distributed lag model	Germany
Li et al., 2020b [78]	Data from official Chinese sources, scenario analysis, Python	China
Tanwir and Hamzah, 2020 [79]	Online questionnaire survey, theory of planned behavior	Malaysia
Kong et al., 2020 [80]	System dynamics model, scenario analysis	China
Burs et al., 2020 [81]	Online questionnaire survey, adaptive choice-based conjoint experiment	France
Zhuge et al., 2020 [82]	Agent-based spatial integrated urban model from previous work, named "SelfSim-EV"	Beijing, China
Chen et al., 2020 [83]	Online questionnaire survey, hierarchical regression analysis	Denmark, Finland, Iceland, Norway, Sweden
Noel et al., 2020 [84]	Semi-structured interviews with experts and stakeholders	17 cities in Denmark, Finland, Iceland, Norway, Sweden (Reykjavik, Akureyri, Stockholm, Gothenburg, Lund and Malmo, Greater Copenhagen Region, Aarhus, Aalborg, Greater Helsinki region, Tampere, Oulu, Greater Oslo region, Trondheim, Tromsø and 2 anonymous cities)
Wee et al., 2020 [85]	Data obtained from official associations, panel and cross-sectional analyses (ordinary least squares, negative binomial regression)	Hawaii, USA
Guerra and Daziano, 2020 [86]	Discrete choice experimental online survey, mixed logit and latent class models	Philadelphia, USA
Mukherjee and Ryan, 2020 [87]	Literature survey, focus groups, data obtained from official Irish associations, count data and spatial econometric models	Ireland
Li et al., 2020c [88]	Stated preference choice experimental online survey, random parameter logit and latent class models	Chinese BEV demonstration pilot cities
Higueras-Castillo et al., 2020 [89]	Online questionnaire survey, structural equation model, artificial neural network	Spain

4.3. Key Determinants affecting the Adoption of Electric Vehicles

According to the PESTLE approach, the key determinants in the analysis are categorized as: (i) political; (ii) economic; (iii) social/sociodemographic; (iv) technological/technical; (v) legal; and (vi) environmental. For each category, the key determinants (either barriers or motivators) that affect the adoption of electric vehicles in different cases and geographic areas are presented.

4.3.1. Political Determinants

Li et al. [76] concluded that consistency, coherence, and credibility of policy mix play a significant role in the intention to acquire electric vehicles (EVs) in China. Similarly, the

analysis of Goel et al. [59] highlights that unclear policies related with the replacement of fossil fuel cars with Evs, through financial incentives, awareness campaigns, etc., constitute a significant barrier toward EV adoption in India. Government incentives also seem to affect the consumers' intention to adopt an EV in Taiwan [54].

Financial and non-financial incentives can play a significant role toward plug-in EV adoption by American consumers according to [73], while Hsu and Fingerman [74] state that such incentives should be expanded to "undeserved communities" in order to increase EV adoption in California, USA. An interesting finding, regarding two different studies in India, is that financial and non-financial incentives are not considered crucial for EV adoption according to [47], while they arise as important determinants in the study of Chhikara et al. [55].

Financial support to consumers by governments is highlighted as an important incentive in various case studies [34,43,55,67,89]. Financial incentives can play an important role toward EV adoption in Virginia, USA [67], India [34], Spain [89] and China [43]. Taxation policies including reduction in taxes for those who purchase an EV seem to be a crucial determinant for the adoption of EVs in Brazil [29] and Ireland [48]. Tax reduction policies have a stronger positive impact on the adoption of EVs by consumers compared to purchase subsidies according to [70]. On the other hand, government policy including subsidies for the purchase of an EV and electricity subsidies related to the operational cost of an EV arise as important determinants related to the adoption of EVs [30,31]. Purchase subsidies are regarded as a determinant of high importance in France, Germany and Norway, according to Künle and Minke [37]. According to Kong et al. [80], purchase subsidies are a determining aspect for the willingness of Chinese consumers to acquire an electric vehicle. Research focusing on specific age groups, such as the research of Sahoo et al. [39] on millennials in India, highlights that psychological motives regarding the perception toward EV adoption are affected by appropriate governmental policies (such as financial incentivization).

According to Ogunkunbi et al. [44], the study of whom refers to 15 European countries, financial subsidies and tax reduction are not positively associated with BEV adoption. The authors of the specific study claim that the previous studies led to different results because the examined policies covered all types of EVs, with end-users preferring other types of EVs (e.g., PHEV) rather than BEV, due to the "lower purchase price, longer range and shorter refueling time".

Regarding other end-user incentivization policies, the research of Stauch [64] concludes that German consumers are more willing to purchase an EV when the acquisition is bundled with a solar energy system, independently of a discount in the total cost, suggesting that relevant policies could increase electric vehicle adoption in general. According to Plananska and Gamma [49], the incorporation of EV insurance, battery assistance and a green electricity certificate can increase the adoption of electric vehicles by Swiss consumers. According to the same study, policies oriented to bundling EV and charging services can determine the adoption of EVs by Swiss consumers, while financial subsidies and investment in charging infrastructure are also identified as important determinants. Li et al. and Li et al. [78,88] found for China that policies such as license restriction rescission, free parking or free charging are more effective than purchase policies for certain consumers, especially younger ones, in combination with information provision and market-oriented incentives, such as personal carbon trading scheme and tradable driving credits. Ma and Fan [75] suggested that the reduction in electricity rate is important to increase BEV attractiveness in China.

As mentioned in the above, another main policy measure that can affect EV adoption combined with financial incentivization refers to information and awareness campaigns [42,56,75,79]. Information campaigns and test-driving possibilities emerge as important determinants in various studies [35,46,48,76], as the familiarity of consumers with EVs and their benefits is linked to the probability of purchasing an EV. Zhang et al. [50] concluded that the perceived value of an EV and the trust in an EV by Chinese consumers are affected by the level of the information on environmental impact, operation and main-

tenance costs, and vehicle attributes, such as speed, user-friendliness, energy efficiency, shortened driving time and longer range due to technological advancement. The study proposes measures such as exhibitions, conferences, EV rental and sharing programs, test-driving, etc. The level of consumer awareness, concerning advantages and financial subsidies, significantly affects the likelihood of purchasing an EV, and in particular a BEV in New Zealand, according to Broadbent et al. [53], with the authors stressing the importance of media for the dissemination of relevant information. Lashari et al. [62] claimed that the awareness of Korean consumers regarding EVs' environmental and economic benefits, as well as regarding the governmental measures linked to existing environmental policies and to the reduction of the EVs' operational cost, constitute determining factors toward EV adoption. Lashari et al. [62] also highlight the significance of awareness campaigns and test-driving incentives in order to inform consumers on EV advantages related to, e.g., environment, economy, safety, easiness to drive and make them familiar with this new technology, in combination with sufficient infrastructure development. Haustein et al. [71] argued that according to their research, information campaigns can significantly affect BEV adoption in Sweden, but not in Denmark. The significance of subsidy policies in India, along with the awareness of consumers concerning the existence of such policies, are highlighted in [40], while the importance of tax allocation and subsidy policies, as well as information campaigns related to EV advantages in the USA, is highlighted in [56].

Many research papers, such as [41,49,58,62,81], concluded that investment on public charging infrastructure, combined with subsidization and awareness, is also a determinant toward increasing EV adoption. The investment in more charging infrastructure facilities and the technological advancement related to, e.g., increased battery capacity can also contribute to increasing EV adoption in Korea, as mentioned in [62]. Geronikolos and Potoglou [63] concluded that investment in charging infrastructure, together with incentives related to EVs purchase cost, tax reduction or exemption, constitute determinants for the adoption of EVs in Greece. Apart from financial incentives, information campaigns focusing on EV advantages, especially the environmental benefits, and investment policies in public charging infrastructure, can contribute to a broader BEV adoption, according to [81]. The analysis executed in [58] also leads to the conclusion that investment in public charging infrastructure and financial subsidies are policies of high importance, along with the consumers' awareness on EVs on behalf of governments and the automobile industry. The effect of public charging infrastructure investments and vehicle subsidies for the acquisition of EVs in California is investigated in [41], documenting that both policies are of high importance within the framework of EV adoption.

Ma and Fan [75] stress the significance of information campaigns, as well as of the reduction in electricity rate, in order to increase EV sales. The same study led to the conclusion that governmental subsidies to operators for the construction of EV charging infrastructure and the policy of limiting the ceiling of the charging service fee in China are not so effective. Zhuge et al. [82] concluded that the policy of the Chinese government related to restrictions on the number of permits per household affects the purchase of EVs, especially of PHEVs. In particular, an increase in the number of permits is allegedly associated with an increase in the purchase of EVs.

4.3.2. Economic Determinants

The high acquisition cost, mainly related to the high cost of the battery, appears as the most important economic barrier toward EV adoption in various studies in Brazil, Ireland and India [29,34,40,42,47,48]. The cost for EV acquisition of an EV comprises one of the important barriers in studies referring to China [68], UK [65] and the Nordic region [84], while it is a key determinant for the adoption of EVs in Korea, especially compared to the cost of the consumer's previous fossil fuel vehicle [60]. Contradictory results regarding the importance of acquisition costs for EV adoption in India derive from the studies of [61] and Goel et al. [59].

Overall, electric vehicles are characterized by lower maintenance cost, affecting profitability of the aftermarket, and lower operation cost compared to conventional cars [29,30,90]. Maintenance costs, mainly linked to battery replacement, are an important aspect for EV adoption in India [59]. Both acquisition and maintenance costs seem to affect the consumers' intention to adopt an EV in Taiwan [54], while acquisition and operation costs constitute important determinants for the adoption of EVs in Virginia, USA [67]. The perception of an EV as an overall economically efficient vehicle constitutes a determining aspect for EV adoption in Korea [62]. However, the comparison of the operation cost between plug-in electric and internal combustion engine vehicles (ICEV) greatly depends on electricity tariffs and petrol prices, with the analysis of Ruoso and Ribeiro [29] indicating that the cost of electricity for charging and high taxation, due to import and production costs, are also important barriers toward EV adoption in Brazil.

An interesting perspective is given by Xia et al. [43], who applied the DOI theory to conclude that the risk of the vehicle price reduction (the vehicle someone purchases today will be discounted in the future) can negatively affect Chinese consumers toward EV adoption.

4.3.3. Social and Sociodemographic Determinants

Regarding social trends, the possession of an electric vehicle is presently considered a status symbol, as indicated by Kester et al. [91] (as mentioned in [29]). Xia et al. [43] confirmed this trend for consumers in Wuhan, China. Another interesting approach related to EV adoption in China was introduced by Li et al. [32], who argued that the selection of an electric vehicle by an end-user can be affected by inter-dependent, self-image motives. In particular, certain people may decide to purchase an EV in order to be regarded by others or because they regard themselves as "environmentalists", others may opt for an EV in order to be "innovation adopters", and others in order to feel or be shown as "ethical consumers" within the framework of their ethical commitment to society to adopt socially desired behaviors. In the same context, Haustein et al. [71] emphasized that the perceived status, lifestyle, social norm, as well as the excitement linked to BEV ownership, are significant motivators in Denmark and Sweden. Social reputation seems to influence the intention toward EV adoption in Spain, according to Higueras-Castillo et al. [89]. Contrary to the above, social status and subjective norms related to EVs are not found to be determining for EV adoption in India [47,66] and Malaysia [79], while the lack of trust in electric vehicles arises as an important barrier in India [59,61] and Korea [62].

Apart from general social trends, the analysis of Goel et al., 2021 [59], shows that the family environment significantly affects decisions on the purchase of EVs in India. Similarly, Dutta and Hwang [54] concluded in their study that "peer pressure" and mass media decisively affect consumers' intention to adopt an EV in Taiwan. An interesting finding from the research of Guerra and Daziano [86] is that the willingness to purchase an electric vehicle decreases with the number of family members in a household, in a study in Philadelphia, USA. The study of Sheng et al. [45] in New Zealand shows the effect of EV acquisition at neighborhood level, i.e., early EV adoption by a member of a neighborhood may promote EV purchase by other neighbors.

In addition to the influence of the social environment, personal behavioral characteristics, such as openness to new experiences and self-esteem, also affect the consumers' perception regarding electric vehicles in China [68,76]. The research of Irfan and Ahmad [57] argues that openness, conscientiousness, extraversion, and agreeableness positively affect EV adoption, while neuroticism generates a negative influence concerning EV adoption in India. Consumer behaviors related to information on EV benefits and to the risks associated with new technology adoption have a determining role according to Singh and Singh [36]. In addition, psychological barriers related with the anxiety for the availability of charging infrastructure during a long trip seem to be important determinants for EV adoption in India, according to Murugan and Marisamynathan [40]. In the same direction, based on the investigation of the relationship between key spatio-temporal aspects and consumers'

intention to purchase an electric vehicle in Auckland, New Zealand, Sheng et al. [45] concluded that the availability of public charging infrastructure in neighboring areas can positively affect the intention to adopt EVs.

Regarding socio-demographics, men, younger people and people with a higher education level are more likely to purchase an EV in India according to a survey conducted by Ali and Naushad [47]. The attractiveness for male and younger consumers is verified for Denmark, Finland, Iceland, Norway and Sweden by Chen et al. [83], despite the fact that, according to previous studies [92–95], the older consumers are usually the ones who can actually afford to purchase an EV in these countries. The same study states that consumers with more than one vehicle and long-distance commuters were less likely to acquire an EV, while consumers who have tried to drive an EV are more likely to acquire one. Another survey by Ju and Hun Kim [33] focused on the influence of perceived EV characteristics (comfort, functionality, availability, price conformity, risk, environmental impact and innovation resistance) on Korean and American drivers between the ages of 24 and 40 (millennials), highlighting the need to study the impact on millennials separately for each country in order to formulate appropriate policies for the promotion of electromobility.

According to Xue et al. [70], consumers with higher income are more likely to purchase an EV. In addition to higher income, Wee et al. [85] highlighted that consumers of a higher level of education are more likely to purchase an EV, according to their study in Hawaii, USA. In addition to higher income, the study of Brückmann et al. [72] shows that having more than one car in the household, owning detached dwellings, being attracted to new technologies and being accustomed to carsharing favor the selection of a BEV in Switzerland. Mukherjee and Ryan [87] claim that Irish consumers with higher education and income, homeowners, medium- and long-distance commuters (due to long-term cost savings related to BEV) and older than 34 years are more likely to become early BEV adopters.

4.3.4. Technological/Technical Determinants

According to various studies worldwide, the insufficiency of charging infrastructure seems to be one of the most important barriers for the consumer adoption of EVs [29,31,34,52,60,70,78]. Charging infrastructure availability is of high importance for EV adoption in China, as stated in [78]. The density of public charging infrastructure is highlighted as an important factor for BEV adoption in Norway [51] and China [75], while it is stressed that this factor does not significantly affect PHEV adoption in China [75]. Haustein et al. [71] concluded that fast charging infrastructure is a significant factor for EV adoption for consumers in Denmark, but not in Sweden. Charging infrastructure availability emerges as the most important factor for EV adoption in India [40,42], while according to the same studies, speed, range, comfort, design and battery technology are also important to Indian consumers. In contradiction to the above, another study in India argues that charging infrastructure is not a determinant of EV adoption in India [47].

Künle and Minke [37] highlight the so-called "chicken–egg paradox" regarding the relation between the availability of charging infrastructure and the number of circulating plug-in electric vehicles, concluding that charging infrastructure is certainly required for a higher EV adoption, but technology itself cannot be regarded as the most decisive factor for EV adoption. In this context, White et al. [38] concluded that the density of public charging stations is an important factor as regards the consumer intention to adopt an EV in USA.

According to Illmann and Kluge [77], the availability of public charging infrastructure affects EV adoption in Germany, but charging time is an even more important determinant for EV adoption. Charging time constitutes an important determinant for the adoption of EVs in Virginia, USA, according to Jia and Chen [67], while battery range and charging infrastructure availability are important to those who already own an EV. On the other hand, charging time (rapid or normal charging) does not influence the intention of Chinese consumers to purchase BEVs according to Li et al., 2020c [88], due to the fact that most consumers remain home for a period of full charge (about 6–8 h). In the same study, battery

warranty and vehicle's depreciation rate comprise important factors for BEV adoption, given the residual value of a BEV, which is allegedly higher than that of an ICE vehicle.

The lack of adequately skilled staff in charging stations and service centers is another barrier regarding the adoption of EVs in India, according to the studies of Ramesan et al. [31] and Goel et al. [59].

Technological advancement in the field of EVs seems to affect the intention to adopt and the actual adoption of EVs in many countries, such as Brazil [29] and India [31]. Smart and automated functions positively affect consumers' choice, according to Ullah et al. [66,69].

A number of studies highlight a combination of the above factors as determinants of EV adoption. For instance, the selection of EVs by end-users in India is determined by vehicle performance [61,66] and battery range. Similarly, EV performance and battery range constitute important factors for EV adoption in the UK [65]. Vehicle performance and charging infrastructure availability seem to affect the consumers' perspective in Taiwan [54]. Chen et al. [83] concluded that charging time and vehicle-to-grid capability are important factors for EV adoption in the Nordic region, while battery life and public charging availability arise as much more important factors for conventional car owners than for EV owners. According to the same study, driving range, speed, acceleration, design and style do not really affect the intention of consumers to adopt EVs, while fuel economy, ease of operation, and technological reliability are important for EV adoption. Driving range and charging infrastructure availability are also highlighted as important for consumers in the Nordic region, according to Noel et al. [84]. The proximity of charging stations and the charging time constitute important factors for EV adoption in Korea, according to Jang and Choi [60]. Range anxiety (especially for long-distance commuters), availability of public charging infrastructure and charging time are considered as main determinants in Hawaii, USA [85] and Spain [89]. Guerra and Daziano [86] concluded that consumers in Philadelphia, USA, are willing to pay for longer EV driving range, shorter charging time and lower operation cost.

4.3.5. Legal Determinants

The legal factor is not thoroughly addressed by recent literature, comprising isolated remarks and proposals referring to incentives for underprivileged citizens, the establishment of obligations to build new charging infrastructure and the control of car ownership and usage. Regarding the first aspect, Hsu and Fingerman [74] stated that financial and non-financial incentives related to EV adoption should be expanded to "underserved communities" in order to increase EV adoption in California, USA. Regarding the second aspect, policies oriented to bundling EV and charging services can determine the adoption of EVs by Swiss consumers [49]. Apart from financial subsidies, obligative installation of charging infrastructure in new facilities, such as house and shopping malls, is important for EV adoption in Switzerland. Finally, referring to the third aspect, existing legislative limitations on car ownership and usage may be negative for EV adoption, as Zhuge et al. [82] concluded that the Chinese policy related to restrictions on the number of permits per household negatively affects the purchase of EVs.

4.3.6. Environmental Determinants

Environmental concerns are presented as a crucial aspect for Indian consumers to adopt EVs [31]. Greenhouse gas emissions, local air pollution and lack of recycling facilities for the lithium-ion EV batteries appear as determinants for the adoption of EVs in this study. However, according to another study for EV adoption in India [47], environmental concerns are not a determining parameter. Environmental concerns are a determining aspect for EV adoption in China in [68] and Switzerland [72], while they seem to influence the intention to adopt an EV in Spain in a less significant way [89]. Environmental concerns also affect the consumers' intention to adopt an EV in Taiwan [54].

The environmentally sustainable performance of an EV can significantly contribute to the diffusion of EVs in Wuhan, China [43]. The perception of benefits for the environment

associated with EV adoption emerges as the most important determinant for the intention to adopt an EV in Korea [62], while environmental awareness significantly affects the intention to adopt a hybrid EV in Malaysia [79]. Environmentally friendly consumer behavior constitutes an important aspect for EV adoption in the Nordic region [83]. The environmental impacts of EVs also constitute an important aspect associated with EV adoption in the UK [65].

5. Discussion of Results and Policy Recommendations

5.1. Discussion of Results

The current paper identifies the key determinants affecting the adoption of private, passenger electric vehicles by consumers through the detailed literature review on the most recent articles published in high-quality peer-reviewed journals. The examined literature mainly covers case studies in a wide array of countries, while a variety of methods are being implemented. The key determinants affecting EV adoption are organized into six categories, following the political, economic, social and sociodemographic, technological and technical, legal and environmental factors of the PESTLE analysis (Table 2).

Table 2. Main determinants affecting EV consumer adoption.

Political	Economic	Social/Sociodemographic
• Purchase subsidies • Tax reductions • Electricity tariff reductions • Information and awareness campaigns • Public charging infrastructure investment policies • Personalized service and "green" certification • Bundling of EV and renewable energy policies	• Vehicle purchase cost • Maintenance cost • Operation cost and fuel economy • Vehicle depreciation-anticipated future discount on current price	• Social status and global trends • Family and peer pressure • Personal attitude toward environmental concerns and new technologies • Sociodemographic characteristics (age, gender, education, income etc.) • Daily transport patterns and travel distance • Experience with EV driving
Technological/Technical	**Legal**	**Environmental**
• Charging infrastructure availability • Charging speed/time • Availability of appropriately skilled technical staff • Electric vehicle range • Smart and automated vehicle functions • Vehicle-to-grid connectivity	• Coverage of less privileged consumers • Obligation for charging infrastructure in new developments • Restrictions for car ownership or use	• Vehicle performance regarding greenhouse gas emissions • Vehicle performance regarding local air pollutants • Lithium-ion battery recycling

As it can be concluded from Table 2, a multitude of determinants affect the attitude of consumers toward the adoption of electric vehicles. Overall, the majority of determinants reported by the literature refer to the comparison of infrastructure and vehicle performance between electric and ICEV, which affect EV attractiveness in terms of cost and quality of service.

In order to elaborate on the results from the presentation of key determinants (Section 4.3), further analysis was conducted to identify which of these determinants are highlighted as the ones of the highest importance regarding EV adoption by consumers. Then, the determinants of highest importance were categorized into the PESTLE categories, according to Table 2. Figure 8 represents the share of papers that highlight a determinant of a specific PESTLE category as one of highest importance regarding EV adoption by consumers. As already discussed in Section 4.3, there are papers that identify determinants of different PESTLE categories as the ones of highest importance.

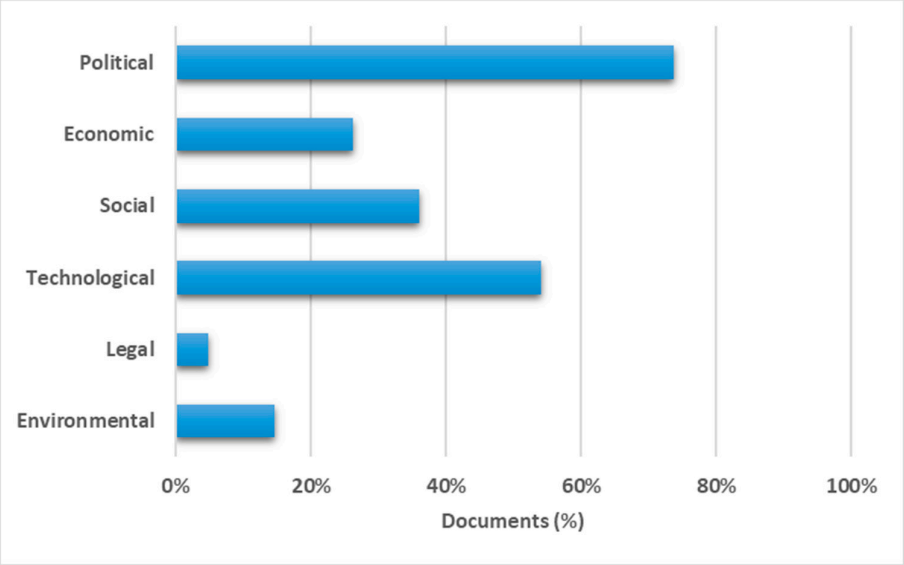

Figure 8. Share of reviewed papers that highlight a determinant of a specific PESTLE category as the determinant of highest importance regarding EV adoption by consumers.

According to Figure 8, a total of 45 of the reviewed papers highlight the political determinants as the most important ones toward EV adoption. More than half of the papers acknowledge the technological and technical determinants as the ones of highest importance, while over one third consider social and sociodemographic determinants as most important. The economic and the environmental determinants are highlighted as the ones of highest importance by 16 and 9 papers, respectively. The legal determinants are considered as determinants of the highest importance by only three papers. However, the political determinants cover policies for the promotion of electromobility that refer to other PESTLE categories, such as the provision of adequate technical infrastructure, namely charging infrastructure, the public awareness regarding the social and environmental benefits of EVs, the reduction of costs for the purchase and use of an EV, through subsidies, taxation policies etc., while they imply specific legislative concerns that should be addressed to ensure the effective implementation of these policies.

Nonetheless, given the increasing environmental concerns of recent years, especially regarding climate change and renewable energy transition, and the social sensitivity related to sustainability issues, a higher significance of environmental determinants was expected as regards their influence on consumer EV adoption. However, the results of the review are not consistent with this hypothesis, as environmental concerns, in most cases, did not have a preponderant place among the factors affecting consumer adoption of EVs.

5.2. Policy Recommendations and Managerial Implications

Charging infrastructure availability and fast charging are identified as important determinants for EV adoption. For this reason, the investment in public charging infrastructure, and especially in fast chargers, along with legislation associated with the obligation for charging infrastructure in new developments, are crucial policies in the framework of promoting EV adoption. Especially concerning fast charging infrastructure, the investment in fast chargers is expected to significantly contribute to the increase in EV adoption, given that the refueling time of an ICEV is much shorter than the recharging time of an EV, using conventional chargers. The ability and intention of consumers to use home charging should be taken into account for the development of appropriate policies for public charging infrastructure.

The level of consumer awareness of EV advantages, especially as regards the environmental impact and the lower operation and maintenance cost of an EV compared to an ICEV, seems to play a significant role toward EV adoption. For this reason, information

campaigns and relevant policies (e.g., test-driving) related to the increase in consumer familiarity with EVs and of their awareness of EV advantages are of high importance.

Subsidies for EV purchase and tax reductions constitute the main determinants for EV adoption, while it is important for relevant policies to be appropriately and clearly communicated to all consumers. Furthermore, policies for bundling of EV purchase and renewable energy policies can be determining for EV adoption. Consumers value their choice depending on their personal image and attitude, mainly regarding innovation and environmental awareness, but also on the influence of their social environment. Age, gender, income, education level and commuting distance seem to also affect consumer adoption of EVs. For this reason, specific policies oriented to attracting target groups of different social and sociodemographic characteristics are necessary.

In order to respond to the remaining technological and environmental barriers concerning EV adoption, research and development is needed for the technological advancement in terms of battery range and battery recycling in a safe and environmentally friendly way. For this reason, policies associated with relevant research and development projects are necessary.

Finally, the current literature review highlights that there are differences among those consumers who already have an EV and those owning an ICEV, as well as among those who have had a driving experience with an EV. Furthermore, the key determinants for EV adoption may differ as to the type of EV engine technology, as mentioned in Section 2. In some cases, differences were observed among the results of studies referring to the same geographical area. The above should be carefully considered in the process of developing and implementing effective policies toward EV adoption.

6. Conclusions and Future Research Directions

The current paper provides a systematic and organized description of key determinants affecting the adoption of private, passenger electric vehicles by consumers, through the review of recent scientific literature. Based on these key determinants, main policy recommendations and implications are presented. As follow-up research, the methodological approach of the present literature review will be adjusted to the identification of key determinants in the adoption of other types of electromobility, such as public transport, shared cars, micro-mobility, freight and commercial vehicles, etc.

A main conclusion from the specific research is that environmental determinants affect EV adoption less than initially expected, despite the increasing concerns about climate change and renewable energy transition. Nevertheless, one of the main determinants deriving from the literature review is the need for awareness campaigns that inform consumers about the environmental advantages of EVs.

Finally, despite the fact that most of the determinants are common among different papers, there is no overall convergence as to which determinants are of the highest importance. Different significance is given to each determinant, depending on the methodological approach, the scope of the research, the study area and the targeted group of consumers. Thus, the development of a flexible methodological framework that will be able to assess the perception of end-users in relation to EV adoption in different contexts is proposed as a main direction for future research. This framework should also incorporate different types of electric vehicles and charging technologies, such as static or dynamic, inductive or conductive charging, etc.

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Abbreviation

GHG	Greenhouse gas
EV	Electric vehicle
PESTLE	Political–Economic–Social–Technological–Legal–Environmental
ICE	Internal combustion engine
BEV	Battery electric vehicle
ICEV	Internal combustion engine vehicle
PHEV	Plug-in hybrid electric vehicle
FCEV	Fuel cell electric vehicle
REEV	Range extender electric vehicle
HEV	Hybrid electric vehicle
UK	United Kingdom
USA	United States of America

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