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Review

Employing bibliometric analysis to identify suitable business models for electric cars

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ABSTRACT

Business model architectures in the car industry are gaining increased attention from scientists and policymakers. Although scientific studies have been conducted to address the pressures faced by future business models to change, no research has examined the bibliometric variables in this area. This study aims to fill the gap by conducting a bibliometric analysis of 104 articles on business models for electric cars. The analysis showed that the literature on business models for electric cars is exhaustive, and it focuses on business model decisions for charging technologies, driver services, electricity management, commercial contracts, and plant. China, the United States of America, and Germany have conducted the maximum number of studies on the aforementioned theme. The topic dendrogram identified two evolving strands of discussions—innovative technologies and resource optimization and electricity management systems and product life cycle. These findings can guide the formulation of environmentally sustainable policies for electric car manufacturing and help car manufacturers to restructure their models.

Contents

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1. Introduction

The automotive industry is stepping into a new era with electric cars. They have returned to the market in response to the need for mitigating increased carbon dioxide emissions (CO_2) resulting from transportation (Kley et al., 2011a,b). Increased environmental awareness has prompted leading car manufacturers to produce hybrid and electric cars to replace the previous internal combustion engines. Nowadays, the economic sustainability of electric vehicles depends on their business models. Therefore, scientific research on and subsequent large-scale application of these business models are critical to influencing electric car purchase decisions.

Over time, there have been several definitions of business models.

Chesbrough (2010) and Osterwalder et al. (2005) define it as means of how companies create value through their products and services and how they deliver and capture it. Other definitions consider business models as a representation of how a company operates (Magretta, 2002); Teece (2010) defines them as the organizational and financial architecture of a business. Matzen et al. (2005) focus on how business models can increase consumer benefits through more innovative offers.

Recently, the business models of companies are focusing on sustainability (Czinkota et al., 2018). In this regard, Nielsen and Morten (2015) define a business model as a sustainable way of doing business.

In the car industry, these business models are facing pressure to change, and these challenges have captured the attention of scientists and policymakers (Wells, 2015).

The aforementioned studies and case studies have explained empirical evidence associated with the business models of electric cars. However, as stated by Casadesus-Masanell and Ricart (2011), 'The success or failure of a company's business model depends largely on how it interacts with models of other players in the industry'. However, the aforementioned studies have not examined the bibliometric variables, based on the context set by Casadesus-Masanell and Ricart (2011). The use of bibliometrics facilitates an identification of the essential quantitative variables of a particular research stream (Junquera and Mitre, 2007). This method allows determining necessary information about a specific research topic, including authors in the field, the number of publications, keywords allowing an interaction between variables (policies, assets, and governance), and countries' data (Casadesus-Masanell and Ricart, 2011). It also allows an implementation of the science mapping techniques (Aria and Cuccurullo, 2017). This study conducted the bibliometrics analysis by using the bibliometrix R-package (Aria and Cuccurullo, 2017). Additionally, biblioshiny, a shiny app providing a web-interface for bibliometrix, was used for creating the topic dendrogram, a conceptual map, and a trend topic figure. Moreover, to identify the most active geographies for this research area, we determined the main keywords using a conceptual chart; this helped us to identify more specific research fields and view and read the most cited papers in this domain.

To attain the study's objectives, we used the following research questions (Zupic and Čater, 2015):

Q1: What is the global trend of scientific publications on business models related to electric cars?

Q2: What information is uncovered from this trend?

Q3: What are the future directions of research in this field?

This bibliometric analysis obtains the following objectives:

(a) Provides bibliometric information on 104 scientific studies extracted from the Scopus database;
(b) Uses the bibliometric R-package and biblioshiny to obtain and record the quantitative data of different selected articles;
(c) Uses variables such as authors per article and an author's dominance index to identify the leading authors in this research area;
(d) Uses citations analysis and collaboration map to understand the network of this research stream;
(e) Studies countries to evaluate electric car production, citations, and networks within each country.

Finally, the paper is organised as follows. Section 2 lists the main bibliometric articles in this field. Section 3 elaborates on the methodology. Section 4 presents the findings of the bibliometric analysis. Section 5 discusses the main elements of a business model for electric cars, based on the findings of the analysis. Section 6 concludes the paper with future implication for research.

2. Related works

Bibliometric methods use bibliographic data from online databases. The bibliometric analysis conducted on the basis of these data allows a scientific study and a comprehensive view of the area of scientific investigation. The accessibility of bibliography data has increased the number of bibliometric reviews in different research areas (Ellegaard and Wallin, 2015). Various studies have applied this method. Table 1 lists the studies that use a similar approach to that of our paper. The scientific articles reported show substantial differences in keywords and research stream approach in relation to the topics under review.

The analysis of Hu et al. (2014) is a scientometrics work based on the keywords 'electric' and 'vehicles'; the main results of this study are linked with the areas of engineering, energy fuels, and transportation science technology. Similarly, the studies by Zhang et al. (2015) and Zhao et al. (2018) provide a comprehensive overview of the research on the reliability of electric vehicles' charging

Table 1
List of studies using the bibliometric method.

References	Fields
Hu et al. (2014)	Electric vehicles
Zhang et al. (2015)	Energy management
Gandia et al. (2018)	Autonomous vehicles
Ertz and Leblanc-Proulx (2018)	Sustainable collaborative economy
Zhao et al. (2018)	Energy Vehicle Reliability
Belussi et al. (2019)	Business model
This paper	Business model for electric vehicles

Source: Authors' elaboration

system. Gandia et al. (2018) present bibliometric and scientometrics analyses of autonomous vehicles. Ertz and Leblanc-Proulx (2018) focus on specific business models of the collaborative economy; Belussi et al. (2019) presents a precise reference map for the bibliometric analysis of business models.

Given the list of bibliometric articles, to the best of our knowledge, this is the first study to conduct a bibliometric analysis of the literature on business models for electric cars.

3. Methodology

As stated in the contribution of Aria and Cuccurullo (2017), the science mapping process and tools were described by Börner et al. (2003) and Cobo et al. (2011). Additionally, the analysis of Zupic and Čater (2015) comprised the following five rigorous steps: study design, data collection, data analysis, data visualisation, and interpretation. This study adopted the science mapping workflow method, considering the five steps followed by Zupic and Čater (2015). The five main phases of the methodology adopted in this study are elaborated below. Fig. 1 shows the methodology followed and its phases.

First, the study defined the three research questions. Subsequently, *business model* and *electric cars* were selected as the primary keywords from the Scopus database. According to Chen and Xiao (2016), keywords can be selected by using the publication keywords from a high level and by using the essential keywords that identify a large search domain and their relationship at the micro-level. This study adopts the second technique. A search for the keyword *business model* returned 338,781 results on Scopus; subsequently, researchers aimed to visualize the knowledge structure on a *microdomain* with the keywords *electric cars* (236 results on Scopus). This keyword search indicates a disintegrated set of interdisciplinary studies on business models for electric cars creates, and calls for systematising the related literature (Table 1).

Until date, the bibliometric analyses on the subject have focused on the engineering aspects of the electric car (Hu et al., 2014; Zhao et al., 2018); however, numerous studies consider other elements such as electric car's energy management (Zhang et al., 2015), charging systems (Globisch et al., 2019; Wu, 2019), sustainable models linked to sharing economy contracts (Ertz and Leblanc-Proulx, 2018), and associated services (Cooper et al., 2019; Giannetti et al., 2016). These elements are highly disintegrated.

The bibliometric method used in this study can help the readers to identify the main research domain variables in a short time, and thus contribute towards integrating these elements in the literature. Concerning the Scopus database, as mentioned by Okoli and Schabram (2010), it is a multidisciplinary database suitable for information systems (IS) researchers. Finally, as stated by Oakleaf (2010), the Scopus includes the Institute for Scientific Information- and Scopus-indexed and ranked papers. Hence, this study used the Scopus database.

In the first phase, the analysis returned 235 documents. However, as mentioned in Guthrie et al.'s (2012) contribution and followed by Massaro et al. (2016) for journal selection, researchers may simultaneously focus on generalist and specialist journals. The use of multiple journals provides a better understanding of the importance and scientific depth of the subject under investigation.

The next step involved considering only peer-reviewed scientific articles. As stated by Kelly et al. (2014), a peer review process facilitates reliable scientific communication, stimulates meaningful research questions, and provides accurate conclusions. Hence, we used the *Document type* filter on Scopus, including only articles. The final sample comprised 104 scientific sources published between 2005 and 2019. The researchers decided not to limit the research duration, given that the research is addressing an undeveloped topic and the analysis also aims to provide a research trend over the years.

After the study design phase, the second step entailed the use of the open-source statistical application R to conduct the business model and electric cars analysis. The data collection stage involved

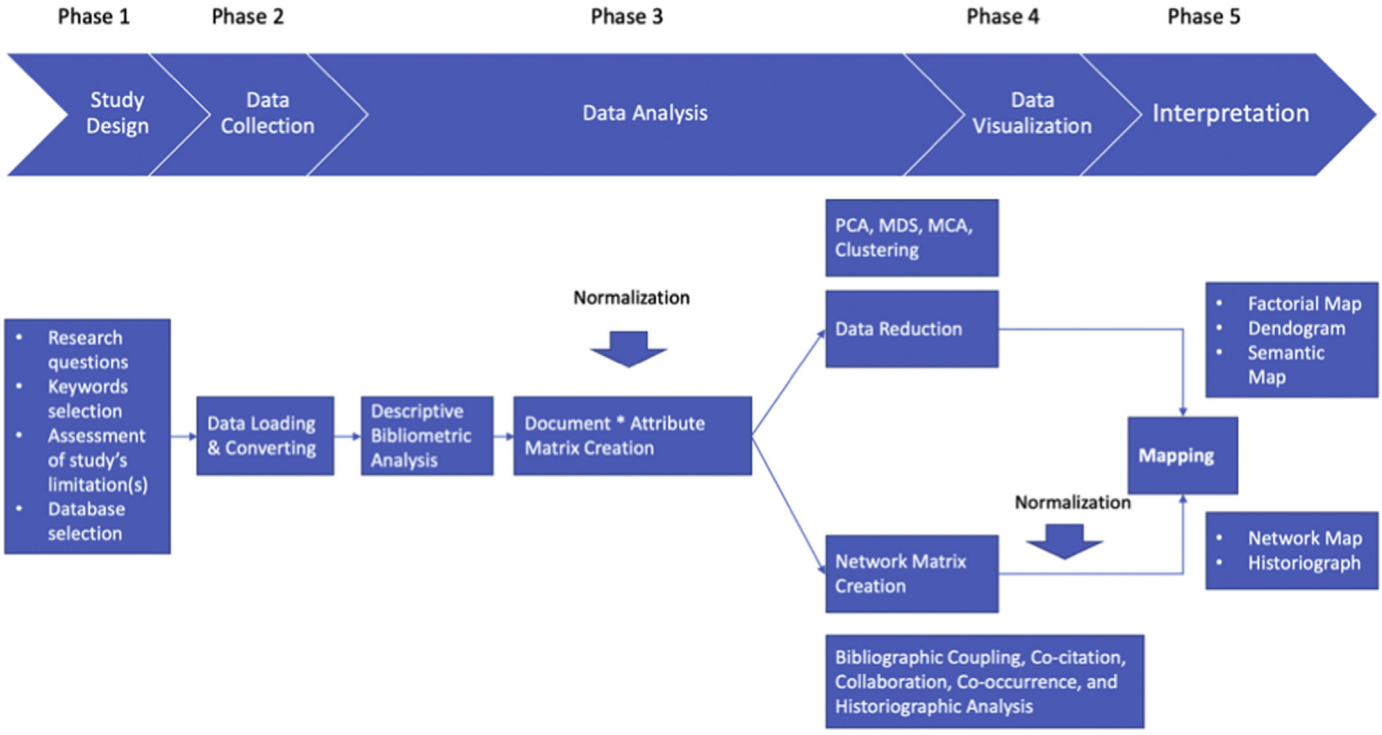

Fig. 1. Main methodology's phases - adapted from Aria and Cuccurullo (2017) and Firdaus et al. (2019).

the creation of the *.bib* file for the third phase, which is Data Analysis. In this phase, researchers used the software R and the bibliometrix codes to perform a descriptive bibliometric analysis and create a matrix comprising all the documents. Additionally, biblioshiny was used for the creation of a conceptual map and co-citation network. The analysis of the results entailed visualisation of the knowledge structure using the data reduction technique.

4. Bibliometric analysis

The analysis of bibliometric results starts with a description of the main bibliometric statistics. Subsequently, the investigation considers authors, indicators, information, and the countries of research.

Subsequently, each of the aforementioned categories are thoroughly analysed using the following elements: (1) type of document, (2) annual scientific production, (3) scientific sources, (4) source growth, (5) number of articles per author, (6) author's dominance ranking, (7) author's keywords, (8) topic dendrogram, (9) the factorial map of the document with the highest contributions, (10) articles' citations, (11) country's production, (12) country's citation, (13) the country collaboration map, and (14) the country collaboration network.

4.1. Descriptive bibliometric analysis

Table 2 shows the information on 104 articles published between 2005 and 2019, which was extracted from the Scopus database.

The strategy of the climate change policy of the United States of America, at the launch of the 10th Conference of the Parties to the UNFCCC (United Nations Convention on Climate Change) in 2004, identified electric car as one of the three pillars developed to mitigate the incidence of pollution and CO_2 emissions (Wright and Fulton, 2005). Therefore, since 2005, electric cars have gained considerable attention from both academia and national policy-makers. Hence, the beginning year of the bibliometric study follows the international trend and coincides with the start of the research conducted on the discussed theme.

The number of keywords used is nine times higher than the number of items. At the same time, keywords plus, which are the number of keywords that frequently appear in an article's title, were four times higher than the number of articles.

The analysis period covers 14 years of scientific production. However, the most significant increase in published articles occurred in the past 3 years (Fig. 2).

On an average, each article has been written by two authors (2.75). Finally, the collaboration index (CI), which calculated as the total number of authors of multi-authored articles/total number of multi-authored articles, is 3.17 (Elango and Rajendran, 2012).

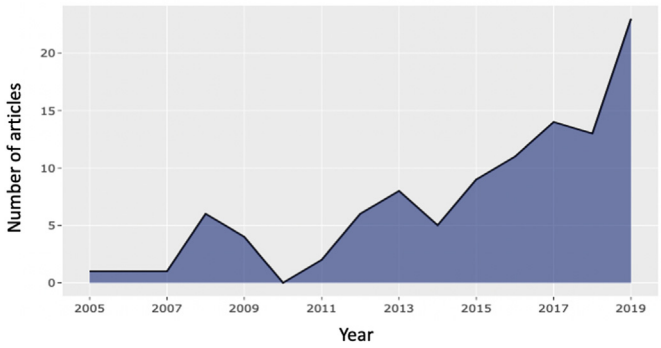

Fig. 2. Annual Scientific production. Source: Authors' elaboration using bibliometrix R-package.

We analysed 104 articles published by peer-reviewed scientific articles. The distribution of the articles does not depict a significant concentration. However, Table 3 highlights that journals specializing in transportation and automotive and mechanical and transport experiments deal with policies and practices related to

Table 3
Studies on business models for electric cars.

Top 20 sources	No.
Energy Policy	7
Nonlinear Dynamics	5
Journal of Cleaner Production	4
Transport Policy	4
Transportation Research Part A: Policy and Practice	4
Automotive Industries AI	3
International Journal of Automotive Technology and Management	3
Mitigation and Adaptation Strategies for Global Change	3
Transportation	3
Transportation Research Part D: Transport and Environment	3
World Electric Vehicle Journal	3
Applied Energy	2
Green Energy and Technology	2
International Journal of Sustainable Transportation	2
Technological Forecasting and Social Change	2
Agro Food Industry Hi-Tech	1
Automotive Engineer (London)	1
Business Process Management Journal	1
Chemical and Engineering News	1
Chemical and Petroleum Engineering	1

Source: Authors' elaboration

Table 2
Main information.

Main Information	Explanation	No.
Documents	Total number of documents	104
Sources	The frequency distribution of sources as journals	69
Author's keywords	Total number of keywords	989
Keywords Plus (ID)	Total number of phrases that frequently appear in the title of an article's references	409
Period	Years of publication	2005–2019
Authors	Total number of authors	286
Authors Appearances	The authors' frequency distribution	305
Authors of single-authored documents	The number of single authors per articles	20
Authors of multi-authored documents	The number of authors of multi-authored articles	266
Authors per document	Average number of authors in each document	2.75
Co-Authors per Documents	Average number of co-authors in each document	2.93
Average citations per article	Average number of citations in each article	14.65
Collaboration Index		3.17

Source: Authors' elaboration

environmental sustainability.

The distribution frequency of articles (Fig. 3) indicates the journals dealing with the topic and related issues. Between 2010 and 2013, it is possible to notice a significant growth in the number of publications on the topic. However, the graph shows the result of the Loess regression. As variables, it includes the quantity and the publication time of the journal under analysis. This method allows the function to assume an unlimited distribution, that is, it allows the function to assume values below zero if the data is close to zero. It contributes towards a better visual result and highlights the discontinuity in the period of the publications (Jacoby, 2000).

4.2. Authors

This section identifies the most cited authors for the electric car model. It also identifies the author's keywords, dominance ranking factor, and the total number of citations. Table 4 identifies the authors and their publications in the top 20 top rankings.

As per the table, the following authors have the highest number of publications, with three publications each: Li Yanfei (Li et al., 2015; Li and Kochhan, 2017), Timmermans Harry (Liao et al., 2018, 2019; Rasouli and Timmermans, 2016), Wang Hewu (Gong et al., 2013a; Ye et al., 2013; Zhou et al., 2015a), and Wang Yunshi (Wang et al., 2017a,b,c). This statistic is followed by other authors with no more than two releases each. While some authors have published as primary authors, most have published as co-authors. Hence, in the next section, we measured the contributing power of each author by investigating the dominance ranking factor through the number of elements.

4.3. Authors' dominance ranking

The dominance factor (DF) is a ratio measuring the fraction of multi-authored articles in which an author acts as the first author (Kumar and Kumar, 2008). Several bibliometric studies use the DF factor in their analyses (Elango and Rajendran, 2012; Gatto and Drago, 2020). The DF ranking calculates the author's dominance in producing articles. The DF factor is calculated by dividing the proportion of the number of multi-authored papers of an author as the first author (Nmf) by the total number of multi-authored papers of the author (Nmt). In the single author case, this is omitted due to its constant value of 1 for single-authored papers. The mathematical equation for the DF factor is shown as:

$$\mathrm{DF} = \frac{Nmf}{Nmt}$$

Table 5 lists the leading top 20 DF rankings. Authoring three

Table 4
Number of articles by the top 20 authors.

Number of articles	Authors (top 20)
3	Li, Y Timmermans, H Wang, H Wang, Y
2	Hao, H Liao, F Loock, M Molin, E Parkhurst, G Pltz, P Tang, T Van Wee, B Zhang, M Zhang, X Zhou, Y
1	Aamir, M Agerskov, Ml Aggeri, F Algers, S Ali, Mm

Source: Authors' elaboration

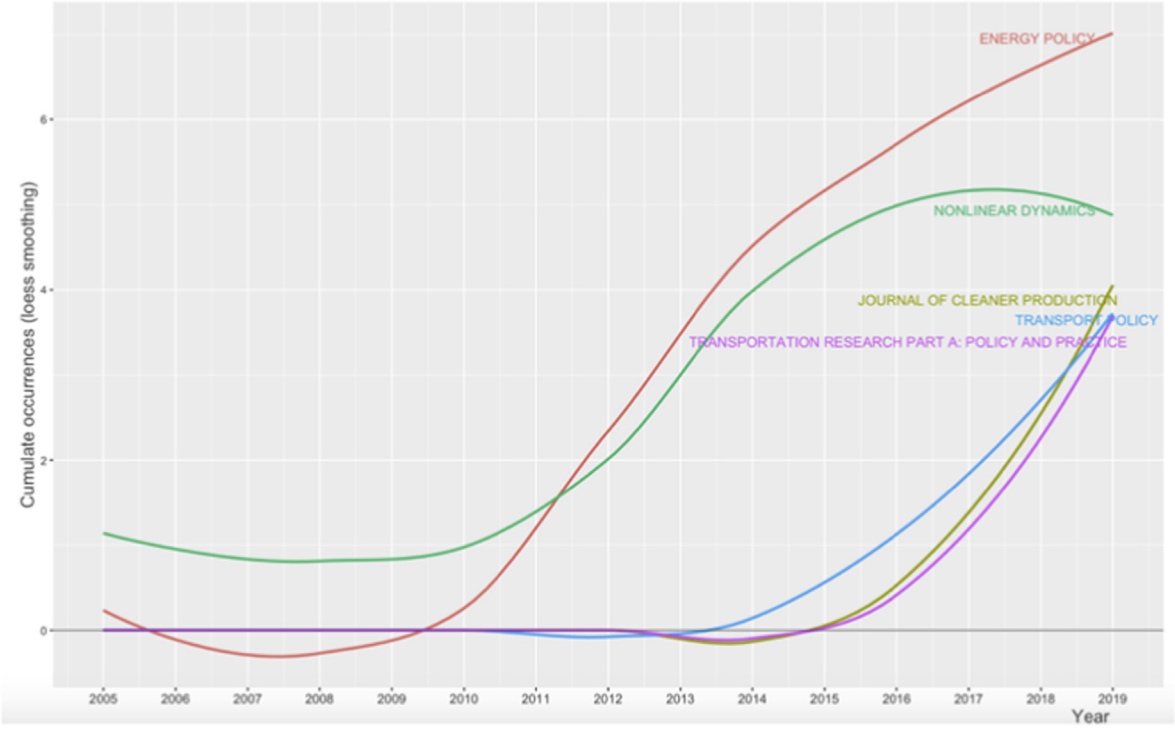

Fig. 3. Source growth. Source: Authors' elaboration using the bibliometrix R-package.

Table 5
Author's dominance.

Rank by DF	Author	Dominance factor	Multi-authored	First-authored	Rank by articles
1	Wang, Y	1.0000000	3	3	19
1	Liao, F	1.0000000	2	2	15
1	Agerskov, Ml	1.0000000	1	1	1
1	Aggeri, F	1.0000000	1	1	1
1	Amir, S	1.0000000	1	1	1
1	Athanasopoulou, A	1.0000000	1	1	1
1	Baresch, M	1.0000000	1	1	1
1	Belmoom, S	1.0000000	1	1	1
1	Bohnsack, R	1.0000000	1	1	1
1	Budde Christensen, T	1.0000000	1	1	1
1	Canals Casals, L	1.0000000	1	1	1
1	Carten, A	1.0000000	1	1	1
1	Casetta, E	1.0000000	1	1	1
1	Cheng, G	1.0000000	1	1	1
1	Cheng, Y	1.0000000	1	1	1
1	Cooper, P	1.0000000	1	1	1
17	Li, Y	0.6666667	3	2	19
18	Loock, M	0.5000000	2	1	15
18	Tang, T	0.5000000	2	1	15
18	Zhou, Y	0.5000000	2	1	15

Source: Authors' elaboration

articles as the first author in three multi-authored articles, Wang Yushi was found to have the highest DF among all the authors. Wang Yushi is followed by Liao Fanchao and other authors who have published two and one articles, respectively, as first authors. Wang Yushi is an assistant professor at the Wased University, School of Creative Science and Engineering; the author is interested in addressing topics dealing with CO_2 emissions and the evaluation of the use of electric cars in areas with high population concentrations such as China. Liao Fanchao is a post-doctoral researcher at the Faculty of Civil Engineering and Geosciences, TU Delf; the author deals with the eHUBS project, which investigates people's preference for mobility hubs equipped with multiple electric transport modes (such as EVs and e-bikes). During PhD, she conducted a research on consumer preference for electric vehicles, which focused on the impact of different business models on vehicle buyers' decision-making. The interest areas of the authors show the relationship between the theme of environmental sustainability and the use of the electric car in regard to sustainable mobility choices. Li Yanfei is in the seventeenth place because he has authored only two out of three articles and has a lower DF than the other authors.

The following section investigates the main keywords used for specific research areas by showing which keywords are related to the electric car model.

4.4. Author's keywords

This section provides information on the relationship between the keywords *electric car* and *business model*. Researchers insert multiple keywords in the articles. This analysis is essential to determine the research trend, identify gaps in the discussion on electric car and its business models, and identify the fields that can be interesting as research areas.

Table 6 highlights the total number of keywords per author in the top 20 positions. The ranking is based on the following elements: *electronic vehicle (s), business model (s),* and *electric cars*. These elements are not predictive and recall the keywords used. However, if we focus on the following keywords, we find important aspects such as sustainability, carsharing, e mobility, and innovation. Except for E-mobility, which represents all the vehicles powered by an electric motor, the keyword analysis finds that the other main strands of the study, such as innovative business models,

Table 6
Author's keywords in articles on business models for electric cars.

Author Keywords (top 20)	Articles
Electric vehicles	13
Electric vehicle	10
Business models	9
Business model	7
Electric cars	6
Sustainability	5
Carsharing	4
E-mobility	4
Electric car	4
Carsharing	3
Innovation	3
Urban mobility	3
Vehicle-to-grid	3
Battery electric vehicles	2
Car-following model	2
Case study	2
China	2
Electric carsharing	2
Electric vehicle sharing	2
Genetic algorithm	2

Source: Authors' elaboration using bibliometrix R package

innovation linked to technology, and sustainability, are related to the use of technology both in carpooling and in normal mobility.

The TreeMap below (Fig. 4) highlights the combination of possible keywords, representing business models and electric cars.

The topic dendrogram in Fig. 5 represents the hierarchical order and the relationship between the keywords generated by hierarchical clustering. The cut in the figure and the vertical lines facilitate an investigation and interpretation of the different clusters. As stated by Andrews (2003), Fig. 5 does not intend to find the perfect level of associations between clusters, but it aims to estimate the approximate number clusters in order to facilitate further discussion.

Concerning the electric power systems (Fig. 5), they are divided into two main strands. The first strand focuses on recycling connected to environmental impact, product life cycle, and industry connections to hybrid vehicles, and the second strand focuses on technology and the fallout and the composition of various models associated with the production of the electric car. If we consider the second block, which is also the one with the most divisions and

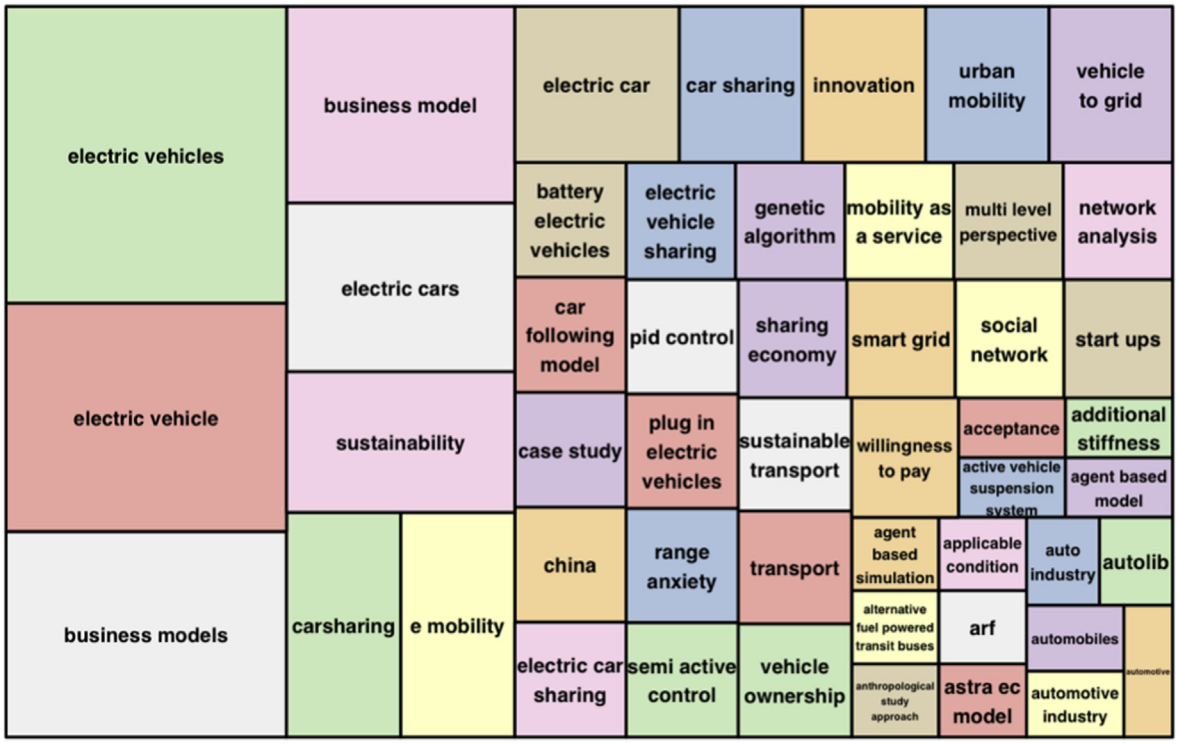

Fig. 4. Word TreeMap.
Source: Authors' elaboration using Biblioshiny

developments, we can define different areas of interest and connection. If we consider sustainable technologies connected to the optimization of resources, we can identify a relationship between these technologies and the electric car. A change in these transportation technologies has affected regional strategies connected to the use of these technologies, particularly in China. The optimization of resources and the policies adopted in this regard are connected to the introduction of new technologies, which influence the choice between the use of public transport and private car. These choices, in turn, influence urban transport policies and decisions concerning the adoption of various technologies and implementation of new models. The business models built on the basis of these approaches and strategies are connected to automotive and fuel manufacturing, the number of sales, cost efficiency models, fleet operations, and adoption of secondary batteries. Business models, fuels, and transactions are connected to car transportation plans, available plug-ins for public recharging, carbon emission, and characteristics of the cells used in the electric cars.

The type of cars used depends on the roads, the cost reduction available, and the cost of fossil fuel. The type of car is always connected to the CO_2 emissions generated and the consequent need to use electric cars to reduce and control emissions, thereby lowering the impact on climate change and reducing the traffic discharge. This implies the significant use of electric cars for mass transportation and its economic and social effects in urban areas.

Furthermore, the word cloud in Fig. 6 highlights aspects related to the electric model, such as sustainability, urban mobility, and carsharing. The figure depicts how sustainability models are linked to the use of the electric car in the most populated areas, such as China. These models also drive changes in policies. In terms of urban mobility, the sustainability factor also promotes the moderate use of electric carpooling in the cases of emergencies and as an alternative to the municipal public service. Fig. 7 represents the search trends based on the keywords analysed. The research commenced in 2011. First, it identified research topics related to automotive and product life cycle; in 2013, the research focused on the development of new technologies; in 2014, the research found the number of articles concentrated on the use of electricity in the automotive sector; in 2015, the research analysed the technologies related to electric cars and their environmental impact. In 2016, the first studies aimed at identifying the optimization of technology and analysing the profitability linked to mobility through the use of innovative technologies such as the electric car. In 2017, the studies in China focused on electric vehicles and their costs and commercial viability, with the first studies investigating new transportation systems. In 2018, the country studied the issues pertaining to sustainability and the use of new technologies to counteract CO_2. In this regard, it analysed electric cars based on the themes studied in 2017—new technologies and transport systems. In 2019, there were articles on the use of electric vehicles for fleet operation; these studies led to new developments on the topic (Oxley et al., 2012). Fleet management optimises costs, risks, and fleet. In other words, fleet managers are responsible for controlling costs, maximizing profitability, and reducing fleet vehicle risks. It involves increasing fleet productivity by using telematic resources and software; these resources help owners gauge maintenance requirements, minimise idle time, downsize fleet, improve tracking and routing, monitor safety, and improve employee efficiency. In fleet management, the GPS tracking solution helps to track the vehicle is closest to the job; this solution minimizes travel time, enables drivers to drop customers at their destinations more quickly, and, eventually, contributes toward customer satisfaction. Fleet management also promotes better management and use of fuel, thereby reducing its cost; in particular, fuel accounts for nearly 40% of fleet ownership (He et al., 2017; Lin et al., 2013). GPS vehicle tracking solutions, as

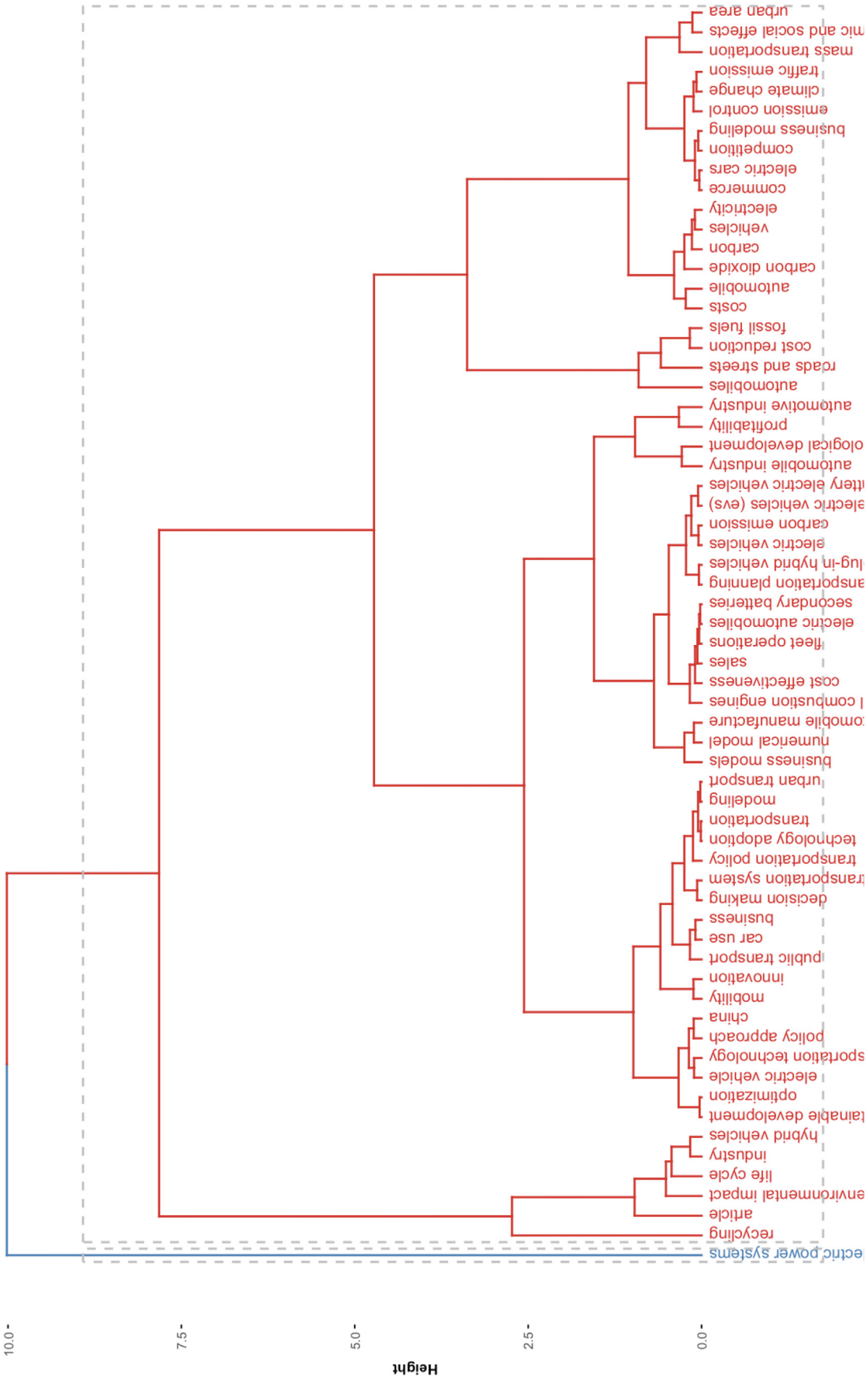

Fig. 5. Topic dendrogram.
Source: Authors' elaboration using Biblioshiny

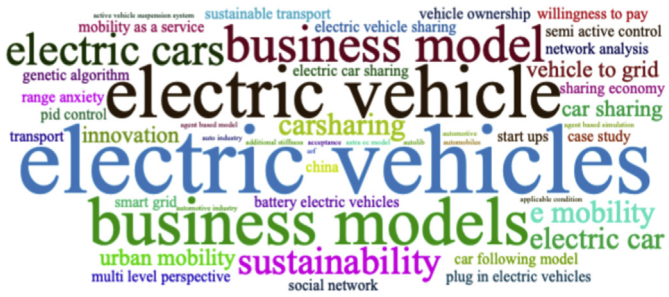

Fig. 6. Word cloud of business model and electric car keywords.
Source: Authors' elaboration using Biblioshiny

part of fleet management, can reduce fuel costs by 20%–25% (Paltsev et al., 2018). These tracking solutions indicate the idle time per vehicle and deliver idle time averages across the fleet. They also monitor fleet performance, track how improvements affect idle time, and educate drivers about the need to reduce idle times. GPS tracking solutions also reduce fuel by optimizing routes. Typically, companies that adopt these solutions reduce total miles driven by 5%–10% (Hill et al., 2019). They help drivers to plan more efficient routes by providing them access to maps and details of the location and destination of each fleet vehicle.

Table 7 represents the number of citations from other articles placed within the top 20 rankings. This shows that a few articles were worth citing only in specific years. Several authors combine the business models of the electric car with other areas; this significantly influences the number of citations, especially when it comes to environmental sustainability and new technologies related to the policies adopted. The highest number of references has been received by an article published in 2011 (Kley et al., 2011b); this has been the most-cited article to date. Four articles—one from 2013 (Gong et al., 2013b), one from 2014 (Loisel et al., 2014), and two from 2015 (Shaheen et al., 2015; Zhou et al., 2015b)—are remarkably significant in terms of the number of citations received in several years and the ranking obtained. This indicates that the papers provide high-quality information on the business model for electric cars. According to the results, Energy Policy is the most cited journal, with citations to five articles published in the journal; this is followed by the Nonlinear Dynamics journal, with citations to three of its articles. Energy policy focuses mainly on the strategies adopted to promote the use of new technologies in the energy sector. The journal also focuses on top-up and diffusion systems in the area and available energy resources. The articles from the journal present an analysis of the electric car model, the impact of policy on areas with high urban density, and market and technical fields.

The other articles in Nonlinear Dynamics focus on the concept of the electric car model and technological and engineering elements. The trend towards a multidisciplinary research on the electric car model has been confirmed. This study also confirms the parallel research areas through the identified keywords—sustainability linked to the models, technology adopted, and policies.

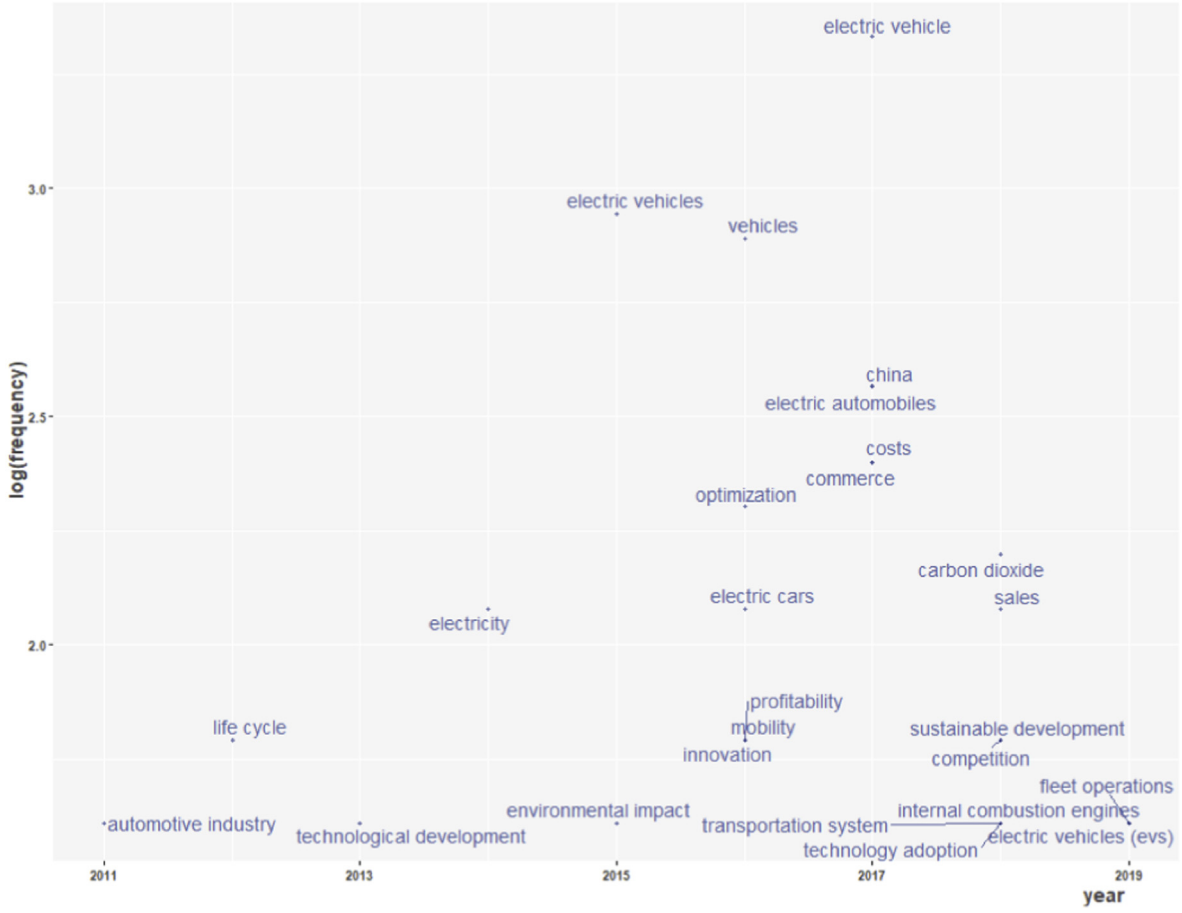

Fig. 7. Trend topics.
Source: Authors' elaboration using Biblioshiny

Table 7
Articles that received citations.

Ranking no.	Authors and their sources (top 20)	Total citations (number of citations received)	Total citation per year
1	Kley, F., 2011. New business models for electric cars – A holistic approach. Energy Policy. 39 (6), 3392-3403	194	24,25
2	Christensen, B., Wells, P., Cipcigan, L., 2012. Can innovative business models overcome resistance to electric vehicles? Better Place and battery electric cars in Denmark, Energy Policy. 48, 498-505	87	12,429
3	Gong, H., 2013. New energy vehicles in China: Policies, demonstration, and progress. Mitig. Adapt. Strateg. Glob. Chang. 18, 207–228.	84	14
4	Loisel, R., Pasaogluac, G., Thiela, C., 2014. Large-scale deployment of electric vehicles in Germany by 2030: An analysis of grid-to-vehicle and vehicle-to-grid concepts. Energy Policy. 65, 432-443	75	15
5	Zhou Y, (2015), Plug-in electric vehicle market penetration and incentives: a global review. Mitig. Adapt. Strateg. Glob. Chang.	71	17,75
6	Shaheen2015. One-way carsharing's evolution and operator perspectives from the Americas. Transportation	59	14,75
7	Junnila, S., 2006. Empirical comparison of process and economic input-output life cycle assessment in service industries. Environ Sci Technol	54	4,154
8	Lin, C., 2013. Life-cycle private costs of hybrid electric vehicles in the current Chinese market. Energy Policy	44	7,333
9	Aggeri, F., 2009. Managing learning in the automotive industry -the innovation race for electric vehicles. Int J Automot Technol Manage	44	4,4
10	Clewlow, RR., 2016., Carsharing and sustainable travel behavior: Results from the San Francisco Bay Area. Transp Policy	42	14
11	Yang, S., 2013. Electric vehicle's energy consumption of car-following models. Nonlinear DYN	37	6,167
12	Marletto G., 2014., Car and the city: Socio-technical transition pathways to 2030. Technol Forecast Soc Change	36	7,2
13	Guo, D., 2005. Nonlinear stiffness of a magneto-rheological damper. Nonlinear DYN	35	2,5
14	Li Y., 2015. Evaluating the energy consumption of electric vehicles based on car-following model under non-lane discipline. Nonlinear DYN	34	8,5
15	Cartenì, A., 2016. A random utility model for park & carsharing services and the pure preference for electric vehicles. Transport Policy	33	11
16	He, L., 2017. Service region design for urban electric vehicle sharing systems. Manuf Serv Oper Manage	32	16
17	Ercan, T., 2015. A hybrid life cycle assessment of public transportation buses with alternative fuel options. Int J Life Cycle Assess	29	7,25
18	Wang, Y., 2017. China's electric car surge. Energy Policy	28	14
19	Rasouli, S., 2016. Influence of Social Networks on Latent Choice of Electric Cars: A Mixed Logit Specification Using Experimental Design Data. Netw Spat Econ	28	9,333
20	Oxley, T. 2012. Pollution abatement from road transport: Cross-sectoral implications, climate co-benefits and behavioural change. Environ Sci Policy	28	4

Source: Authors' elaboration

4.5. Country

This section analyses the diffusion of electric car model themes. It highlights the country to show the geographies of this research. It includes all published articles, the total number of citations, and the collaboration network. The following subsections start with an analysis of the total number of published articles.

4.6. Country total of articles

Fig. 8 and Table 8 display the countries where the electric car business model theme has been considered. China tops the list of countries with the maximum number of articles on the topic (43); as already highlighted by several articles, China has been most affected by pollution and new policies adopted for sustainable sustainability. It is followed by the United States of America (22), Germany (21), the United Kingdom (13), Italy (9), and the Netherlands (9). It is immediately evident how the theme has developed in countries located in different continents, highlighting a growing interest in globalized policies related to pollution and sustainable mobility. In Asia, China has the highest concern towards pollution control. The United States of America and Canada are equally concerned, while South America is the most representative country. Germany and the United Kingdom have also published the maximum number of articles on the topic in Europe. The diffused blue colour in Fig. 8 demonstrates a remarkable development in the topic in different countries (Germany, the United Kingdom, Italy, the Netherlands, France, Sweden, Spain, Belgium, Portugal, and Switzerland).

The figure shows that many areas have still not engaged in the scientific debate. One such area is the Middle East; although studies focus on oil use in areas such as the United Arab Emirates, Qatar, Saudi Arabia, Oman, and Kuwait, the research on electric car has still not developed in the country (Farahat, 2016).

4.7. Country publications and collaboration map

This section discusses articles on business models and electric cars in terms of single or multiple publications in each country. In this regard, it also aims to observe collaboration and networking between countries. Table 9 highlights the average citation by state, and shows that the United States of America, Finland, and Denmark have a higher average of citations than the other countries. China, Germany, the United States of America, the Netherlands, Denmark, and Italy have the most significant number of citations. The automotive sector of these countries may have witnessed a substantial development, drawing the attention of researchers to this subject area.

Fig. 9 depicts the global collaborations. The blue colour on the map represents research cooperation among nations. Additionally, the pink border linking the states indicates the extent of collaboration between the authors. It is interesting to see how countries with the maximum number of publications on the electric car business model have engaged in such collaborations. Although the United States of America, China, Germany, and the United Kingdom have engaged in the most significant collaborations with countries that are sometimes very distant from each other and therefore have failed to develop the theme, the collaboration can lead to a sharing of policies and market collaboration.

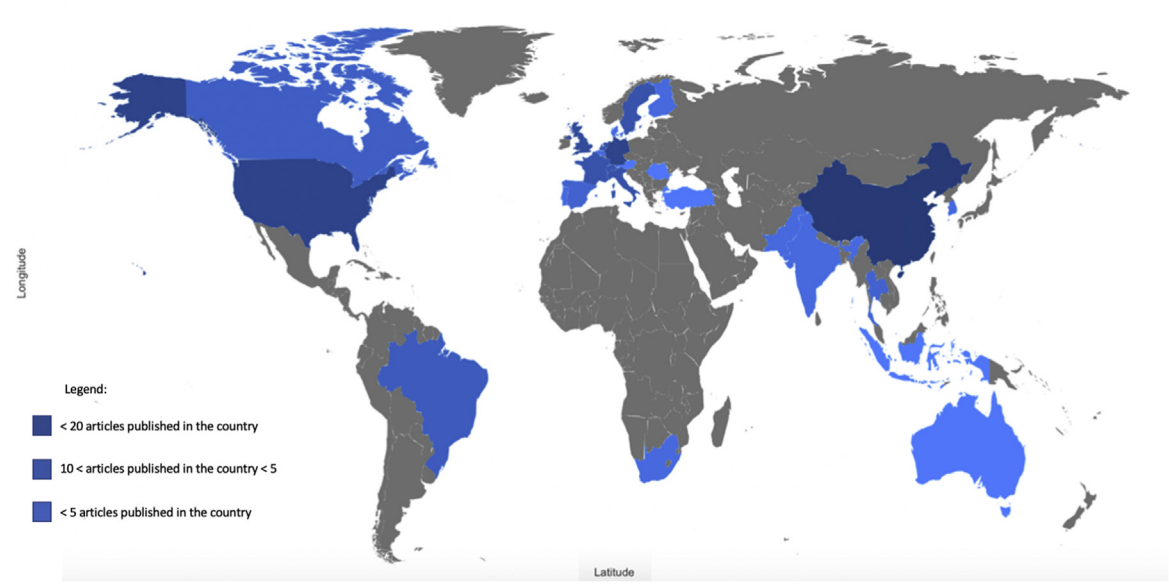

Fig. 8. Country's production.
Source: Authors' elaboration using Biblioshiny

Table 8
Total number of articles published in each country.

Country	Total number of articles
China	43
The United States of America	22
Germany	21
The United Kingdom	13
Italy	9
Netherlands	9
France	8
Sweden	8
Switzerland	8
Brazil	5
Canada	4
Singapore	3
Spain	3
Thailand	3
Belgium	2
Denmark	2
Finland	2
India	2
Pakistan	2
Portugal	2

Source: Authors' elaboration

Table 9
Country and their total number of citations.

Country	Total citations	Average article citations
China	274	19,6
Germany	255	19,6
The United States of America	172	57,3
The Netherlands	113	18,8
Denmark	88	44
Italy	77	25,7
Finland	54	54
Canada	44	14,7
France	44	22
Singapore	32	32
United Kingdom	31	10,3
South Africa	27	27
Switzerland	24	12
Korea	23	11,5
Belgium	12	12
Thailand	11	11
Spain	8	8
Brazil	2	2
Austria	1	1
Indonesia	1	1

Source: Authors' elaboration

4.8. Business model for electric cars

In general, the literature underlying business models for electric cars appears to be extensive. Hence, it is important to evaluate the value created through these models and identify innovation models (Chester et al., 2019) and possible structural impediments to the diffusion of certain products (Krommes and Schmidt, 2017; Nieuwenhuis, 2018).

Furthermore, the research team considered the bibliometric analysis (Fig. 5) to identify five macro variables dominant in the field and used as keywords by authors. Additionally, the following section aims to explain the status of the debate on the business model for electric cars and highlight future research considerations. These elements are shown in Fig. 10.

4.8.1. Charging technologies

One of the notable aspects of electric vehicles (EV) is their charging system, which comprises individual charging points based on direct agreements between the company and the applicant, common charging points in the workplace, public charging stations, and fast-charging stations.

Each choice presupposes an underlying business model decision. According to Wu (2019), business models should be based on driving, charging, and battery switching dynamics. It is essential to decide which role the service provider can play. The analysis finds that policymakers rely on fixed charging contracts in order to maintain the EV sharing activity. However, this decision can change with an increase in energy costs. If the vehicle sharing network increases pricing, then most recommended charging technology would be direct charging by the network's energy operator. However, the analysis of Globisch et al. (2019), based on assessments of

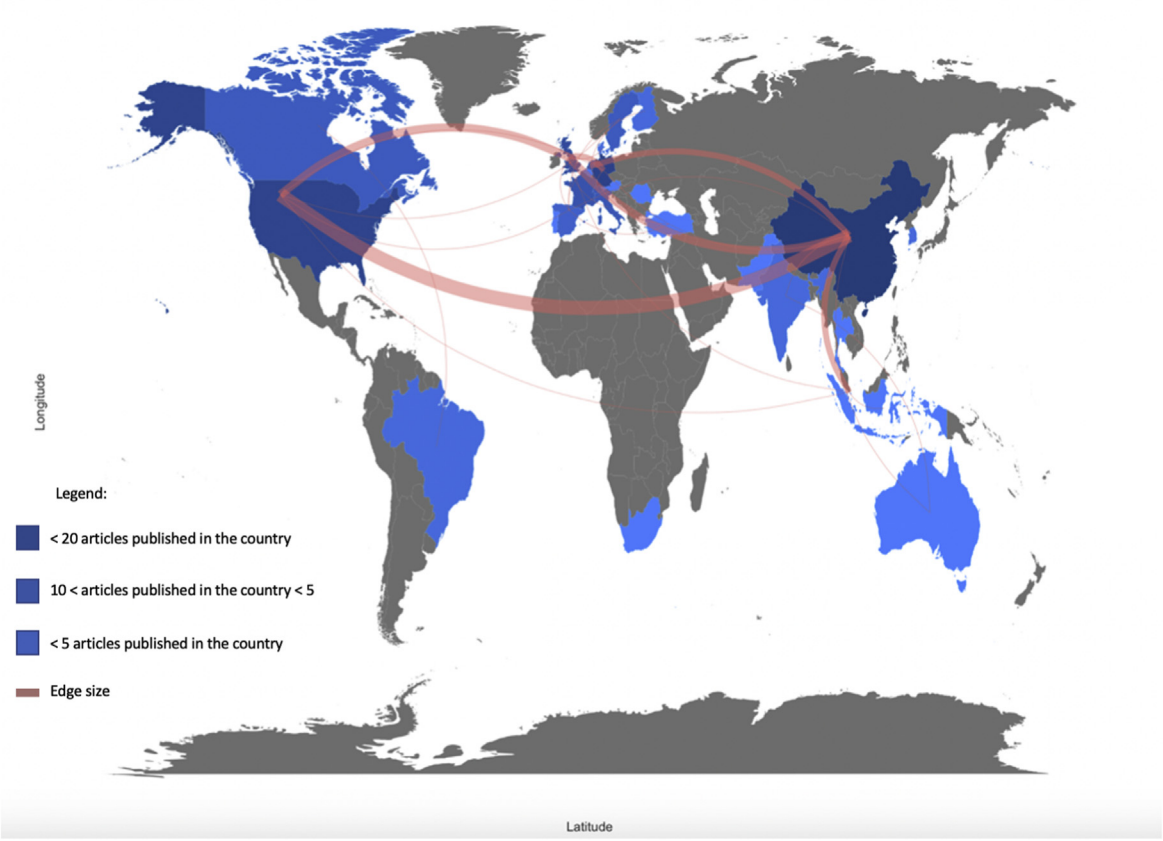

Fig. 9. Country collaboration map.
Source: authors elaboration using Biblioshiny

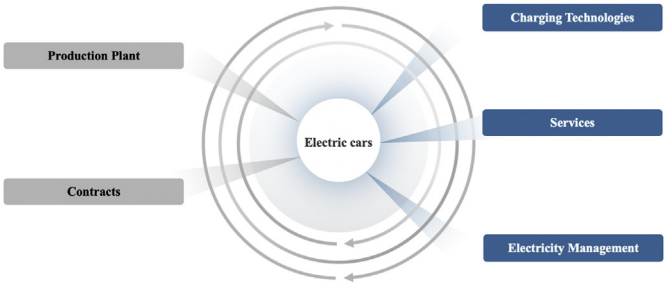

Fig. 10. Business models and electric cars: Macro variables.
Source: Authors' elaboration

1003 German car drivers, concludes that drivers express reluctance to pay necessary charges against the use of public charging infrastructure (Baresch and Moser, 2019). This challenge can be overcome by solar charging stations (Robinson et al., 2014). Although these charging stations can be costly to install in public and industrial spaces, these costs can be covered through sponsorships, percentage subscriptions, or a free usage model for buyers of EVs from specific car manufacturers'

4.8.2. Services

High vehicle production costs are driving companies to focus on a wide range of services for drivers (Cooper et al., 2019; Giannetti et al., 2016). The primary evidence is concerned with personalisation and user experience enhancement services, generic mobility services, shared mobility and related cars (Athanasopoulou et al., 2019).

Concerning the business model for personalisation and improvement services, they are provided as part of the complementary or after sales services by car manufacturers. They may include navigation services, vehicle support services, advanced charging services, and WI-FI services inside vehicles.

In the case of generic mobility services, articles show that radical changes in vehicle management and driving will affect car manufacturers' business models.

Shared mobility, which is a part of the sharing economy, has led to new business models managed by third-party companies instead of vehicle manufacturers. According to Clewlow (2016), in San Francisco, the number of owned vehicles is lower as the city focuses on sustainable mobility. Besides, privately owned vehicles in the city are hybrid, plug-in hybrid electric, or fully electric vehicles. These choices influence manufacturers' sales model and marketing choices for that area.

Concerning the insurance services, the evidence from Wu (2019) shows that, in the case of vehicle sharing, insurance with a fixed premium must be preferred if there are many users. The increase in marginality can be achieved by using hourly premium insurance.

4.8.3. Electricity management

Concerning increased energy use due to the use of EV, Kalathil et al. (2019) show that new companies can be created to share and store electricity to meet diversified supply and demand.

4.8.4. Contracts

On the one hand, the high initial purchase costs of vehicles, and, on the other hand, the need to reduce pollutant emissions from

internal combustion engine cars have contributed to the development of new contracts for driving electric cars. The only area of debate lies in the extension or withdrawal of political support for the purchase of EVs.

To reduce the purchase price of vehicles, Nian et al. (2019) propose a cost-sharing scheme between the seller and the buyer. This model predicts the partial payment of the car and the commitment of the buyer to purchase electricity. The commercial contract is based on a minimum charging threshold that buyers will have to meet to cover the costs.

In other schemes, the battery may not be included in the purchase. It would give companies an opportunity to provide specific leasing or rental contracts for the battery, covering the charging costs' (Li and Kochhan, 2017; Ye et al., 2013). Under this type of scheme, the consumer preference analysis of Liao et al. (2019) shows that the model can be driven by lease EV vehicles and not just batteries. Those who perceive the added value of the electric car are more inclined to purchase through leasing. Government's financial incentives can also increase sales and consideration.

4.8.5. Production plant

Another challenging point is the transformation of production facilities, in light of new business models for the automotive sector. The transformation of vehicle ownership models also requires a change in the vision of the manufacturers. This thesis is supported by Nieuwenhuis (2018); the author describes how new 3D printing can revolutionise the business models of production plants. This can be achieved by establishing retail micro-factories capable of meeting a diversified demand (Wells, 2013).

5. Discussion

This bibliometric analysis focused on determining the research trend in terms of authors, citations, journals, and sub-topics.

This bibliometric analysis identifies authors with the highest number of publications (3)—Li Y, Timmermans H., Wang H., and Wang Y. They analyse business models for electric cars from different perspectives; however, Li Y. focuses more on energy consumption and mobility models. Timmermans H. analyses consumer preferences and the impact of electric cars on the current business models. Wang H. considers the possibility of battery leasing. Finally, Wang Y. analyses the environmental implications.

In terms of dominance ranking, Wang Y. gets the highest rank; he is the director of the China Center for Energy and Transportation at the UC Davis Institute of Transportation Studies.

The analysis shows that journals with the maximum number of articles on the topics are Energy Policy with seven publications and Nonlinear Dynamics with five publications; they are followed by the Journal of Cleaner Production with four publications.

In the case of Energy Policy, the contributions focused on the analysis of innovative business models and their life cycle. In Nonlinear Dynamics, the articles dealt with the engineering aspects of electric vehicles. Finally, the contributions of the Journal of Cleaner Production aimed to address the effects of business models and the environment.

Regarding citations analysis, the holistic approach of Kley et al. (2011b) led them to receive the highest number of citations.

From the keywords used, the business models adopted for electric cars are driven by the factors of innovation, including E-mobility and car-sharing, electric batteries, and energy management. This evidence further demonstrates the broad approach of this research area in defining the business models. Moreover, the topic dendrogram (Fig. 5) describes two evolutions of the discussion. The first group considers innovative aspects of business models, including innovative technologies and resource optimization. The second group represents the less-explored area of electricity management systems, including battery recycling and life cycle.

Besides, this study also discovers that business models for electric cars were adopted by considering (1) charging technologies, (2) services, (3) electricity management, (4) contracts, and (5) plant. Each of them is divided into elements currently under discussion by researchers (Table 10).

The research also shows a lack of relationship between sustainability and policies aimed at increasing the share of renewable energy for recharging electric batteries. One of the issues not included in the scientific discussion of business models is the role that smart cities can play with respect to the elements indicated in Table 10. Particularly, smart cities are looking for sustainability models for vehicle management (Trindade et al., 2017). From this point of view, it would also be interesting to investigate the role of public authorities in promoting the innovation of electric car business models. Moreover, this research area seems to lack an in-depth discussion on battery disposal as an intrinsic element of the business model of EV manufacturers.

From country point of view, China (43 publications), the United States of America (22 publications), and Germany (21 publications) have the highest number of studies on the subject. China, in particular, has been witnessing an increase in road transportation since the past several years, which has increased its use of fossil fuels. These fuel significantly increase the emissions of greenhouse gases and pollutants (Yan et al., 2010). Therefore, at the scientific level, by promoting the use of both pure and hybrid electric vehicles, researchers have tried to propose alternatives to traditional engines in order to increase environmental sustainability (L.-Y. He and Chen, 2013).

Collaboration between countries (Fig. 9) shows that most of the countries developing this theme are in the European macro-region. The analysis also shows that regions such as South America, Africa, Russia, and the Gulf countries are not scientifically analysing the issue.

6. Conclusion

This study aims to provide a bibliometric analysis of the publications on the business models for electric cars. Although there is a considerable amount of literature on this subject, we observed that the literature lacked a bibliometric analysis. Using science mapping workflow and multiple research questions, we investigated the trend of scientific publications on the subject, unexplored information, the future directions, and implications.

For accurately answering these research questions, we conducted a bibliometric analysis by using *bibliometrix* R-package.

The analysis highlights that it is essential to have sustainable

Table 10
Electric cars' business model elements under discussion.

Macro variables	Elements under discussion
Charging technology	Individual charging point
	Public charging stations
	Fast-charging stations
	Solar charging stations
Services	Personalisation and user experience services
	Generic mobility
	Shared mobility
	Insurance
Electricity management	Energy management
	Energy storage
Contracts	Cost-sharing scheme
	Leasing of batteries
	Leasing of cars
Production Plant	3D printing
	Microfactories

Source: Authors' elaboration

business models for the following aspects of electric cars: charging technologies, services, electricity management, contracts, and production plant.

Here, the possibility of creating a theoretical common framework within national organisations could bring exciting results for both car manufacturers and the environment as well as for electric car buyers.

This work offered a broad comprehension of bibliometric variables of business models and electric cars and can contribute towards progressing scientific research in this field. Besides, researchers could benefit from that analysis and integration of multidisciplinary fields.

Additionally, the study also highlights unexplored topics that can be studied further by researchers and dealt from policymaking and managerial perspectives.

Concerning future research, we believe that an analysis of the break-even point between the use of electric cars and traditional cars at a scientific level can further develop this topic and indirectly contribute towards the management of business models, thereby benefitting managers and policymakers.

We also believe that future research may focus on impact and sensitivity analyses of electric car contracts. Besides, further case studies could investigate how business model related to electric cars affect population-intensive countries. This can be particularly interesting for all the institutions working in highly populous countries as China.

Furthermore, only 10% of the results was considered to analyse the application of business models for electric vehicles. A higher identification of cases can be useful to identify the endogenous and exogenous variables of countries and their way of influencing purchasing choices, laws, procurement systems, technologies, and market type.

Additionally, further analysis could also identify why some parts of the world did not conduct studies on this area. It would be useful to conduct a comparative analysis between countries active in this field of research and countries that are not currently involved. This would make it possible to identify variables affecting the presence or absence of electric cars.

In conclusion, there is currently a lack of specific analyses on procurement policies, management and policies pertaining to the vertical and horizontal integration of companies, and sales and marketing initiatives for electric cars. Research in this direction can further increase the comphrensiveness of the topic.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

CRediT authorship contribution statement

Silvana Secinaro: Data curation, Project administration, Resources, Supervision, Validation, Writing - original draft. **Valerio Brescia:** Formal analysis, Methodology, Writing - original draft, Writing - review & editing. **Davide Calandra:** Formal analysis, Methodology, Software, Writing - original draft, Writing - review & editing. **Paolo Biancone:** Conceptualization, Funding acquisition, Supervision, Validation, Writing - original draft.

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Appendix A. Supplementary data

Supplementary data related to this article can be found at https://doi.org/10.1016/j.jclepro.2020.121503.

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