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Evaluating the Automotive Sector's Economic, Social, and Environmental Contributions: A Bibliometric Analysis (1967-2025)

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Abstract. The automotive sector plays a decisive role in shaping the economic, social, and environmental trajectories of nations worldwide. Despite its centrality, existing bibliometric studies have mainly focused on specific automotive subfields rather than providing an integrated mapping of the sector's economic, social, and environmental contributions. This paper addresses that gap by analysing 320 documents retrieved from Scopus for the period 1967 to 2025. Using Biblioshiny and VOSviewer, the study applies performance analysis, co-citation analysis, bibliographic coupling, keyword co-occurrence mapping, and thematic evolution analysis. Results show a sustained annual growth rate of 5.71%, with Germany, China, and the United States as leading contributors. The keyword co-occurrence network identifies five research clusters centered on regional economic development, global value chains, environmental impact, manufacturing efficiency, and sustainable mobility. The thematic map reveals that economic and social effects and environmental impact constitute motor themes, while life cycle and supply chain topics remain emerging. These findings offer actionable insights for researchers and policymakers navigating the sector's triple transition toward electrification, digitalization, and circularity.

Keywords: *Automotive industry; Bibliometric analysis; Economic contributions; Environmental sustainability; Social impact; Biblioshiny; VOSviewer; Scopus.*

1. Introduction

The automotive sector occupies a structural position in the global industrial economy that few other industries can match. Its economic footprint extends well beyond the factory floor, encompassing networks of primary suppliers, logistics operators, retail distributors, maintenance services, and financial intermediaries. Globally, the sector generates revenues exceeding 2.5 trillion USD annually and contributes roughly 10% of GDP in developed economies (Vaz et al., 2017). In Europe alone, it employs approximately 13.8 million people across manufacturing, distribution, and maintenance functions (Helmold, 2021), while in Germany it accounts for 11.5% of national GDP (Teipen et al., 2023). These figures capture only the direct dimension of a contribution that cascades through upstream industries such as steel, chemicals, and electronics, and downstream services ranging from insurance to digital platforms.

Yet the sector's primacy comes at a significant environmental cost. Passenger cars and vans collectively emitted 3.5 gigatons of CO2 in 2020, representing close to one-tenth of global emissions (Molnar et al., 2024). Road transport accounts for approximately 12% of worldwide greenhouse gas output (Cruceru et al., 2024), a figure that has continued to rise despite successive rounds of emissions regulation. This duality between indispensable economic engine and environmental liability has generated a rich body of scholarly work examining the sector from economic, social, and

environmental perspectives. Research traditions in industrial economics, transport geography, environmental management, supply chain science, and regional development have each contributed partial views. What remains missing is a systematic synthesis of how these strands relate to one another within a unified intellectual framework.

Bibliometric analysis provides precisely that kind of synthesis. By treating the published literature as a dataset, it enables the identification of dominant research themes, key contributors, knowledge gaps, and thematic evolution patterns without the selection biases inherent in traditional narrative reviews (Donthu et al., 2021; Aria and Cuccurullo, 2017). Prior bibliometric studies of automotive research have addressed sub-domains such as supply chain risk management (Saberi et al., 2019), electric vehicles (Li et al., 2019), and autonomous vehicles (Clements and Kockelman, 2017), but, to the best of our knowledge, none has undertaken a comprehensive mapping of the literature specifically addressing the economic, social, and environmental contributions of the sector as an integrated whole.

This paper fills that gap by analyzing 320 documents retrieved from the Scopus database for the period 1967 to 2025. The study is guided by four research questions: How has scholarly production on the automotive sector's contributions evolved over nearly six decades? Which countries, institutions, and authors have shaped this research landscape? What thematic clusters characterize the field and how have they changed over time? And what are the emerging frontiers and underexplored dimensions that should guide future inquiry?

The contribution of this study is threefold. Theoretically, it advances automotive contributions research by proposing an integrated cross-disciplinary framework that connects economic, social, and environmental research traditions previously examined largely in isolation from one another. Methodologically, it combines performance analysis, science mapping, and thematic evolution techniques within a single Scopus-based bibliometric protocol, offering a replicable template that can be extended to other industrial sectors facing comparable multidimensional evaluation challenges. Practically, it identifies concrete thematic gaps and priority areas that can inform funding agencies, industry associations, and policymakers seeking an evidence-based view of where scholarly knowledge of the sector's contributions is most and least developed.

The remainder of the paper proceeds as follows. Section 2 reviews the relevant literature situating this study in relation to prior bibliometric and automotive contributions research. Section 3 describes the data collection process and the analytical methods employed. Section 4 presents results across performance analysis, science mapping, and network analysis. Section 5 identifies limitations and future research directions, and Section 6 concludes.

2. Literature Review

The automotive industry's economic significance has been extensively documented. Its role as an engine of GDP growth, employment generation, and foreign direct investment attraction is well established for major automotive nations including Germany, the United States, Japan, China, and increasingly India and Brazil (Peters et al., 2014; Teipen et al., 2023; Torok, 2022). The sector's integration into global value chains constitutes one of the most analytically productive frameworks for understanding its economic geography: backward linkages to raw material suppliers and forward linkages to service providers create multiplier effects that extend its impact far beyond assembly plants (Helmold, 2021; Pavlinek, 2018). Studies of emerging economies have further shown how automotive cluster formation can catalyze broader industrialization processes, attract foreign direct investment, and upgrade domestic supplier capabilities (Guadalupe et al., 2020).

The social dimension of automotive contributions has attracted growing scholarly attention, particularly in relation to employment quality, wage premiums, and regional labour market effects. Automotive wages consistently exceed the manufacturing average in most producing nations (Peters et al., 2014). The sector's capacity to support highly skilled employment across engineering, logistics, and commercial functions makes workforce planning a critical strategic concern for both firms and governments (Farooq et al., 2024). More recently, research has examined how the transition to electric vehicles may disrupt existing employment patterns, particularly in regions dependent on internal combustion engine component manufacturing (Teipen et al., 2023).

Environmental research on the automotive sector has evolved from early life cycle assessment studies of vehicle components toward more systemic analyses of the sector's contribution to carbon emissions, resource consumption, and circular economy transitions. Zah et al. (2007) established a methodological benchmark for automotive life cycle assessment that subsequent researchers have refined and extended. The electrification transition has generated a new wave of environmental research examining battery material supply chains, end-of-life recycling, and the conditions under which electric vehicles genuinely reduce net lifecycle emissions (Li et al., 2019; Ohno et al., 2015). Circular economy frameworks have been applied to automotive supply chains with growing frequency since 2015 (Zimmer et al., 2017; Nechita et al., 2025).

Bibliometric analysis has proven to be a powerful tool for synthesising these diverse research traditions and identifying structural patterns that individual studies cannot reveal. The Bibliometrix R package developed by Aria and Cuccurullo (2017) and the VOSviewer software (Van Eck and Waltman, 2010) have become standard instruments for this type of analysis. Previous bibliometric studies in adjacent fields include Zaki and Madkour (2025) on university social responsibility, and El Khlifi and Madkour (2025) on climate risk and financial stability, both of which demonstrate the analytical value of integrating performance analysis with science mapping methods. The present study adapts this methodological approach to the automotive contributions' literature, offering, to the best of our knowledge, one of the first integrated bibliometric maps of the field's economic, social, and environmental dimensions.

3. Data and Methodology

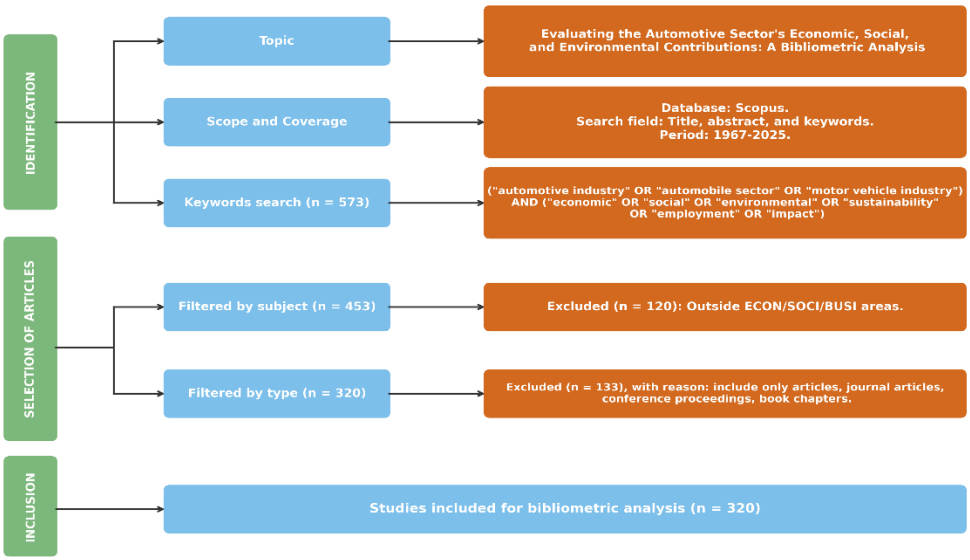
Bibliometric analysis is a quantitative research method designed to evaluate global trends within a specific scholarly domain by analyzing academic publication outputs indexed in databases such as Scopus or the Web of Science (Ellegaard and Wallin, 2015; Zhu and Liu, 2020). The approach distinguishes between performance analysis, which evaluates the bibliometric output and impact of scholarly actors, and science mapping, which uncovers the intellectual and conceptual structure of a research field through network analysis and thematic mapping (Aria and Cuccurullo, 2017).

The Scopus database was selected as the sole data source on account of its broad international coverage, particularly in economics, management, environmental science, and engineering, and its well-structured citation metadata. Comparative assessments have confirmed that Scopus indexes a wider range of journals than the Web of Science and provides more consistent citation formats (Mongeon and Paul-Hus, 2016). Combining both databases would risk data duplication and inconsistencies that could distort network and co-citation analyses. To ensure homogeneity, replicability, and analytical reliability, a single-database strategy was retained.

The search strategy targeted publications whose titles, abstracts, or keywords contained the terms "automotive industry" OR "automobile sector" OR "motor vehicle industry", combined with

"economic" OR "social" OR "environmental" OR "sustainability" OR "employment" OR "impact". The search covered the period from 1967, corresponding to the earliest Scopus-indexed publications linking these themes, to 2025. The initial query returned 573 documents. Following the PRISMA framework, the selection proceeded through identification, screening, and eligibility stages. During the screening stage, records outside the subject areas of Economics, Business, and Social Sciences were excluded, leaving 453 records. Subsequently, only peer-reviewed journal articles, conference proceedings, book chapters, and review articles published in English were retained. Editorials, notes, errata, non-English publications, and records lacking complete bibliographic metadata or a retrievable abstract were excluded, resulting in a final dataset of 320 documents. Finally, titles and abstracts were examined to ensure that the automotive sector constituted the primary analytical focus rather than an incidental example within broader manufacturing, transport, or policy studies. Applying these criteria in sequence, the final dataset comprised 320 documents. The selection process is illustrated in Figure 1.

Figure 1. Research methodology and document selection process following the PRISMA framework



Source: Authors' own elaboration

The dataset was analysed using two complementary instruments. Biblioshiny, the interactive web interface of the Bibliometrix R package (Aria and Cuccurullo, 2017), was used for performance analysis covering publication trends, country contributions, author impact, and thematic mapping. VOSviewer (Van Eck and Waltman, 2010) was used for the construction and visualization of keyword co-occurrence networks, bibliographic coupling maps, and co-citation networks. A thesaurus file was created within VOSviewer to standardize synonymous terms and reduce terminological fragmentation (Kirby, 2023). The overall analytical workflow covered five dimensions: descriptive statistics, article influence analysis, source analysis, author and country profiling, co-citation and bibliographic coupling mapping, keyword co-occurrence analysis, and thematic evolution analysis. The methodology is summarized in Figure 1 above.

4. Results and Discussion

The bibliometric analysis presents findings from two complementary perspectives: general information and performance analysis in Section 4a, and science mapping and network analysis in Section 4b. Each perspective provides distinct insights that collectively build a comprehensive understanding of the intellectual landscape of automotive contributions research.

a. General Information and Performance Analysis

i. Descriptive Statistics

The dataset comprises 320 documents authored by 865 scholars across 199 publication venues, spanning nearly six decades from 1967 to 2025. The annual growth rate of scientific production stands at 5.71%, reflecting sustained but measured expansion of the field. Co-authorship is the norm, with an average of 2.92 authors per document and an international co-authorship rate of 17.81%. Sixty authors published single-authored documents, indicating that solo contributions, while present, represent a minority practice in a field where empirical complexity generally rewards collaborative approaches. The average citation count per document is 14.22, and documents have an average age of 9.47 years, suggesting the field draws substantially on established foundational works while also citing more recent contributions. Table 1 presents the full set of descriptive statistics.

Table 1. Main Information about the Dataset

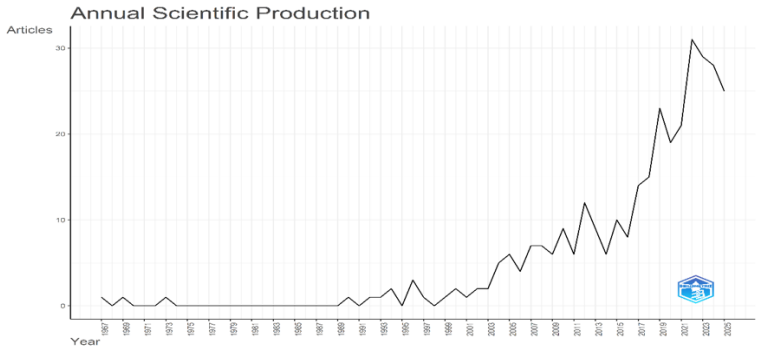
Description	Results	Description	Results
Timespan	1967 : 2025	References	2,568
Sources (Journals, Books, etc.)	199	Authors	865
Articles	320	Authors of single-authored docs	60
Annual Growth Rate (%)	5.71	Single-authored docs	66
Article Average Age (years)	9.47	Co-Authors per Article	2.92
Average Citations per Article	14.22	International Co-authorships (%)	17.81

Source: Own elaboration with data from Scopus database.

Note: This table summarizes key metrics of the dataset, including timespan, sources, articles, growth rate, article age, citations, authors, and collaboration patterns.

Figure 2 illustrates the annual scientific production over the study period. Publications remained sparse and irregular from 1967 through the late 1990s, rarely exceeding three articles per year. A first meaningful acceleration is observable around 2001 to 2003, coinciding with the broader institutionalisation of sustainability science and growing policy attention to the automotive sector's environmental footprint. A second, more pronounced growth phase begins around 2015 and intensifies from 2019 onwards, with output reaching 31 articles in 2021 before stabilising around 25 to 29 articles annually in subsequent years. This acceleration reflects the compound effects of COVID-19 supply chain disruptions, intensified decarbonisation policy pressure, and the rapid scaling of electric vehicle markets globally.

Figure 2. Annual Scientific Production on the Automotive Sector's Contributions (1967-2025)



***Source**: Biblioshiny analysis of Scopus data (N = 320).*
***Note**: This figure illustrates the temporal trends in publication volume over time, highlighting growth phases and fluctuations in research activity.*

ii. Influential Articles

Table 2 identifies the ten most globally cited documents in the dataset. Zah et al. (2007), published in the Journal of Cleaner Production, leads with 355 citations, establishing life cycle assessment of biofuels in automotive contexts as a methodological reference point. Li et al. (2019) follows with 205 citations for their analysis of China's electric vehicle policy landscape in Energy Policy, reflecting the field's growing engagement with clean mobility transitions. Wells (2005), published in Supply Chain Management: An International Journal with 184 citations, represents the foundational work on sustainable automotive supply chains.

The presence of three articles by Pavlínek in the top ten (ranks 6, 7, and 10) is particularly notable: collectively these works (Pavlínek, 2009; 2012; 2018) have accumulated 349 citations and address the restructuring of automotive value chains in Central and Eastern Europe through a political economy of global production framework. Rehnberg and Ponte (2018), with 144 citations, examine how product upgrading and modularity shape value capture across automotive global networks, while Zimmer et al. (2017) and Ohno et al. (2015) address circular material flows and resource efficiency in production and end-of-life contexts respectively.

Table 2. Most Influential Articles (Top 10 by Global Citations)

Rank	Document	Citations	Rank	Document	Citations
1	ZAH R, 2007, J CLEAN PROD	355	6	PAVLÍNEK P, 2009, EUR URBAN REG STUD	136
2	LI J, 2019, ENERGY POLICY	205	7	PAVLÍNEK P, 2018, ECON GEOGR	122
3	WELLS P, 2005, SUPPLY CHAIN MANAGE	184	8	ZIMMER K, 2017, J CLEAN PROD	119
4	REHNBERG M, 2018, GLOBAL NETW	144	9	OHNO H, 2015, RESOUR CONSERV RECYCL	100
5	WINSCHE WE, 1973	142	10	PAVLÍNEK P, 2012, ECON GEOGR	91

Source: Own elaboration with data from Scopus database
Note: This table lists the ten most influential articles based on global citation counts, highlighting key contributions to the field.

iii. Most Relevant Sources

Table 3 presents the leading publication venues by number of documents. SAE Technical Papers dominates with 25 publications, reflecting the engineering-oriented tradition in automotive research where practitioner-relevant conference proceedings hold significant standing alongside peer-reviewed journals. The International Journal of Automotive Technology and Management (12 documents) and the Journal of Cleaner Production (11 documents) represent the field's two main academic journals straddling industry-specific management research and environmental science respectively. Resources, Conservation and Recycling (4 documents) and Society and Economy (4 documents) confirm the field's genuine interdisciplinarity, connecting materials science, circular economy, and regional economic analysis within the same corpus.

Table 3. Most Relevant Sources by Number of Publications

Sources	N. of Articles	Sources	N. of Articles
SAE Technical Papers	25	Asia Pacific Business Review	3
Int. Journal of Automotive Technology and Management	12	Ekonomicky Casopis	3
Journal of Cleaner Production	11	Problems and Perspectives in Management	3
Resources, Conservation and Recycling	4	ZWF Zeitschrift Fuer Wirtschaftlichen Fabrikbetrieb	3
Society and Economy	4	Advances in Transdisciplinary Engineering	2

Source: Own elaboration with data from Scopus database

Note: This table lists the most influential sources based on the number of documents published in each venue.

iv. Influential Authors

Table 4 identifies the most productive authors by total publications (TP) and total citations (TC). Pavlínek P leads with six publications and 424 citations, making him the single most cited and prolific author in the dataset. His sustained focus on automotive industry restructuring in post-socialist Europe, analysed through the lens of global value chain theory and economic geography, has produced foundational works that continue to attract cross-disciplinary citations. Wells P ranks second with four publications and 217 citations; his work on automotive sustainability and supply chain restructuring addresses the sector's systemic transition challenges. Lampón JF, also with four publications, has contributed to the study of production relocation and international manufacturing strategies in the automotive sector.

Among authors with fewer publications, Nakajima K stands out with 127 citations from three articles, reflecting high-impact contributions to material flow analysis and resource efficiency in automotive production. Arto I (two publications, 81 citations) and Bailey D (two publications, 61 citations) represent the regional economics and employment dimensions of the field. The distribution confirms that the field lacks a dominant paradigmatic figure but contains a productive nucleus of scholars whose work spans value chain analysis, regional economics, environmental assessment, and manufacturing management.

Table 4. Most Influential Authors

Author	TP	TC	Author	TP	TC
PAVLÍNEK P	6	424	ARTO I	2	99
WELLS P	4	217	BAILEY D	2	61
LAMPÓN JF	4	52	BECK V	2	4
NAKAJIMA K	3	127	BLENGINI G	2	30
ALI AK	2	81	CADARSO M-A	2	43

Source: Own elaboration with data from Scopus database

Note: TP = Total Publications; TC = Total Citations. This table identifies influential authors based on their total publications and total citations.

v. Influential Countries and Organizations

Table 5 reveals a marked geographic concentration of scholarly output. China leads with 65 publications and 383 citations, followed by the United States (59 publications, 258 citations) and Germany (54 publications, 479 citations). Germany's high citation count relative to its publication volume reflects the depth of impact of key German-affiliated works, particularly those addressing value chain restructuring and sustainability transitions. India (46 publications) and the United Kingdom (37 publications) constitute the next tier, while Spain, Japan, Czech Republic, Brazil, and Italy each contribute between 16 and 32 documents.

The prominence of the Czech Republic (22 publications, 176 citations) is noteworthy and reflects the country's analytical significance as a case study of foreign direct investment-driven automotive development within the European Union. Much of this output is associated with Pavlínek's research programme on the automotive periphery of Central and Eastern Europe. Brazil's relatively low citation count (13 TC) despite 20 publications suggests that Brazilian automotive research, while productive, circulates primarily within regional networks and has not yet achieved broad international uptake.

Table 5. Most Relevant Countries by Scientific Contributions and Citations

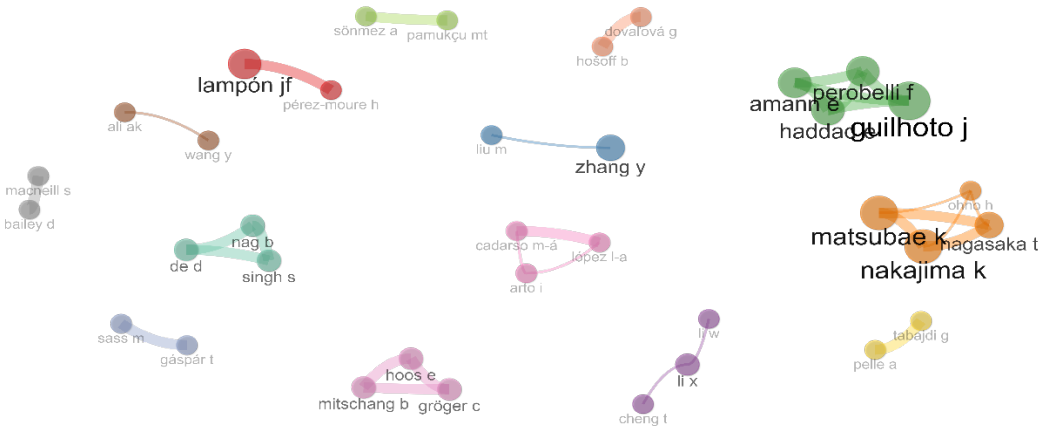
Country	TP	TC	Country	TP	TC
CHINA	65	383	SPAIN	32	158
USA	59	258	JAPAN	27	186
GERMANY	54	479	CZECH REPUBLIC	22	176
INDIA	46	125	BRAZIL	20	13
UK	37	264	ITALY	16	67

Source: Own elaboration with data from Scopus database

Note: TP = Total Publications; TC = Total Citations. This table ranks countries based on their total publications and total citations.

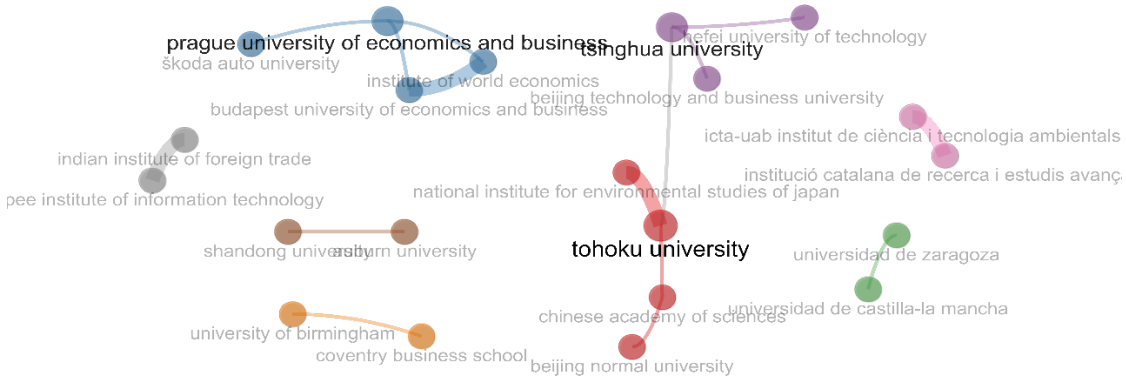
Figures 3 and 4 display the co-authorship networks at the author and affiliation levels, while Figure 5 maps the country-level collaboration network. The author network confirms the fragmented collaboration structure typical of a diverse interdisciplinary field: distinct clusters form around Lampón JF, Pavlínek P, Nakajima K and Guilhoto J, with limited bridges between them. Affiliation-level coupling reveals similar patterns, with Prague University of Economics and Business forming the central node of Central European cooperation, connected to Tsinghua University and other Asian partners through shared reference frameworks.

Figure 3. Co-authorship Network Visualization of Relevant Authors



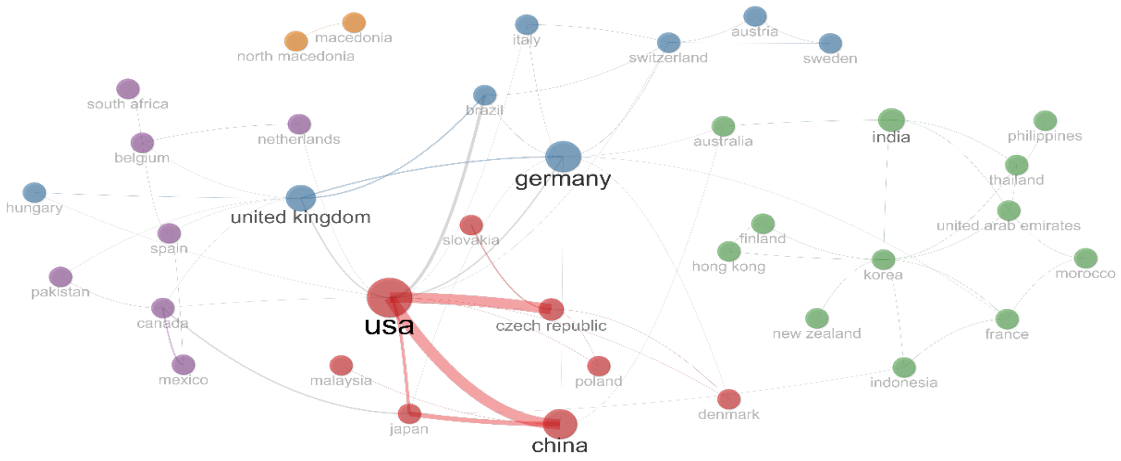
Source: VOSviewer analysis of Scopus data.
Note: Minimum co-authorship threshold of 2 documents and 6 citations. Node size reflects number of publications; edge thickness reflects co-authorship strength.

Figure 4. Co-authorship Network Visualization of Relevant Affiliations



***Source**: VOSviewer analysis of Scopus data*
***Note**: Minimum threshold of 2 documents and 6 citations. Each cluster represents a group of affiliated institutions sharing collaborative publication activity.*

Figure 5. Country Scientific Production and Collaboration Network



Source: Biblioshiny analysis of Scopus data.
Note: Node size reflects total publications; edge thickness reflects bibliographic coupling strength. The USA-China-Germany triangle constitutes the dominant axis of international collaboration.

Table 6. Most Influential Organisations

Rank	Affiliation	No. of Articles	Rank	Affiliation	No. of Articles
1	National Inst. for Environmental Studies of Japan	5	6	Kyushu University	4
2	Prague University of Economics and Business	5	7	Middle East Technical University (METU)	4
3	Tohoku University	5	8	Tsinghua University	4
4	Universidad de Zaragoza	5	9	University of Birmingham	3
5	Universidade de Vigo	4	10	Budapest University of Economics and Business	3

Source: Own elaboration with data from Scopus database.
Note: This table lists the leading organizations by number of articles, reflecting institutional concentration in key automotive research hubs.

b. Science Mapping and Network Analysis

The science mapping analysis focuses on five dimensions: co-citation analysis to identify knowledge foundations, bibliographic coupling to map intellectual proximity, keyword co-occurrence to reveal thematic structures, and thematic evolution to trace shifts in research priorities over time.

i. Scientific Collaboration Network

The co-authorship network presented in Figure 3 covers authors with at least two publications and six citations. The network reveals a field characterised by relatively loose inter-cluster connectivity. Several distinct research communities are identifiable: a cluster led by Lampón JF focused on automotive production geography and offshoring decisions; a group centred on Nakajima K and Matsubae K addressing material flow analysis and resource efficiency in Japanese automotive production; and a Central European cluster anchored in global value chain analysis. Most collaborations are geographically proximate, confirming the observation from prior bibliometric

studies of automotive research that knowledge exchange remains largely bounded by regional academic networks even as international co-authorship rates have increased.

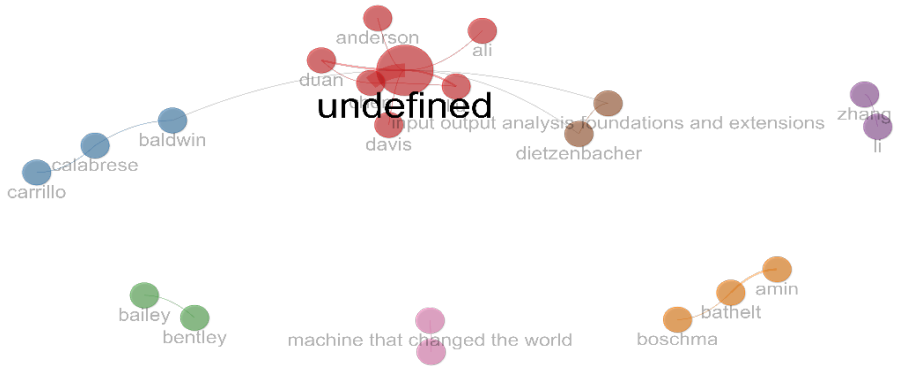
At the institutional level, Figure 4 shows that the largest connected component links Tsinghua University, Prague University of Economics and Business, Tohoku University, and several European institutes through shared bibliographic references. This component bridges East Asian environmental science traditions with European economic geography and value chain research. Figure 5 presents the country-level network: the USA, Germany, China, and the United Kingdom occupy the most central nodes, consistent with their dominance in publication volume. The strong coupling between USA and China reflects shared engagement with global value chain restructuring and electrification policy, while Germany's connections to Central European partners mirror the region's integrated automotive production networks.

ii. Knowledge Foundations through Co-citation Analysis

Figure 6 presents the co-citation network of references with a minimum co-citation threshold of five, covering the 32 most co-cited foundational works. The network reveals four distinct intellectual clusters that correspond to the field's major analytical traditions.

The first cluster groups works applying input-output analysis to trace automotive industry linkages and value added within national and global economic systems, with undefined (an unlabelled foundational text on input-output methodology) and Dietzenbacher serving as key reference points. The second cluster addresses the automotive industry's contribution to regional economic development in specific territorial contexts. The third cluster, anchored in the Machine That Changed the World (Womack et al., 1990), represents the lean production tradition that has shaped automotive manufacturing research since the 1990s. The fourth cluster connects works addressing material flows, end-of-life recycling, and resource efficiency in automotive production contexts.

Figure 6. References Co-citation Network



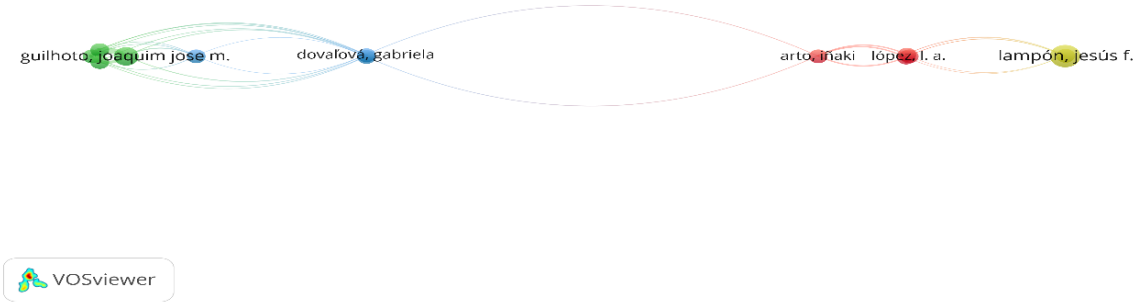
Source: VOSviewer analysis of Scopus data.
Note: Minimum co-citation threshold of 5 citations. Node size reflects co-citation frequency; colours distinguish intellectual clusters. This figure depicts the knowledge foundations of the automotive contributions' literature.

iii. Bibliographic Coupling of Authors, Affiliations, and Countries

Bibliographic coupling measures the intellectual proximity of scholarly actors by counting the references they share, providing a retrospective view of who is working on similar problems (Zupic

and Cater, 2015). Figure 7 presents the bibliographic coupling of authors. The dominant cluster groups researchers engaged in input-output and value chain analysis, including Baldwin, Calabrese, Carrillo, and Dietzenbacher, connected by their shared use of foundational texts on economic linkage measurement. Separate clusters cover regional automotive economics, lean manufacturing, and environmental impact assessment, each drawing on distinct reference pools.

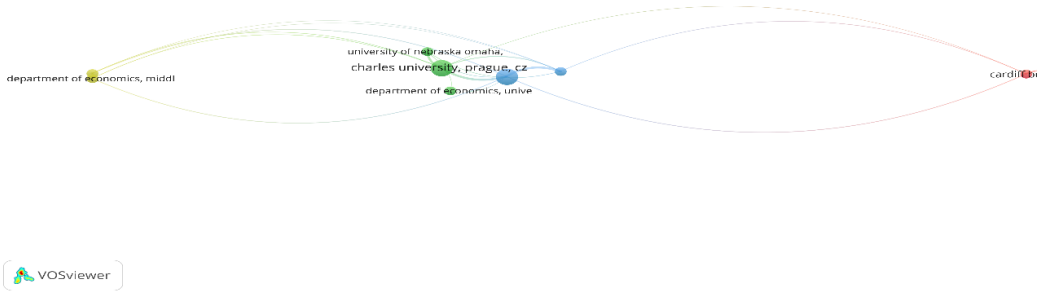
Figure 7. Bibliographic Coupling of Authors



Source: VOSviewer analysis of Scopus data.
Note: Minimum publication threshold of 2 documents and 6 citations. Each cluster groups authors sharing common reference frameworks, indicating intellectual proximity.

Figure 8 illustrates bibliographic coupling at the affiliation level. The largest cluster links Tsinghua University, national environmental research institutes, and several European business schools through shared engagement with sustainability-oriented automotive research. The coupling between Chinese universities and Japanese environmental institutes is particularly strong, reflecting shared analytical frameworks around material efficiency and industrial ecology.

Figure 8. Bibliographic Coupling of Affiliations

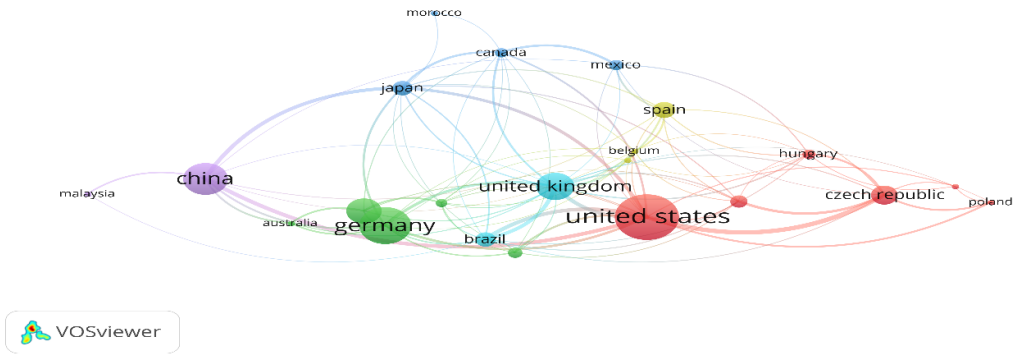


Source: VOSviewer analysis of Scopus data.
Note: Minimum publication threshold of 2 documents and 6 citations. Node size reflects publication volume; edge thickness reflects coupling strength between affiliated institutions.

Figure 9 maps the bibliographic coupling at the country level. The United States, Germany, China, and the United Kingdom constitute the central nodes of the network, consistent with their dominance in output volume. The strong coupling between the USA and China reflects shared reference pools addressing global value chain restructuring, electric vehicle policy, and economic impact modelling.

Germany's tight coupling with Czech Republic, Spain, and other European partners mirrors the geographic logic of European automotive production networks, within which academic collaboration closely tracks industrial interdependencies.

Figure 9. Bibliographic Coupling of Countries



Source: VOSviewer analysis of Scopus data.

Note: Minimum threshold of 5 documents and 43 citations. Node size reflects total publications; edge thickness reflects shared reference volume. The USA-Germany-China triangle dominates the network.

iv. Co-occurrence Analysis of Keywords

Table 7 presents the top ten keywords by frequency of occurrence. "Automotive industry" leads overwhelmingly with 203 occurrences, confirming its status as the definitional anchor of the dataset. "Automobile industry" (59 occurrences) functions as a near-synonym, the two together constituting the field's terminological core. "Economic impact" (23), "regional development" (20), and "input-output analysis" (19) reflect the economic geography and macro-level analytical tradition, while "supply chains" (17) and "supply chain management" (16) represent the operational and logistical research tradition. "Life cycle" (16) and "automotives" (17) bridge the field's environmental and production-oriented communities.

Table 7. Top Keywords by Frequency of Occurrence

No.	Keyword	Occurrences
1	Automotive industry	203
2	Automobile industry	59
3	Economic impact	23
4	Regional development	20
5	Input-output analysis	19
6	Automotives	17
7	Supply chains	17
8	Automobiles	16
9	Life cycle	16
10	Supply chain management	16

Source: Own elaboration with data from Scopus database

Note: This table lists the top keywords related to automotive sector contributions, ranked by frequency of occurrence in the dataset.

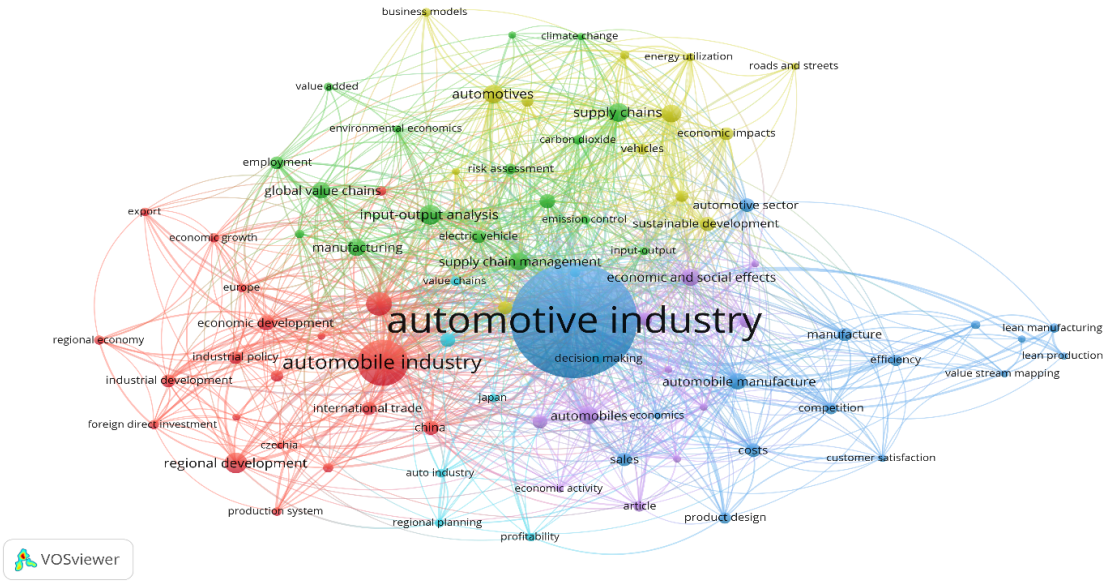
Figure 10 presents the keyword co-occurrence network generated by VOSviewer. Five thematic clusters are identifiable from the colour-coded communities. The red cluster (largest) groups terms related to economic development and regional impacts: "regional development," "regional economy,"

"economic development," "employment," "industrial policy," "export," and "international trade." This cluster represents the macro-economic and regional geography tradition that has studied how automotive clusters shape territorial development.

The blue cluster aggregates manufacturing and operational efficiency terms: "automobile manufacture," "lean manufacturing," "lean production," "efficiency," "value stream mapping," and "competition." This reflects the industrial engineering tradition that has examined how automotive manufacturers optimise production systems and compete on cost and quality. The green cluster connects sustainability-oriented terms: "supply chains," "automotives," "environmental economics," "carbon dioxide," "vehicles," "sustainable development," and "electric vehicle," capturing the field's growing engagement with the environmental transition.

The yellow cluster covers production economics and value chain analysis: "global value chains," "input-output analysis," "manufacturing," "supply chain management," and "value chains." These terms reflect the analytical tradition using input-output and value chain frameworks to trace the sectoral interdependencies that amplify the automotive industry's economic footprint. The purple cluster, smaller and more peripheral, groups terms associated with market behaviour and consumer economics: "sales," "customer satisfaction," "product design," "profitability," and "decision making."

Figure 10. Network Visualisation of Keyword Co-occurrence



Source: VOSviewer analysis of Scopus data (N = 320)
Note: Minimum co-occurrence threshold of 3. Node size reflects keyword frequency; edge thickness reflects co-occurrence strength. Five thematic clusters are identified by colour.

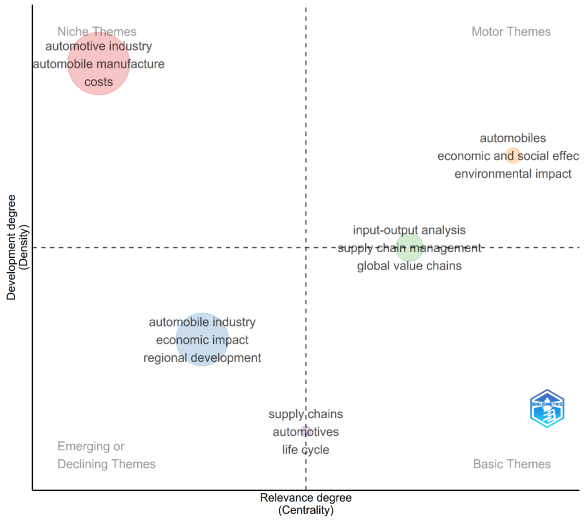
v. Thematic Structure through Thematic Map and Thematic Evolution

Figure 11 presents the thematic map generated by Biblioshiny, plotting research themes against two axes: centrality (relevance degree, measuring how broadly a theme connects with others) and density (development degree, measuring the internal coherence of a theme's constituent keywords). The four-quadrant structure yields the standard classification of motor themes (high centrality, high density),

niche themes (low centrality, high density), basic themes (high centrality, low density), and emerging or declining themes (low centrality, low density).

The thematic map reveals a field in transition rather than one dominated by fully consolidated paradigms. At the applied analytical thresholds, the motor themes quadrant (high centrality, high density) appears relatively sparse, reflecting the fragmented nature of automotive contributions research across disparate disciplinary traditions. Nevertheless, themes such as "economic and social effects," "environmental impact," and "automobiles" occupy the upper-right region, approaching motor status due to their strong internal coherence and growing cross-disciplinary relevance. In contrast, the niche quadrant (low centrality, high density) groups manufacturing-focused terms ("automotive industry," "automobile manufacture," "costs"), indicating well-developed but relatively self-contained technical research. Basic themes (high centrality, low density) such as "economic impact" and "regional development" serve as foundational pillars for the field but lack theoretical consolidation. Finally, emerging or declining themes (low centrality, low density) include "supply chains," "automotives," and "life cycle," suggesting that while methodologically important, these topics have not yet formed a cohesive, centrally positioned research community within the corpus. Three factors help explain why these themes remain peripheral rather than marginal in an absolute sense. First, life cycle assessment and supply chain research on the automotive sector originated largely within engineering and operations management outlets that are only loosely cross-referenced by the economics and regional-development literatures anchoring the motor themes, limiting the centrality these topics can achieve within the present corpus. Second, both themes gained sustained momentum only from the mid-2010s onward with the acceleration of electrification and circular economy agendas, so they have had less time to accumulate the citation density and cross-cluster linkages that characterise more established research areas. Third, life cycle and supply chain studies of the automotive sector tend to apply case-specific or product-specific methodologies rather than a shared analytical framework, which keeps their internal density comparatively low even as the volume of publications grows.

Figure 11. Thematic Map of Automotive Contributions Research



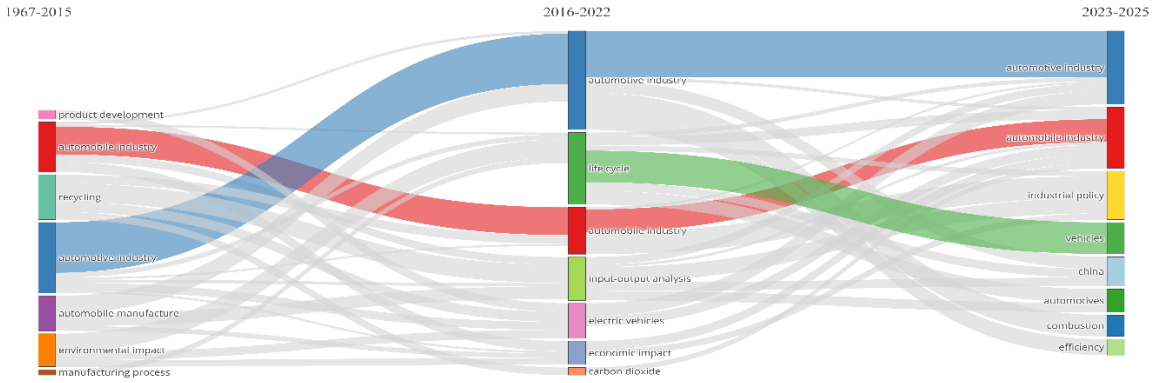
Source: Biblioshiny analysis of Scopus data

Note: Axes represent Centrality (relevance degree) and Density (development degree). The four quadrants classify themes as Motor, Niche, Basic, or Emerging/Declining based on their position along these two dimensions.

Figure 12 provides the thematic evolution diagram, tracing how research themes shifted across three periods: 1967 to 2015, 2016 to 2022, and 2023 to 2025. The diagram reveals a clear transition in the field's thematic centre of gravity. During the first period, the dominant themes were "automobile industry," "automotive industry," "recycling," and "automobile manufacture," reflecting a literature primarily concerned with industrial organisation and early environmental management concerns. The transitional period from 2016 to 2022 shows the consolidation of "life cycle," "input-output analysis," "electric vehicles," and "economic impact" as significant themes, corresponding to the mainstreaming of sustainability science and the emergence of the electrification transition as a major policy and market reality.

The most recent period from 2023 to 2025 shows the dominance of "automotive industry" and "automobile industry" as persistent anchors, alongside the strengthening of "vehicles," "industrial policy," "automotives," and "combustion" as emerging topics. The appearance of "industrial policy" as a growing theme in the most recent period reflects intensified government intervention in automotive sector transformation globally, from the United States Inflation Reduction Act to European Green Deal industrial strategies. The persistence of "combustion" as a research term in 2023 to 2025 may reflect transition studies examining the phase-out of internal combustion engine vehicles rather than their promotion.

Figure 12. Thematic Evolution of Automotive Contributions Research (1967-2025)



Source: Biblioshiny analysis of Scopus data
Note: The figure illustrates the transition of primary research themes over three distinct periods: 1967-2015, 2016-2022, and 2023-2025, highlighting shifts in thematic emphasis.

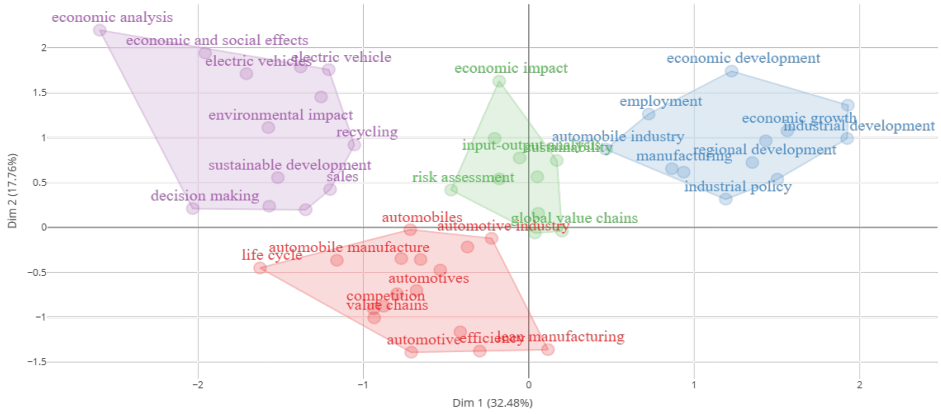
Figure 13 presents the conceptual structure map generated by Multiple Correspondence Analysis (MCA), applied to 50 pre-selected keywords across the full corpus. MCA reveals latent dimensions in the data by identifying co-occurrence clusters and illustrating the interactions between terms (Aria and Cuccurullo, 2017). Four conceptual clusters emerge from this analysis.

Cluster 1 (upper right, blue) groups terms associated with economic and industrial development: "economic development," "employment," "industrial development," "regional development," "manufacturing," and "industrial policy." This cluster corresponds to the tradition of regional economic analysis that has examined how automotive clusters contribute to territorial development through multiplier effects, labour market impacts, and knowledge spillovers. Cluster 2 (lower left, red) aggregates manufacturing efficiency and production system terms: "automobile manufacture," "lean

manufacturing," "competition," "value chains," "efficiency," and "lean production." This cluster reflects the industrial engineering tradition rooted in the lean production paradigm.

Cluster 3 (upper left, purple) groups sustainability and environmental transition terms: "electric vehicles," "electric vehicle," "environmental impact," "recycling," "sustainable development," "economic and social effects," and "economic analysis." The co-presence of environmental and economic terms in this cluster is analytically significant: it confirms the progressive integration of sustainability and economic analysis frameworks that the keyword co-occurrence network also suggested. Cluster 4 (lower right, green) connects supply chain and global value chain terms: "input-output analysis," "supply chain management," "risk assessment," "sustainability," and "global value chains," representing the analytical tradition that examines the automotive sector's systemic economic linkages.

Figure 13. Conceptual Structure Map using Multiple Correspondence Analysis (MCA)



Source: Biblioshiny analysis of Scopus data

Note: This figure depicts four conceptual clusters illustrating the intellectual architecture of automotive contributions research. Dim 1 explains 32.48% of variance; Dim 2 explains 17.76%.

c. Limitations and Future Research Directions

This study carries several limitations that should guide the interpretation of its findings and the design of future research. The exclusive use of the Scopus database, while justified by its consistency and coverage advantages, inevitably excludes publications indexed solely in the Web of Science, regional databases, or non-indexed venues. Given that the Web of Science includes a "hot papers" functionality and distinct journal coverage in engineering disciplines, future studies should compare results across multiple databases to assess coverage sensitivity.

The restriction to English-language publications may systematically underrepresent scholarly contributions from non-Anglophone research communities, particularly in Germany, Japan, Brazil, and South Korea, where high-quality automotive research is produced in national languages. Future bibliometric studies of automotive contributions should incorporate multilingual searches and consider databases with stronger coverage of non-English academic output.

The thematic map's finding that no research cluster has achieved motor theme status simultaneously along both centrality and density dimensions points to a deeper structural limitation of the field: the absence of an integrative theoretical framework capable of bridging economic geography, environmental science, and supply chain management around a shared set of concepts and methods.

Future research should invest in building such frameworks, potentially drawing on socio-technical transition theory, industrial ecology, or the sustainable value chain literature as integrating perspectives.

From a methodological standpoint, the bibliometric approach adopted here describes the intellectual structure of the field but cannot assess the quality, validity, or policy relevance of individual contributions. Combining bibliometric mapping with systematic content analysis or expert interviews would provide a richer understanding of how the field's thematic architecture relates to real-world knowledge needs. Hybrid bibliometric-econometric models that combine network analysis with panel data regression to trace causal relationships between research activity and industrial outcomes would also advance the field.

5. Conclusion

This paper has presented, to the best of our knowledge, one of the first comprehensive bibliometric analyses of research addressing the automotive sector's economic, social, and environmental contributions, drawing on 320 documents from Scopus spanning 1967 to 2025. The analysis documents a field characterised by sustained growth at an annual rate of 5.71%, concentrated in major automotive economies, and structured around four main research traditions: regional economic development analysis, global value chain and input-output modelling, environmental life cycle assessment, and manufacturing efficiency and production systems.

The thematic map reveals that economic and social effects and environmental impact function as motor themes, well developed internally and broadly connected to other research areas, while life cycle and supply chain topics remain in the emerging zone despite their analytical importance. The MCA conceptual structure confirms that the most productive intellectual territory lies at the intersection of sustainability frameworks and economic development analysis, an area where multiple disciplines are converging but have not yet produced a unified research programme.

For researchers, the findings highlight several productive directions for future inquiry. The socioeconomic consequences of electric vehicle adoption on incumbent regional automotive clusters represent an urgent and underexplored dimension, particularly for Central European, South American, and South Asian economies whose automotive sectors depend heavily on internal combustion engine component manufacturing. The integration of circular economy principles into regional industrial policy frameworks for the automotive sector remains theoretically underdeveloped despite growing empirical urgency. Cross-country comparative analyses using longitudinal panel data to trace the relationship between automotive sector development and human capital formation would also contribute meaningfully to the field.

For policymakers and industry strategists, this study underscores that the automotive sector's contributions cannot be assessed through a single-dimensional lens. Economic multiplier effects, employment quality, environmental liabilities, and technological transition costs must be evaluated jointly to support decisions about industrial policy, regional development investment, and sustainability regulation. These implications translate differently across the three groups the study speaks to. For automotive manufacturers, the concentration of research around lean production, manufacturing efficiency, and value-chain restructuring suggests that competitive advantage increasingly depends on documenting and communicating labour-quality and circularity outcomes alongside cost and productivity metrics, since these dimensions are attracting growing scholarly and regulatory attention. For governments, particularly in regions whose automotive clusters remain

dependent on internal combustion engine component manufacturing, the persistence of "industrial policy" as a strengthening research theme signals a need to pair electrification incentives with active labour-transition and supplier-diversification programmes rather than relying on market mechanisms alone. For investors and financial institutions, the thematic map's finding that life cycle and supply chain risk topics remain under-consolidated points to a due-diligence gap: environmental and social risk exposure in automotive supply chains is not yet matched by a mature body of standardised assessment methods, which argues for caution in relying on any single sustainability metric when pricing automotive sector risk. The bibliometric evidence presented here provides a structured map of where the scholarly community has invested analytical effort and where significant gaps remain, offering an evidence base for research prioritisation and funding allocation.

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