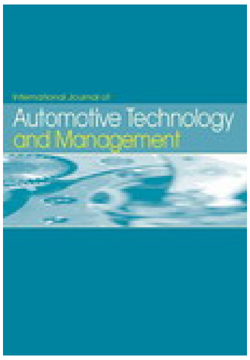

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Automotive alliances in times of technological uncertainty

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Abstract: For decades, the literature has analysed the different elements of strategic technological alliances in the automotive industry. However, few empirical studies have analysed the rapidly changing constellation of automotive alliances in the last decade. This article presents a systematic literature review supported by the analysis of 309 automotive alliances (collected during 2018–2023), providing insights into the primary motivations for these alliances and identifying their players. It is also clear that the traditional alliance structure of the sector is changing rapidly, expanding into inter- and intra-industrial relationships, particularly with ICT firms. However, the analysis shows that traditional automotive original equipment manufacturers (OEMs) remain in the driving seat regarding inter- and intra-industry alliances, as they search for ways to influence and transform the industry by partnering with allies and newcomers. The findings are relevant to understanding the current changing automotive network dynamics in designing industrial and environmental policies and strategies.

Keywords: strategic alliances; automotive network; intra- inter-organisational collaboration; green manufacturing; automotive industry.

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1 Introduction

In the early 2000s, discussions took place in the European Union (EU) and the USA on implementing more rigorous environmental standards and legal regulations on CO2 emissions. This forced the automotive industry to develop greener technologies, products, and processes.[1] As in previous decades, these regulations pushed forward technological developments within the industry, mainly in relation to making automobiles safer, faster, and more energy efficient.

This was followed by the environmental and energy crises of the mid-2010s, which pushed governments in the EU and the USA to enforce even stricter environmental regulations and enact energy efficiency legislation, setting the path for the autonomous, connected, electric, and shared (ACES) automotive trends. These trends posed a threat to the traditional internal combustion engine. ACES involved higher levels of digitalisation and the adoption of Industry 4.0 (I4.0) technologies in their development. This has changed intra-firm relationships in the industry and created major entry opportunities for new players, resulting in rapid changes to automotive global value and supply chains

(Krzywdzinski et al., 2023; Wang et al., 2022). All of these changes accelerate the ongoing technological changes taking place in the auto industry (Bergsen, 2020; Pardi, 2021), particularly during and since the COVID-19 crisis, reinforcing the relevance of strategic technological alliances in the sector.

Automotive alliances are a mechanism with which to reduce technological uncertainty, achieve technological upgrading, and increase market share, and have been addressed in the literature since the early 1980s (see seminal work of Burgers et al., 1993). Among their main benefits is that they facilitate the sharing of knowledge and expertise among their partners, creating new knowledge within the firm, and adding external knowledge. They also encompass sharing risks and costs in developing new products and technologies (Isoraite, 2009; Sadowski and Duysters, 2008; Schoenmakers and Duysters, 2006).

Another important aspect associated with alliances is rivalry or competition. As mentioned in the literature, firms ally to build their capabilities so that they can compete with each other (Michaeux, 2015). The ongoing dynamism in the automotive economic and technological landscape has intensified rivalry among firms, which have been forced to constantly reorient their goals and practices to increase efficiency and lower costs and risks. In this new ecosystem, firms need not only to produce 'cheaper and better', but also to anticipate innovation and digital strategies (Kohnova and Salajova, 2023), increasing rivalry both inter- and intra-industry (Michaeux, 2015).

Strategic alliances[2] are the driving force behind firms' competitive advantage, as they allow them to acquire (new) knowledge, global expertise, and productivity skills from outside the firm (Abbas and Tong, 2023; Isoraite, 2009). However, the (automotive) partnerships or alliances we have witnessed in the last five years differ significantly in nature (and number) from the traditional automotive alliances we saw in the 1990s and 2000s.[3] In this study, we looked at (international) strategic alliances between firms, including all forms of formal or informal associations such as joint research and development (R&D), long-term sourcing, shared distribution/services, mergers and acquisitions, and other alliances (Dzienis and McCaleb, 2024; Henderson et al., 2014).

With the booming of electrification, today's auto trends involve the development of automotive firms allying with non-auto organisations in search of more efficient and high-powered (electric) vehicles (i.e., the Ionity alliance), autonomous driving (i.e., BMW's alliances with Intel and Aptiv, among others), and car-sharing (i.e., Honda-General Motors, BMW and Mercedes-Benz) (Sigal, 2018). Even though the literature has explored leadership roles between incumbent automotive firms and new entrants under discontinuous technological change (Alvarez Leon and Aoyama, 2022; Cabigiosu, 2022; Mule et al., 2021; Pi and Li, 2022), there is insufficient empirical evidence on the dynamism and characteristics of ongoing automotive alliances in the ACES era. This call for research under the currently evolving regulatory frameworks, geopolitical trends, and changing global ecosystems is supported by scholars like He et al. (2020), Dzienis and McCaleb (2024) and Nippa and Reuer (2019), among others.

The objective of this article is twofold: first, it aims to deepen the understanding of firms' motives/motivations for entering automotive alliances during the last five years (as discussed in the recent literature). Secondly, it attempts to analyse the nature of the emerging constellation of alliances[4] in this time of high technological uncertainty, to identify its key players and the patterns of disruption and transformation in relation to traditional automotive alliances. This study contributes to operations research and strategic management literature by providing empirical insights into this rapidly changing industry. Following the findings from the literature review, the article classifies the empirical results according to the main motivations that actors have for establishing alliances. It includes an empirical analysis based on a dataset of strategic automotive technological alliances (n = 309) collected from 2018 to 2023, identifies the leading players, and provides insights into the ongoing intra-industrial relationships in this dynamic constellation.

The following section presents the research design and methodology and describes the data used in the analysis. Section 3 provides the main discussion on strategic technological alliances in the automotive industry. Section 4 presents the empirical results of the analysis, followed by a discussion of the findings and conclusions in Section 5. Section 6 presents the limitations of the study

2 Research design

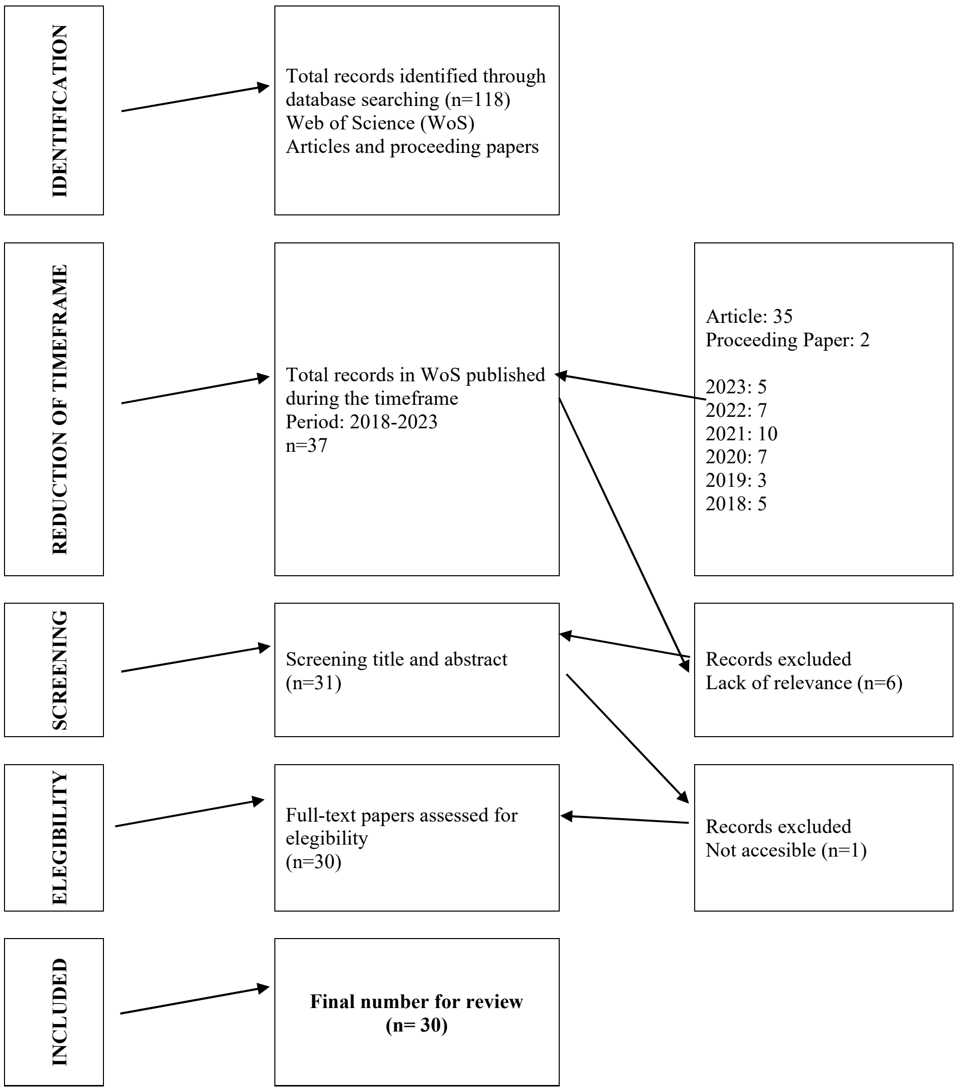
This study was built in two stages. In the first stage of the analysis, an extensive systematic literature review was conducted on strategic (technological) alliances in the automotive industry. To identify relevant peer-reviewed academic articles, we based the search on two keywords as topics: *Alliances* AND *Automobile*. The search was conducted in Web of Science, targeting only peer-reviewed publications in English. The search was performed in February 2024, and resulted in 118 hits. When narrowing the search to publication years covered in the study, namely 2018–2023, the number of articles was reduced to 37. After excluding papers that were not relevant to the study and those that were not accessible, the search resulted in 30 peer-reviewed articles (see Figure 1). The literature analysis allowed us to build a general taxonomy of the main types of alliances based on the main motivation of firms to ally.

In the second stage of this analysis, the literature review was substantiated by an empirical analysis of an author-compiled dataset (with information collected from March 2018 to December 2023), including 309 alliances with 253 firms. This dataset (herein referred to as *Alliance 4.0*)[5] was developed by combining information from specialised automotive platforms (e.g., JustAuto.com, MotorPasion.com, and ClusterIndustrial.com), business press, industry reports, newsletters, and magazines. In the development of *Alliance 4.0*, the researchers conducted cross-sectional searches to corroborate or expand the information obtained.

The *Alliance 4.0* dataset selects intersectoral technological cooperation through agreements and alliances towards the automotive sector, including relationships between and across not only automotive original equipment manufacturers (OEMs) and automotive original equipment suppliers (OESs), but also information and communication technology (ICT) firms, non-automotive companies, and firms from different economic sectors. The analysis further distinguishes between traditional OEMs (i.e., Ford, Toyota) and emergent ones (i.e., Tesla, Geely).

In analysing the network of alliances (n = 309), the authors used an open-source network analysis and visualisation software called Gephi, written in Java on the NetBeans platform. Further, the dataset was classified and analysed according to the taxonomy design in this research using MS Excel and SPSS. Following Renart (2008), the constellation of alliances was analysed from the perspective of the automobile industry, with the unit of analysis alliances per se (i.e., their number, motivation, and main characteristics).

Figure 1 Search conducted for this systematic literature review



Source: Elaborated by the authors

3 Strategic technological alliances in the automotive industry

The automotive industry is a high-tech manufacturing sector with a high level of globalisation, high levels of investment by its primary stakeholders, rapidly changing technological requirements, and in which learning and technological paradigms are constantly upgrading and modernising (Vallejo, 2017). Therefore, it is a case study analysed in the literature to understand phenomena and relationships between different actors and aspects of its innovation ecosystem.

In our literature analysis, the most significant number of papers discuss automotive alliances as a mechanism adopted by automotive firms (e.g., OEMs) to manage their (open) innovation (R&D) activities over time, particularly in periods of technological uncertainty, to acquire complementary (technical and market) resources (Candelo et al., 2021; Wen et al., 2021). International alliances are also seen as a mechanism for influencing inclusion in global value chains (Kandrashina et al., 2020). Several panel data analyses highlight the relevance of network knowledge (technological) diversity in the innovation performance of auto firms (Jinyan et al., 2023; Wen et al., 2021), which is no longer restricted to the internal technological network of the firm, but now includes external (R&D) networks that allow it to obtain and expand its resources (Jinyan et al., 2023; Ye and Liu, 2022).

Technological knowledge alliances are also sought by firms as a mechanism for technological standardisation (Häfner et al., 2022; Jinyan et al., 2023; Wen et al., 2020), as firms engaging in standardisation alliances have a higher degree of influence in the industry, increasing the acceptability of their new products (Nambisan, 2013).

The papers analysed recognise increasing 'coopetition'[6] through strategic alliances between automotive OEMs (Blazquez Jimenez and Sanchis, 2023), as well as the disruption of traditional arrangements between automotive OEMs and their OESs (e.g., Bosch, Denso, Continental) by cross-sectoral and inter-industry alliances with artificial intelligence developers, navigation and sensing technologies firms (e.g., NVIDIA, Intel, Mobileye, IBM), and technology investors such as Apple, Softbank, Rakuten, and Baidu (Alvarez Leon and Aoyama, 2022).

Under changing environmental regulations (or protection) and clean-energy regulations, automotive firms tend to integrate cross-boundary resources through alliances or coopetition with disruptive technological entrants (Pi and Li, 2022). The literature indicates that automotive firms' strategic cooperation alliances with governments and internet enterprises (e.g., BMW Group and Amazon Cloud Technology signed in September 2018) benefit distribution and carbon-credit-trading, becoming a mechanism for subsidising R&D (He and Liu, 2023). When inter-dependence among firms increases, firms become more sensitive to other firms' risks (Hallikas et al., 2004), particularly when they share information systems (Rebula De Oliveira et al., 2023). In times of technological uncertainty and technological transitions, firms modify and expand their supply chain strategies by increasing their number of partners to widen their technological landscape until a dominant design arises (Cabigiosu, 2022).

Another aspect addressed in the literature is the provision of alternative services to automotive users through automotive alliances. For example, alliances between coopetitors in the provision of car-sharing technology, such as BMW and Daimler AG, which merged their short-term car rental services *DriveNow* and *Car2Go* in 2019 to create *ShareNow* (Sigal, 2018), later joining *Free2Move* from Stellantis in 2022. Another example of this intra-sectoral alliance uses I4.0 technology (i.e., blockchain, internet of vehicles, and 6th generation wireless communication network) to provide its users with parking space information.

In broad terms, the motives of automotive firms to establish alliances could be classified, as indicated by March (1991) in his study on organisational learning, as those seeking exploitation (i.e., the intensification of existing capabilities) and those seeking exploration (i.e., experimenting with or establishing new assets and capabilities), as well as those seeking both strategies or ambidextrous alliances (Lavie et al., 2010). Table 1 presents some more detailed motives/motivations for establishing alliances, as identified in studies on strategic alliances addressing goals and motives for an alliance across firms (March, 1991; Yang et al., 2013; Zhao et al., 2005), focusing on those studies addressing automotive alliances.

Table 1 Motivations for strategic alliances (examples from the literature)

Strategic alliance motivation	*Examples*	*Automotive industry studies*
Risk management of political and business risks	To strengthen market position or to avoid bankruptcy	Mladjan and Markovic (2019), Rajan et al. (2021)
Creation of new and additional exploitation of existing capabilities	Generation of new products and services To acquire/develop complementary assets To acquire new skills, competencies, capabilities To transfer/internalise technological knowledge (creation and diffusion of technological capabilities)	Mladjan and Markovic (2019), Kukkamalla et al. (2021), Rajan et al. (2021), Zhao et al. (2005), Kukkamalla et al. (2021)
Reaction to competitor's actions	To seek protection from the aggressive actions of incumbents and new players in the industry	Mladjan and Markovic (2019), Downes and Nunes, 2013, Kukkamalla et al. (2021), Dzienis and McCaleb (2024)

From the literature review and taking the motivation for the alliance as the unit of analysis, we classified the papers reviewed into four categories, namely:

1 alliances for (technological) knowledge
2 alliances for green manufacturing
3 alliances for the provision of services
4 alliances to address supply chain risk.

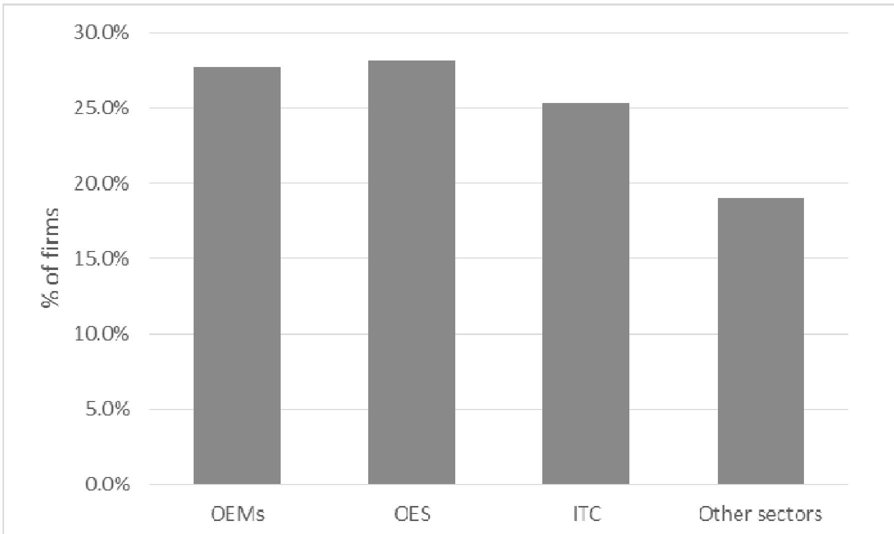
The analysis of *Alliance 4.0* is driven by this classification.

4 Analysis

The analysis is based on the dataset *Alliance 4.0*, which includes 309 alliances and 253 firms from different sectors. As indicated in Figure 2, the sample includes 28% automotive OEMs, 28% automotive OES, 25% ICT firms, and 19% firms from other economic sectors. It further distinguishes between traditional OEMs (41% of the OEM sample), including firms like Ford, Nissan, Renault, and Toyota, among others, and emergent OEMs (59% of the OEM sample), including firms like Tesla, Geely, and BYD, among others.

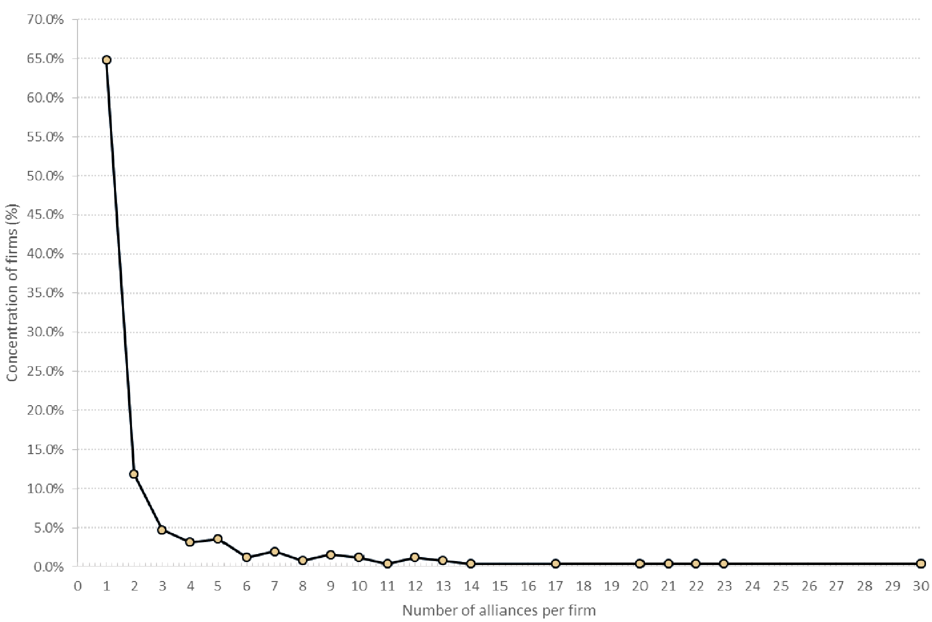
Figure 3 shows a skewed distribution of the number of alliances entered into by the firms in the sample: the majority had only one alliance (65%), and only a small percentage of firms had ten or more alliances (6%). Regarding the composition of alliances, the analysis indicates that about 65% are between two firms, 23% are between two and five firms, and about 12% are with more than five firms (with a maximum of eight firms per alliance).

Figure 2 Sample composition by type of firm (n = 253)



Source: Elaborated by the authors using information from *Alliance 4.0*

Figure 3 Distribution of firms by number of alliances



Note: N = 253 firms with a mean of 2.74 alliances/firm.

Source: Elaborated by the authors using information from *Alliance 4.0*;

The analysis also shows that about 70% of alliances in the sample (n = 309) are formal, namely, joint ventures and mergers and acquisitions (M&A), while about 30% are memorandums of understanding, agreements, or other types of more informal association. This finding aligns with the literature, which states that in times of systemic changes in production and new governance structures, the formalisation of alliances is a strategic move by manufacturing firms to facilitate internationalisation and technological upgrading, expand their geographic scope, and influence ongoing technological networks (Mule et al., 2021; Sacomano Neto et al., 2017; Townsend et al., 2017).

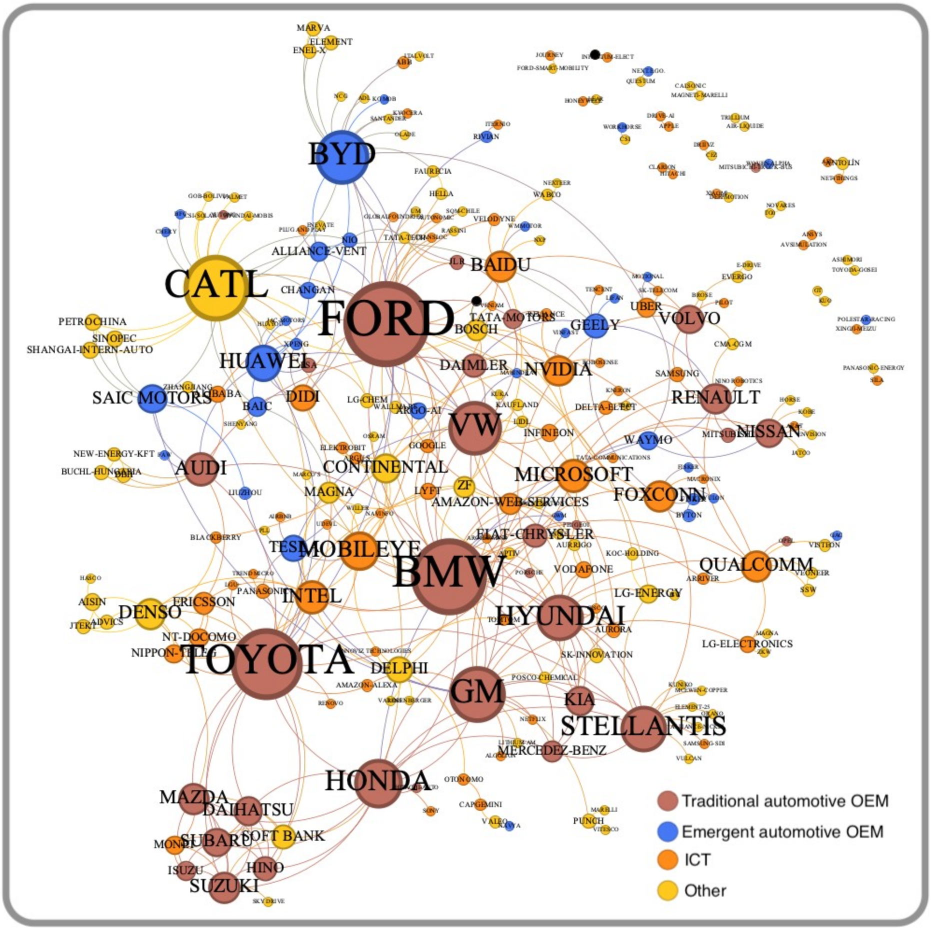
As indicated in the literature on automotive alliances and ecosystems, the number of alliances in *Alliance 4.0* increased exponentially between 2018 and 2023. When analysing the sample according to place of action of the alliance (n = 194), we found that 32% of firms were from the USA, 20% were from Europe, 23% from China, and about 25% from the rest of the world. According to the analysis, about 35% of alliances in the USA seek to reduce supply chain risk, while 22% seek to strengthen or develop their capabilities and explore alternative (automotive) services (22%). In Europe, about 32% of alliances seek to strengthen capabilities or create knowledge, followed by those exploring alternative services (26%) and those oriented towards green manufacturing (24%). Alliances in China are primarily focused on green manufacturing (40%) and the creation of new knowledge (33%).

Figure 4 presents the constellation of alliances based on the frequency of alliances per firm, distinguishing between traditional OEMs and emerging OEMs. In line with the findings of Mule et al. (2021), the analysis of *Alliance 4.0* shows that traditional OEMs are the main players in forming strategic alliances with other traditional OEMs, OESs, and ICT firms. As in Mule et al. (2021), which analysed automotive alliances during 2010–2015, our findings identify that traditional OEMs hold the dominant position in this period of technological uncertainty, followed by emergent OEMs, which are much less central. This trend was already identified by Sigal (2018), who identified large alliances, such as Ionity (including BMW Group, Ford Motor, Daimler, and VW, among others), in which partners engage horizontally seeking to build green vehicles and establish charging networks across Europe.

For example, Figure 4 shows Ford as the only firm in this constellation with 30 alliances. BMW closely follows Ford with 23 alliances, Toyota with 22, and Volkswagen with 20. In addition, emergent OEMs like BYD have 17 alliances, Huawei automotive division and Stellantis have 13 each, and Hyundai Motor Group has 12. Emerging OEMs like Geely and Tesla have the same number of alliances as traditional OEMs like Renault, Volvo, or Audi.

Figure 4 identifies Ford, BMW, and Toyota as those firms with the highest score in *betweenness centrality*, a property that quantifies the number of times the firms act as a bridge (Hanneman and Riddle, 2005).[7] According to social network analysis, nodes that have a privileged intermediation position in some way are also controllers or regulators of the information flows that circulate in the network. Figure 4 also shows that ICT firms play a similar role to traditional OESs in engaging in automotive alliances. This phenomenon has been explored in the literature, indicating that the entrance of technological firms, such as Apple, Google, or ICT start-ups, has increased their participation in associations with automotive firms to provide competitive opportunities through disruptive technological solutions (Kukkamalla et al., 2021).

Figure 4 Constellation of firms by number of alliances (n = 309) (see online version for colours)



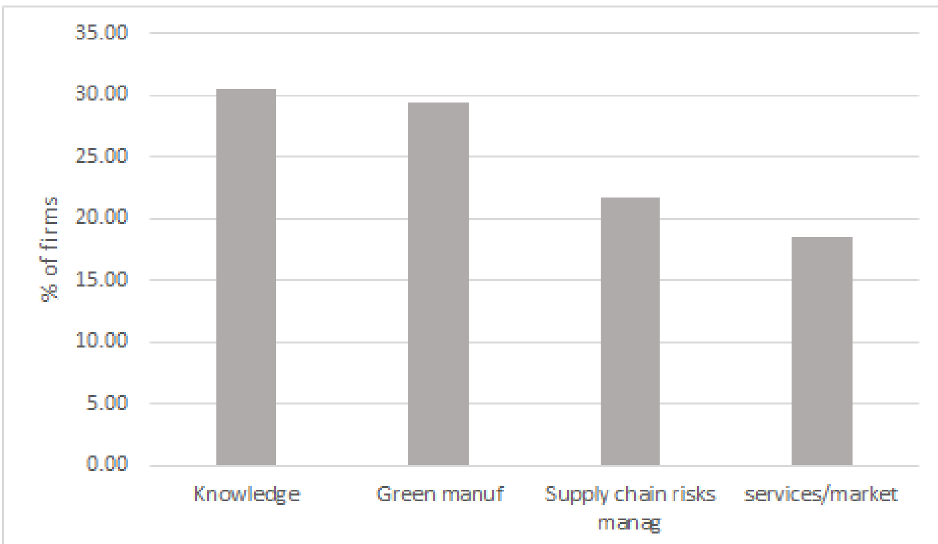
Note: 'Others' include OESs and other economic sectors like energy and retail.

Source: Elaborated by the authors based on data from *Alliance 4.0*

In line with the empirical findings of Häberle (2023), Figure 4 shows that traditional and well-established automotive OEMs have the resources to invest in new technologies through alliances with their strong network of suppliers (i.e., OES). In addition, traditional, well-established OEMs influence the implementation of disruptive trends through intra-industry alliances with newcomers.

Next, using the classification of alliances by motivation derived from the systematic literature review, alliances in *Alliance 4.0* were classified into four main categories according to their main motivation for establishing alliances (n=309). These motivations were established from the specifications in the press releases that were examined to build the dataset. Figure 5 indicates that about 31% of alliances were established to increase, strengthen, or build (technological) knowledge (i.e., VW and Kuka Robots, BMW, Arriver, and Qualcomm Technologies). These alliances are closely followed by those seeking to improve green manufacturing (about 29% of alliances), with examples like Ford and SK Innovation, GM and POSCO Future M Co. Ltd. for battery components, Geely, and Baidu. The analysis also shows that about 22% of the alliances aim to provide a service (i.e., Hyundai and Nvidia). About 18% were seeking an alliance to address supply chain risks and to improve market share (i.e., Ford and Global Foundries and Renault and Qualcomm Technologies). These trends are similar to those highlighted by Mule et al. (2021), who, in their study of 281 alliances (2006–2015), found that automotive OEMs sought R&D and manufacturing alliances to develop capabilities toward a new automotive architecture, with an increasing number of alliances seeking higher marketing and brand recognition and commercialisation.

Figure 5 Distribution of alliances according to motivation for establishment (n = 309)



Source: Elaborated by the authors based on data from *Alliance 4.0*

Table 2 Cross-tabulation of alliances according to motivation and focus areas (n = 309)

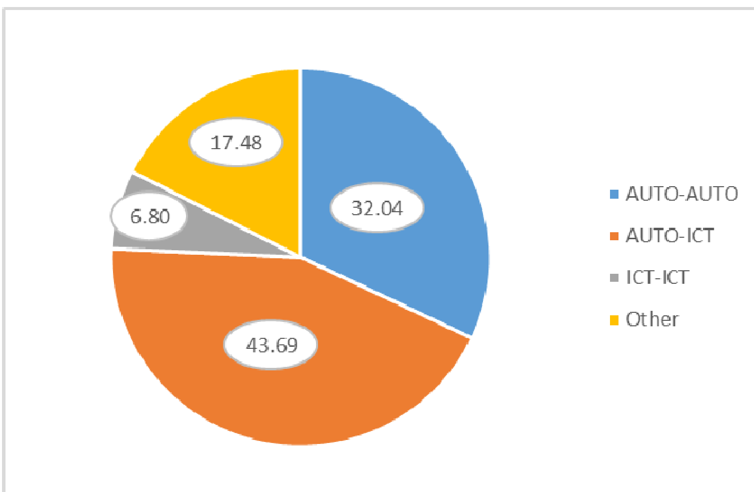
Main motivation for establishing the alliance	*Percent*	*Automotive items*	*Mobility ecosystem*	*Business environment*	*Total*
Knowledge	30.42	72.34	9.57	18.09	100%
Green manufacturing	29.45	80.22	9.89	9.89	100%
Supply chain risk management	21.68	89.19	0.00	10.81	100%
Provision of services/market access	18.45	52.87	26.44	20.69	100%
	100%				

Source: Elaborated by the authors based on data from *Alliance 4.0*

Table 2 shows the relationship between the main purpose of the alliance and its main areas of attention. The analysis shows that about 71% of alliances are focused on (technical) aspects related to the automobile, about 16% on improving the business environment, and about 13% on the (new) mobility ecosystem. The analysis understands alliances focused on the automobile as those addressing issues directly related to it, such as the powertrain, batteries, or software, among other things. Those focused on the firm's business environment relate to seeking to improve the marketing of their products, build up a brand, or open more market options. Alliances focused on the mobility ecosystem are related to sensors, connecting platforms, clouds, and even electric charging points, etc.

The literature extensively discusses the inter-industry nature of today's alliances, in which automotive firms are linking to players from other economic sectors to bring new and innovative skills and technologies (Sigal, 2018). The analysis of *Alliance 4.0* provides empirical evidence to support this claim. Figure 6 indicates that about 44% of alliances in the sample are intra-industry between automobile firms and firms from the ICT sector. Traditional alliances between automobile firms comprise about 32% of the sample, supporting previous evidence that although an array of newcomers have entered the ongoing automotive alliances, traditional OEMs are still reinforcing and strengthening cooperation with each other (Mule et al., 2021; Sigal, 2018). Alliances between firms of non-automobile sectors addressing automobile solutions represent about 7% of the sample.

Figure 6 Distribution of inter- and intra-industry alliances (n = 309) (see online version for colours)



Source: Elaborated by the authors based on data from *Alliance 4.0*

5 Discussion of findings and conclusions

Without a doubt, in the last decade (with a particular emphasis on the last five years), the automotive industry has undergone a technological transformation characterised by high levels of technological uncertainty, in which previously established networks and systems are no longer sufficient to face the new technological and environmental patterns. Therefore, as indicated by the theory and confirmed by our empirical analysis, the industry is engaging in an increasing number of (technological) alliances and intra-industry collaborations, as a survival strategy during the ongoing period of transformational uncertainty, in which the relevance of software and semiconductors in the automobile will continue to rise.

The empirical analysis of *Alliance 4.0* shows that the strong partnership between traditional OEMs and OESs remains vital in the ongoing constellation of alliances. This finding indicates that traditional OEMs are in the driving seat regarding inter- and intra-industry cooperation, followed by emergent OEMs. Therefore, our empirical evidence does not support the assertion of authors like Blazquez Jimenez and Sanchis (2023) that there is a disruption of the traditional relationships between OEMs and OESs.

As highlighted by Zhao et al. (2005), this is an industry in which collective knowledge plays a more substantial role than in other industries; therefore, the strong trust in the existing relationship between traditional OEMs and their first-tier suppliers (e.g., OESs) is of significant relevance in establishing partnerships during times of high uncertainty (Cabigiosu, 2022). From the empirical analysis, we could assume that these pre-existing relationships are a base for seeking further technological complexities with new entrants and the intra-industry. This is supported by empirical findings that indicate that OESs and ICT firms are present with similar relevance in this new dynamic constellation, confirming theoretical arguments that traditional OEMs only engaged in new technologies and software solutions during periods of technological uncertainty at a later stage, and not earlier (Cabigiosu, 2022; Häberle, 2023).

When classifying the alliances according to their main motivation, the analysis indicates that about 60% of them were established to search for new knowledge or achieve green manufacturing, with most focusing on automotive production and processes. *Alliance 4.0* also indicates that traditional automotive OEMs have a greater number of alliances than emergent automotive OEMs. This is in line with the literature, which indicates that knowledge sharing is not an easy task guaranteed by the alliance per se and that working in an alliance is challenging; therefore, those firms with prior alliance experience have a higher positive level of knowledge transfer during the alliance (Rishabh et al., 2023; Sadowski and Duysters, 2008).

As indicated in the literature, the alliances in the sample included inter- and intra-industry, with a critical number of (43%) automotive alliances with the ICT sector (intra-industry), particularly regarding R&D and capacity-building, as well as the development of services (i.e., e-mobility) and market access. This finding highlights the recognition and relevance of automotive OEMs opening up to new providers during periods of high technological uncertainty and opening up to learn with/from others by bridging competencies from outside players, including competitors.

This article contributes to the understanding of the ongoing transformation of the automotive industry through a dynamic constellation of inter- and intra-industry alliances. The increasing number of alliances registered in the last five years shows that automotive OEMs are searching for ways to influence and transform the industry by partnering with allies and newcomers. The study identified a new constellation of alliances shaping the automotive global value chain, in which stakeholders diversify their roles, finding not only traditional automotive OEMs and automotive OESs, but also non-traditional auto firms, particularly in the design and implementation of ACES technologies (mostly on electrification and autonomy), with ICT firms pushing the frontier of these type of technological cooperation.

6 Limitations of the study

Although this study produced interesting insights, the analysis has some limitations. First, it is restricted to secondary data captured by *Alliance 4.0*, which does not provide enough information to present case studies to complement the global trends analysed here. Second, we acknowledge that *Alliance 4.0* is a random sample of those alliances published during the study period; the universe of automotive alliances during this period is much larger, and the results of this study only reflect those alliances within our sample. Third, given the nature of the data, the study does not explore network properties such as centrality, intermediation, and proximity. Instead, visual tools of social network analysis were used to illustrate some visible properties of the network relationships between firms and provide some preliminary insights into the ongoing changing nature of automotive alliances.

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Notes

1 For more on the influence of environmental regulations on the development of cleaner technologies, see Yarime et al. (2008).

2 Here understood as voluntary [business] agreements between at least two firms to reach [strategic] objectives of common interest (Isoraite, 2009; Mockler, 1999).

3 In the 1990s, the entrance of microelectronics favoured the initial adoption of lean production in the auto industry, requiring constant challenges in production processes, higher levels of automation, and technological efforts requiring automotive firms to achieve more complex technological capabilities (Jonker et al., 2006). Therefore, it is not surprising that even in the mid-1990s, the automotive industry was already starting to show an increasing trend towards strategic alliances in the forms of mergers and acquisitions (e.g., the Renault alliance with Nissan in 1999 and the later acquisition of Isuzu; the acquisition of Jaguar Land Rover by Tata Motors in 2008; and the acquisition of Volvo by Chinese Geely in 2010), joint ventures (e.g., Daimler AG and Robert Bosch GmbH for the development of traction motors for electric vehicles in 2011), and heavy exchanges of capital stakes (Vallejo, 2017).

4 The term 'constellation' in this context refers to a set of firms, linked through alliances, that compete in a specific business domain (as defined by (Gomes-Casseres, 2003). The term was coined by Lorenzoni and Ornati (1988) refering to constellational structures as entities that need to tie themselves to others, as they would not survive in isolation. This terminology is also used by authors like Alvarez Leon and Aoyama (2022) in studies of the automotive industry.

5 The authors are currently working on a book and other publications using this author-compiled database, which is the first academic journal publication using this database.

6 The term 'coopetition' was coined by Noorda (founder of Novell) in 1980s to describe firms that pursue cooperation and competition simultaneously (Feiyang et al., 2021). The term is understood to mean an alliance or cooperation between competitors (Blazquez Jimenez and Sanchis, 2023; Pi and Li, 2022; Rothaermel and Deeds, 2004).

7 The degree, which is a property that in social network analysis corresponds to the number of links that a node has with others, is a measure of centrality, as it is an indicator of interaction opportunities and alternatives.