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Exploring Innovation Ecosystem of Incumbents in the Face of Technological Discontinuities: Automobile Firms

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Abstract: In recent years, the innovation ecosystem concept has received much attention in the strategy and innovation fields to address radical or discontinuous innovation. This study aims to explore the innovation ecosystem construct of incumbents in the face of technological discontinuities, focusing on the ecosystem actors (that is, incumbents, component providers, and complementors) and their activities for sustainable value creation. First, we conducted a literature review of 34 highly cited and relevant research documents discussing the innovation ecosystem concept to extract key phrases for the innovation ecosystem's research framework. Then, through the lens of dynamic capabilities, the five core capabilities of incumbent focal firms—collaboration and networking, opportunity sensing, entrepreneurial orientation, knowledge management, and strategic flexibility—are derived as key elements of the research framework. In addition, the following case study conducted by the content analysis of two leading automobile incumbents, Volkswagen and Toyota, supports and concretizes the established research framework. We conclude that as the value chain in the industry is open to diverse emerging experts holding critical technologies in the era of discontinuous innovation, the ecosystem actors are extensively linked beyond existing industry boundaries. Next, incumbents' proposed five core capabilities are essential for their successful navigation of the complex innovation ecosystem. Finally, the case study also indicates that the traditional automobile giants in the existing ecosystem are heading toward sustainable value creation via technology internalization and dominant platform building to transform themselves into leaders of a new innovation ecosystem in the era of Connected, Autonomous, Shared and Services, and Electric (C.A.S.E.) innovation in the automobile industry.

Keywords: innovation ecosystem; incumbents; technology discontinuities; dynamic capabilities; automobile firms

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1. Introduction

In the rapidly changing business world that is increasingly becoming more complex and uncertain, most firms can hardly sustain their competitive advantages for a long time using the usual do-it-alone strategies [1]. Moreover, as only a few firms possess all the resources and capabilities for breakthrough innovation, the collaboration of multiple stakeholders is deemed essential to attract customers by providing complementary components or services [2,3]. Therefore, the survival of firms in the modern world is highly dependent on the benefits of an overall business ecosystem. Consequently, studies in innovation and technology management are increasingly focusing on the complicated networks of diverse actors in business ecosystems rather than on firm-level phenomena [3–5].

Different players compete for scarce resources in the business ecosystem by establishing partnerships with other organizations [3,6]. As technology progression is shaped by the activities of the heterogeneous participants composing the ecosystem, individual firms tend to rely on independent collaborators or complementors to enhance the value of their technology platform [7,8]. Therefore, the ecosystem perspective considers the actor network of loosely connected independent actors over which the focal firm has no direct control and its alliances in the supply chain [9,10]. For this reason, an innovating firm needs to consider how to align those actors, as part of their growth strategy, toward an integrated customer-facing solution [11].

When technological changes are discontinuous and, therefore, incompatible with the incumbent ecosystem, management becomes complex and uncertain, which is a key challenge for sustainability [12,13]. In such environments, the incumbents must compete against new entrants armed with disruptive technologies and cooperate with various ecosystems' complementors to avoid being overthrown from their dominant positions in the market. Moreover, as prior rational innovation practices often do not work in the context of technological discontinuities, incumbent firms need to pioneer breakthrough innovations outside the dominant regime and dynamically control the value creation process [11,13,14].

To address radical, discontinuous innovation or emerging industries, the innovation ecosystem concept that brings value creation to the center stage of the existing market has received much attention in the strategy and innovation fields in recent years [3,14,15]. While the extant literature on strategy and networks has been criticized for overemphasizing value capture over value creation, the innovation ecosystem addresses cross-organizational collaboration for value co-creation and co-innovation for sustainable growth [15–18]. Many innovation actors possessing different complementary resources are trying to build or join an innovation ecosystem to enhance their resources and capabilities, updating strategies and dynamically interacting with ecosystem participants in a loosely coupled manner [1,14,19]. Incumbent established firms often build complicated innovation ecosystems based on their resource and technology advantages, encouraging other firms to reap the benefits by joining the innovation ecosystem [19,20]. These concerted efforts by individual firms to keep innovating and improving collectively help keep all firms in the innovation network at the head of their competition.

Although it is increasingly significant for firms to adjust their innovation strategies to ecosystem-based co-innovation, studies concerning innovation ecosystems are still at an early stage and have been criticized for theoretical inconsistency and for lack of sufficient conceptual studies or in-depth empirical support [1,15,21,22]. Moreover, few studies have investigated the incumbent firms' ecosystem-level capabilities to successfully cope with dynamically evolving ecosystems in the face of technological discontinuities [9]. Some scholars argue that there is a gap among various approaches such as the resource-based view, the dynamic capability view, and the ecosystem perspective, which could be bridged for better conceptualization [9,15,17]. This study aims to clarify the conceptual framework of the incumbents' innovation ecosystem in the era of the paradigm shift, combined with a dynamic capability approach and an in-depth case study.

This study first constructs a research framework of incumbents' innovation ecosystem in the face of technological discontinuities, including ecosystem actors (incumbent focal firms, component providers, and complementors) and their activities for sustainable value creation. The incumbents' activities or core capabilities essential for successful navigation through a complex network were clarified through the lens of dynamic capability by conducting a literature review of research documents relevant to the innovation ecosystem or dynamic capabilities. The dynamic capability view provides micro-foundations for innovation ecosystem development and helps clarify ecosystem-level phenomena in a volatile and fast-changing environment [11,23–25]. Thus, this study aims to establish the innovation ecosystem construct that reflects the incumbents' virtuous cycle of sustainable competitive advantages in the era of paradigm shift. Secondly, based on the conceptual outline of the innovation ecosystem, we conducted an in-depth empirical study to support and enrich the research outcome. We investigated two major incumbents, Volkswagen (VW) and Toyoda, in the automobile industry experiencing discontinuous technological change characterized by C.A.S.E. (Connected, Autonomous, Shared and Services, and Electric) by content analysis of media articles between the year 2016–2021. The activities of the two incumbent firms, as focal firms in the innovation ecosystem, focus on their interaction with other actors in the ecosystem and the dynamic capabilities behind their activities.

This study is structured as follows. The first part is the introduction. The second section presents the theoretical background by reviewing the existing literature, and the third section provides the conceptual research framework. Next, the development of the conceptual research framework is discussed, and in the fifth section, the results of the empirical study are described. In the final section, we discuss the implications of this study and suggest future research directions.

2. Theoretical Background

2.1. Innovation Ecosystem

Many scholars have recently turned their attention towards the ecosystem activities involved in innovation, development, and commercialization, from traditional outsourcing of most production activities [15]. Various conceptualizations of the ecosystem have been offered, reflecting the diverse theoretical backgrounds of the research traditions to address these phenomena of organizational collaboration and joint value creation [4,9,26–28]. The existing literature on ecosystem research encompasses two main perspectives of management: the business ecosystem perspective, which emphasizes the value capture process, and the innovation ecosystem perspective, which predominantly refers to value creation. Value-creating activities for customers and other stakeholders precede the value capture process, which focuses on firm-level profit-taking activities for competitive advantages [15,16,18].

A biological concept of the ecosystem has been utilized to address complex interdependence and complementary relationships among organizations beyond their industries, first termed the business ecosystem by Moore [12,19,20]. Moore (1993, 1996) proposed that a business ecosystem describes the organizational and individual networks that cooperatively and competitively develop valuable products and services for customers [12,20]. The term also emphasizes the role of business actors driven by market forces in establishing value networks through evolving and interacting with other actors in the ecosystem [20,21,29]. The business ecosystem construct focuses on the value capture process of how firms sustain their competitive advantages by profit-taking activities [15,18].

More recently, the innovation ecosystem construct, which has its main roots in business ecosystem research, has gained prominent attention to craft strategies in dynamic and co-evolving ecosystems [5,16,30]. The term took off after the research article by Adner (2006), which emphasized the complementary innovations from participants within the ecosystem to achieve the focal firm's success in a dynamic market and highlighted the co-evolution of value [2,5,16,31]. Within the innovation ecosystem, each firm is highly dependent on the resources of other organizations. Thus, the collaborative arrangements through which firms combine their offerings into a coherent, customer-facing solution are important [2,16]. Therefore, the innovation ecosystem approach primarily focuses on inter-firm vertical and horizontal collaborative linkages, integration of upstream and downstream complements, and the ecosystem actors' simultaneous cooperative and competitive network [16,32–35].

Previous studies have suggested various definitions of the innovation ecosystem. According to Granstrand and Holgersson (2020), an innovation ecosystem is defined as the evolving set of actors, activities, and artifacts, including complementary and substitute relations of actors [3]. Other research proposed a network of interdependent actors who combine specialized yet complementary resources to co-create and deliver an overarching value proposition to end-users and appropriate the gains received in the process [11]. Xu et al. (2018) conceptualized the term as a complex, dynamic system that includes science, technology, and business sub-ecosystems [29]. An innovation ecosystem also represents the feature of structural dynamics among heterogeneous stakeholders, including focal firms, customers, suppliers, government agencies, and associations, among others [32].

The innovation ecosystem comprises varied expertise and skillsets with cross-functional cooperation between all partners and stakeholders [36,37]. Kandiah and Gossain (1998) argue that manufacturers, suppliers, competitors, complementors, and other industry players are key to the value creation of an ecosystem [32]. Ecosystem actors, interacting flexibly and loosely coupled, are co-evolving and continuously adapting to the environment to survive and sustain competitive advantages and avoid yielding to increasing pressure from new market entrants [1]. According to Adner and Kapoor (2010), relations in an innovation ecosystem evolve in unforeseen and unstable ways, moving from cooperation to competition and vice-versa [15]. In particular, novel and discontinuous technological innovations are generated through more complex and dynamic ecosystems, adding complexity to the ecosystem concept [29,38].

2.2. Technological Discontinuities and Incumbents

Technological discontinuities arise when the next-generation technology platform emerges and can be commercialized to fit into current market needs or consumption patterns, thereby displaying existing products or services [39,40]. Even though the new technology domain may have lower performance than incumbent technology initially, a similar market need might be fulfilled by a discontinuous technology with an entire new knowledge base, opening a window of opportunities for complementors and competitors [7,41]. Such a technological discontinuity in an ecosystem inaugurates the ferment era, a period of turbulence and uncertainty until a dominant design is finally selected [41,42]. As the technological and market uncertainties are typical to discontinuous innovation, thus making the innovation process more complex, firms' capabilities to manage such uncertainties are significant for their long-term survival [39,43,44].

Path-breaking innovations inherently challenge the prevailing ecosystem, for instance, its established rules, actors' behaviors, and artifacts, by rendering existing competencies obsolete [7,11]. Incumbent firms may have difficulties reacting to technological discontinuities because they often focus on developing existing technology domains to reap maximum benefit, consequently resisting change [41]. In addition, incumbent firms' willingness to bring about new technologies and innovations can loosen their existing ecosystem linkages with suppliers and complementors, which may generate difficulties in value creation if they cannot secure appropriate and continued support from complementors [7,41]. Challenges are intensified if the ecosystem actors are unwilling to easily adopt the new technology platform due to the barriers of a lack of knowledge or desire [39,45–47]. Therefore, incumbent complementors should renew their learning and invest in acquiring the new technological capabilities quickly, taking the risk of significantly altering the existing knowledge base [7]. As the capabilities and maturities of actors comprising an ecosystem play a key role in successfully creating value for customers, focal firms in the face of technological discontinuities are required to analyze the most challenging bottleneck for the whole system [8,48].

While incumbent firms must always be ready to work with upcoming technological disruptions, re-evaluating and reconfiguring the strategies that have been working for them, new entrants pioneering discontinuous innovations focus on how new technology benefits the customer and on how to overcome the resistance of the incumbent ecosystem [11,39,41,49]. In the era of a paradigm shift, the focal firms need to adopt out-of-the-box strategies based on dynamic capabilities for long-term survival.

2.3. Dynamic Capability View

Along with the business ecosystem's increasing complexity and dynamism, many strategic management studies have focused on dynamic capabilities as the forefront of a firm's sustainable competitive advantage [50]. Furthermore, technological discontinuities, which contain high degrees of risk and uncertainty, request incumbent firms' dynamic capabilities to leverage external networks and ecosystems to adapt to a volatile business environment that demands constant improvements [9,12,23,24,51,52].

Dynamic capabilities can be defined as the firm's ability to integrate, build, and reconfigure internal and external competencies to address rapidly changing environments [23]. Eisenhardt and Martin (2000) suggested that a firm's dynamic capabilities are the organizational and strategic routines through which a firm achieves new resource configurations as markets change [24]. Dynamic capabilities are also conceptualized as a learned and stable pattern of collective activity through which an organization systematically generates and modifies its operations routinely to improve effectiveness and productivity [53]. Some scholars have named dynamic capabilities higher-order capabilities with which a firm operates to extend, modify, and create first-order operational capabilities [25,54].

Dynamic capabilities of focal firms to keep reconfiguring their core competencies to maximize value creation and manage technological discontinuities are necessary for successful management of the innovation ecosystem and long-term survival of organizations [24,55,56]. Furthermore, the focal firms' dynamic capabilities enable them to uniquely combine resources through coordinating innovation ecosystem actors and thereby generating hard-to-imitate outcomes [23,57–59]. Helfat and Raubitschek (2017) argued that dynamic capabilities, including innovation, environmental sensing, and integrative capabilities, are crucial for ecosystem orchestration and platform leadership [26,60]. Thus, linking studies on the dynamic capability view and the innovation ecosystem might help scholars understand valuable resources and capabilities for ecosystem actors in a dynamic context [61].

3. Conceptual Framework

3.1. Conceptualizing the Innovation Ecosystem

By reviewing the existing studies on the innovation ecosystem and dynamic capability view, a meaningful conceptual bridge could be established between them, thereby helping us to clarify constituting elements of the innovation ecosystem framework. Figure 1 describes the core capabilities of the focal firms that are essential for successful management of the innovation ecosystem and linkage to corresponding higher-level dynamic capability components that are critical to sustaining competitive advantages in environmental change. The literature review result according to each category can be described as follows:

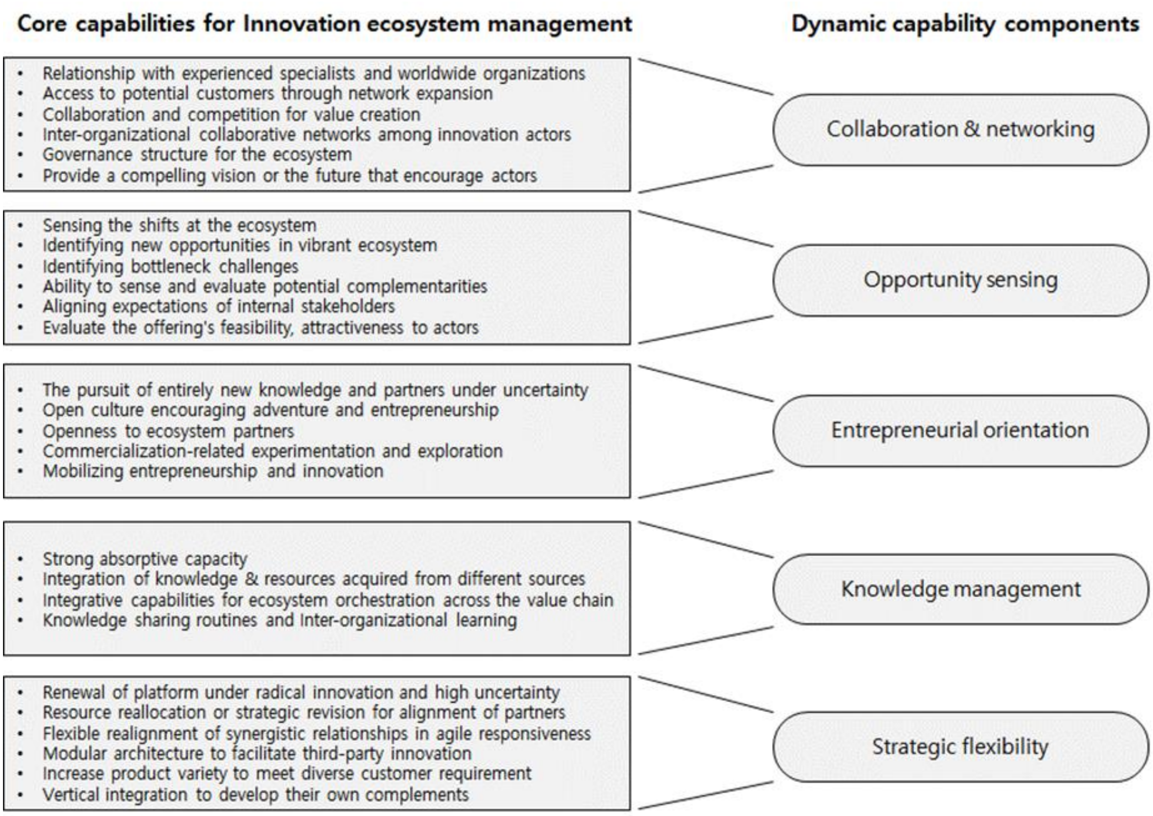


Figure 1. Key phrases in the innovation ecosystem and dynamic capability study.

3.1.1. Collaboration and Networking

The literature on the innovation ecosystem emphasizes interdisciplinary and inter-organizational collaborative networks among all partners and shareholders [5,26,29,36,62]. Complementary and mutually beneficial relationships between ecosystem actors enable co-evolution of players' capabilities while mitigating risks that lead to market share loss during discontinuous innovation [31]. Close collaboration with innovative suppliers through frequent iterations in the design and development stage brings new, inimitable artifacts to the ecosystem, thereby alleviating the risk of market shifts resulting from next-generation innovations from new market entrants [16,20,33,63]. Moreover, by maintaining a solid relationship with organizations that enjoy a good reputation worldwide, firms can access the infrastructure of partnering organizations and potential customers, expanding professional networks [5,19]. Such vertical and horizontal cooperative ties are based on a compelling vision provided by focal firms and mutual trust to share valuable resources [20,22] willingly. The ecosystem networks are complex relationships, including competition and cooperation between diverse ecosystem actors [2,3,32]. The simultaneous cooperative and competitive network between focal firms and the other actors nourishes ecosystem development [32]. In addition, focal firms should establish an effective governance structure for the ecosystem, managing strategic fit to local laws and regulations [9].

As an ecosystem-level phenomenon is gaining more attention, the role of networks and inter-organizational relationships have been emphasized as being essential parts of dynamic capability studies [64,65]. Firms can sustain competitive advantages by close communication with cooperative organizations built on mutual trust and benefit [66–68]. Moreover, building and sustaining effective networks is critical to identifying opportunities, garnering necessary resources, and sharing risk and uncertainty [69–72].

3.1.2. Opportunity Sensing

According to previous studies on the innovation ecosystem, a focal firm's ability to identify and select critical cooperation partners in consideration of mutual benefits and compatibility of the strategic goals has been emphasized [9,39,73]. The firm must actively screen previously unknown potential collaborators in distant markets and evaluate opportunities with different partners, including research institutes and universities [5,9]. These new partnerships help the focal firms reinvent their products and services consistent with market demand. In addition, understanding regulations and laws concerning ecosystem activities should be considered [9]. By analyzing external threats and opportunities, a firm can properly evaluate its offerings' likely attractiveness to customers and expect possible consequences of innovative collaboration in the ecosystem [2,9,74]. The ability to sense and evaluate potential entrants and substitutes to rival ecosystems and potential complementarities is significant to seizing upcoming opportunities and leading new markets [10,34]. In the vibrant ecosystem, the sensing capability of alerting the shifts in the ecosystem, searching for new opportunities, and changing customer requirements is more important [11,14,63]. A focal firm's ability to identify bottleneck challenges that constrain the overall performance of the ecosystem is also critical [12].

Environmental sensing is emphasized in many studies related to the dynamic capability view [55]. It is a prerequisite capability to enable proper strategic action by detecting an opportunity or threat, exploring new resources, and taking appropriate environmental measures [51,75–77]. In addition, as market uncertainty increases, such cognitive flexibility becomes more important for corporate management [78].

3.1.3. Entrepreneurial Orientation

A focal firm's entrepreneurial orientation that encourages adventure in the pursuit of entirely new knowledge under uncertainty is essential to pioneer within the ecosystem [1,3,5,9]. A firm needs to deliberate experimentation to explore a new field that is technically feasible and commercialized despite uncertainty [13,26,29,39]. Exploratory projects of experimentation and exploration help the firm predict which offers might gain the highest adoption rate and manage the experimentation-driven transformation of the innovation ecosystem [11,12]. The openness to the innovation platform is also a vital component of entrepreneurial culture for value co-creation with diverse ecosystem actors by open innovation [9,22]. In particular, mobilizing the entrepreneurial culture inside and outside the established firms motivates individuals to think outside the box to pursue innovation or start their businesses [6,13].

Entrepreneurial orientation focuses on dynamic capabilities studies as a core competence for successful new market entry [79,80]. The degree of innovativeness, proactiveness, risk-taking, and competitive aggressiveness are dimensions of entrepreneurial orientation [79,80]. In particular, incumbent firms require entrepreneurial orientation to overcome organizational inertia while accepting unfamiliar changes. In addition, the entrepreneurial orientation of decision-makers can facilitate organizational innovation and consequently enable rapid market preemption [55].

3.1.4. Knowledge Management

A focal firm with strong absorptive capability can better use various knowledge sources, e.g., institutions, universities, and regulators. [5,9,32]. Inter-organizational, cross-functional, and cross-project learning improve an organization's existing knowledge base, thereby rapidly bringing creative outcomes [12,34]. Learning from the lessons of others in different ecosystems or different institutional settings provides an optimal path to success [11]. Integrating knowledge across the value chain, that is, upstream suppliers and downstream complementors, is critical for ecosystem orchestration [22,29,32,60]. Sourcing and integrating new components into a firm's internal technologies to create new products are increasingly vital activities of the innovation ecosystem [5,16]. A platform owner's strategy of sharing the integrated knowledge with independent complementors, e.g., teaching them how to develop for the platform, can accelerate their learning process, minimize defections, and attract more players. An innovation ecosystem can survive and prosper upon shared knowledge, skills, and roadmaps [3,14,81].

The knowledge management process of absorbing external knowledge or resources from diverse sources, integrating them with internal capabilities along the value chain to create maximum values, and sharing created knowledge with internal or external members is regarded as a critical dynamic capability that quickens integration of the most advanced technologies, quickly grasping business opportunities [82,83]. Furthermore, bundling different technology fields by interacting with diverse organizations can provide new value to the market [84,85].

3.1.5. Strategic Flexibility

While maneuvering in total uncertainty of discontinuous innovation, mechanisms for self-renewal such as simultaneous reconfiguration of the industry platform and current resource base is an essential strategy [6,15,22]. A focal firm's strategy should be flexible to continuously re-evaluate and re-orchestrate the whole ecosystem actors to promote harmonious growth of an ecosystem in agile response to the environmental change [3,9,14]. After recognizing gaps in resource or strategic fit among ecosystem actors, the focal firm needs to realign key players to minimize these gaps and maximize the actual contributions of the partners to the ecosystem [9,10]. To increase strategic flexibility, a firm can meet diverse customer demands and react faster to new requirements by developing various products [14,62]. In particular, by building an open or modular architecture, a focal firm can efficiently diversify products and third-party innovation while maintaining control over the independent innovators [26,62]. Sometimes, a focal firm reconfigures the value chain structure to mitigate bottleneck challenges. For instance, upstream challenges in the supply of components can be resolved by vertical integration, that is, by developing its complements to compensate for the components [7,16].

Likewise, under discontinuous innovation, a highly uncertain market highlights the dynamic capability to manage risk and optimize their profit with strategic flexibility [55].

Strategic flexibility to meet an increasing variety of market needs includes diversifying business models, reconfiguring existing resources, vertical integration or disintegration in the supply chain, and ambidextrous management associated with exploitation and exploration [51,67,85–88]. In addition, agile response to changing market needs such as the time-to-market launch of a firm's new products ahead of the competitors is regarded as an important capability of this category [66,89,90].

3.2. Research Framework

According to the arguments described above and based on the conceptual scheme proposed in Grandstrand and Holgersson (2020), we propose the innovation ecosystem framework of incumbents in the face of technological discontinuities as shown in Figure 2, which is composed of three entities, namely ecosystem actors, activities, and artifacts [3]. To take a closer look at an innovation ecosystem, we must first examine the ecosystem actors formed by the complex network of cooperation or competition [91]. The ecosystem actors include incumbents as focal firms, that is, main ecosystem actors in orchestrating positions, component providers, and complementors in varying levels of distance from the end customer [2,11,14,92]. Component providers supply key components essential for the development of innovative products. Focal firms in the value chain directly bundle them. At the same time, complementors develop resources or services that complement focal firms' value creation in a loosely connected manner to focal firms [16]. A self-reinforcing cycle in the innovation ecosystem can be operated when focal firms attract developers of complementary goods, and the complementors attract customers, increasing the installed base [41]. The ecosystem actors cooperate in developing and defending their ecosystems while competing to gain market share [1,19,93].

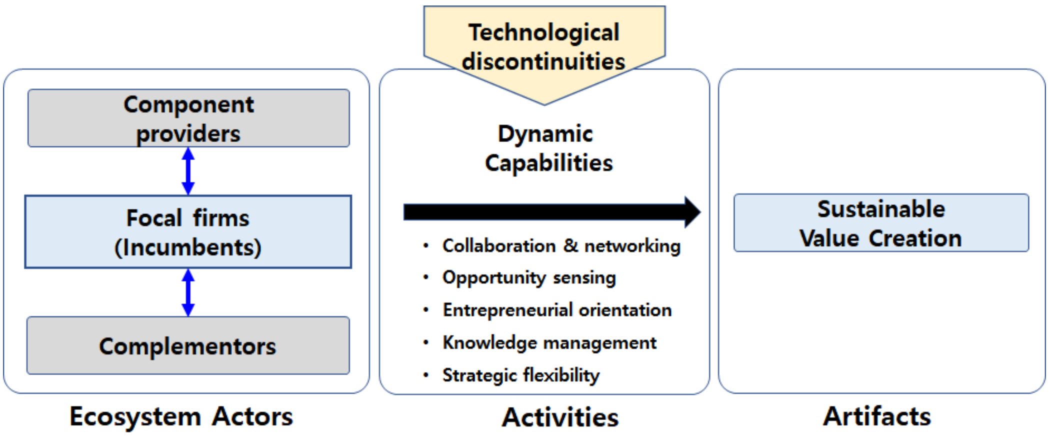


Figure 2. Innovation ecosystem framework of incumbents in the face of technological discontinuities.

The ecosystem can evolve and flourish as ecosystem actors behave vigorously based on their dynamic capabilities, that is, collaboration and networking, opportunity sensing, entrepreneurial orientation, knowledge management, and strategic flexibility, as was derived in the previous section. Therefore, the studies of the innovation ecosystem and dynamic capabilities emphasize those keywords as vital components of focal firms' success in navigating a complex ecosystem network during the technological shift. In particular, we posit that incumbent firms' successful voyage into an uncertain place is highly dependent on the aforementioned five elements. First, as do-it-alone strategies of the incumbents do not properly work in the era of discontinuous innovation, they need to establish an extensive collaborative network taking advantage of their strength in resources and experiences. Second, they should also sense changing demand, optimal partners suitable for seizing new opportunities, and possible bottleneck challenges in the value chain. Third, established firms, which tend to focus on the prevailing ecosystem to reap maximum profit and resist change, an entrepreneurial orientation to experiment and innovate with an open mindset will be a critical element to sustain their superior position in the face of path-breaking innovations that inherently challenge the incumbent ecosystem. Fourth, the incumbents can secure state-of-the-art knowledge by a knowledge management process of absorbing new knowledge from external sources, e.g., new ventures, and integrating them with internal capacities to create more innovative artifacts, much faster than by in-house development. In this case, they can also increase the installed base with continuous support from ecosystem actors by sharing the new knowledge with them. Finally, the incumbents' strategic flexibility to alter their resource bases and reconfigure their current strategies will be inevitable choices along with the fast-changing situation since the established competencies of incumbents can often become obsolete in the era of discontinuous technological change.

As a result of such activities in the face of technological discontinuities, successful incumbents create sustainable value, e.g., innovative outcomes, defined as artifacts in our research framework. In summary, an innovation ecosystem of incumbents can achieve sustainable evolution through continuous innovation activities driven by dynamic capabilities in relationships with ecosystem actors [1].

4. Research Method

This study first establishes the innovation ecosystem's research framework in the face of technological discontinuities. It explores the core capabilities of incumbent firms for ecosystem management while maintaining competitive positions through the lens of dynamic capability. For the conceptual approach, we reviewed 34 highly cited research documents selected by keyword search (using the keyword "innovation ecosystem") in the Web of Science database and by snowball sampling from the references of each document. Key phrases that interpret essential capabilities in the innovation ecosystem were extracted from each document and then developed into more abstract categories. The derived categories were investigated through the lens of dynamic capability by reframing them into the keywords of dynamic capabilities that relevant research documents have previously highlighted. The initial construction of the innovation ecosystem framework is proposed based on the induced constituents.

We additionally performed multiple case analyses of automobile firms to concretize and validate the constructed research framework. The automobile industry experiencing rapid and discontinuous technology transition toward next-generation technology platform characterized by C.A.S.E. is an adequate case for this research. A qualitative case study design is fitted to investigate a long-term, complicated theme that is hard to understand clearly. Thus, it can provide abundant insight into the innovation ecosystem's dynamic, complicated phenomenon [50,94]. The case study includes two leading automobile incumbents, VW and Toyoda, ranked in the top two by the number of vehicle sales in 2013–2020 (Figure 3). Analysis of these two firms' activities as focal firms with other ecosystem actors and the similarities or differences in strategies and capabilities can provide sufficient evidence for the study.

For an in-depth case analysis of multiple firms, we conducted content analysis for media articles collected from newspapers, corporate websites, and industrial magazines, containing a rich amount of events and official interviews relevant to the research topic for the specific period of interest. In addition, we collected relevant articles published between 2016 and 2021, which provided us with useful evidence of each firm's activities, capabilities, and strategies in the innovation ecosystem under technological transition. The content analysis starts from abstracting phrases or sentences from each of the collected texts, investigating their relevance to the category schemes which comprise the developed conceptual framework. The described qualitative coding process of content analysis was performed via NVivo, a qualitative data analysis software package (Figure 4). For reliability check of data coding results, two coders conducted the identical coding process independently according to mutually agreed definitions. The coding results reached sufficient agreement through a series of meetings and adjustments.

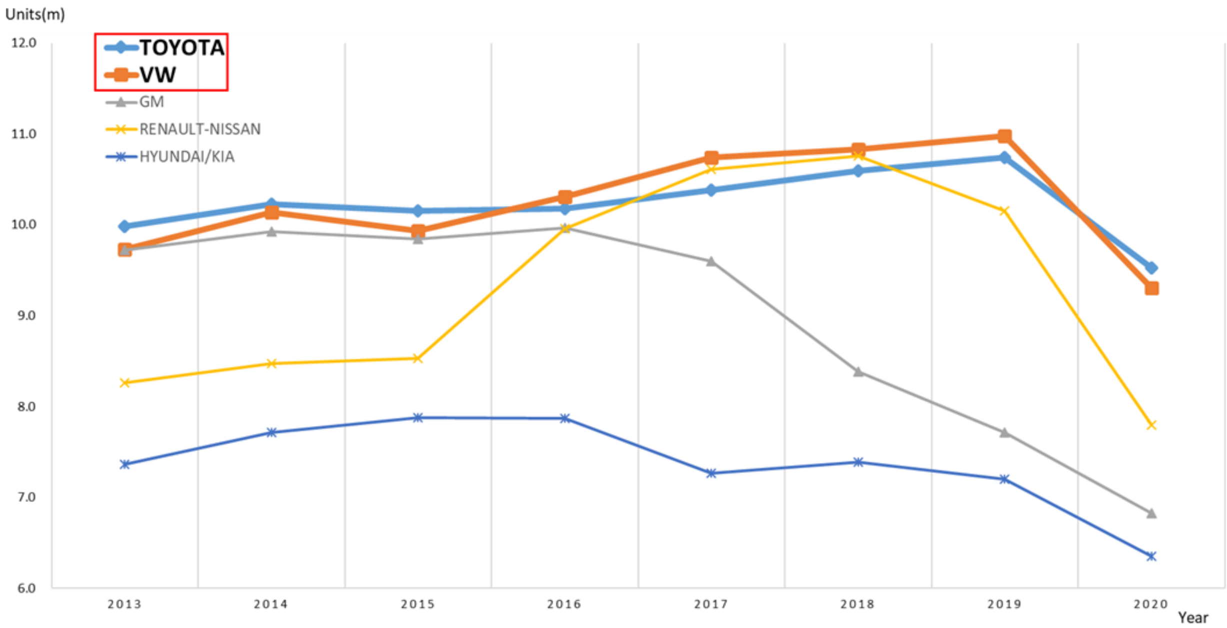


Figure 3. Automotive manufacturing groups by the number of vehicles sales between 2013 and 2020. Source: Global Sales of Major Automakers and Groups by MARKLINES (http://www.marklines.com, accessed on 22 September 2021).

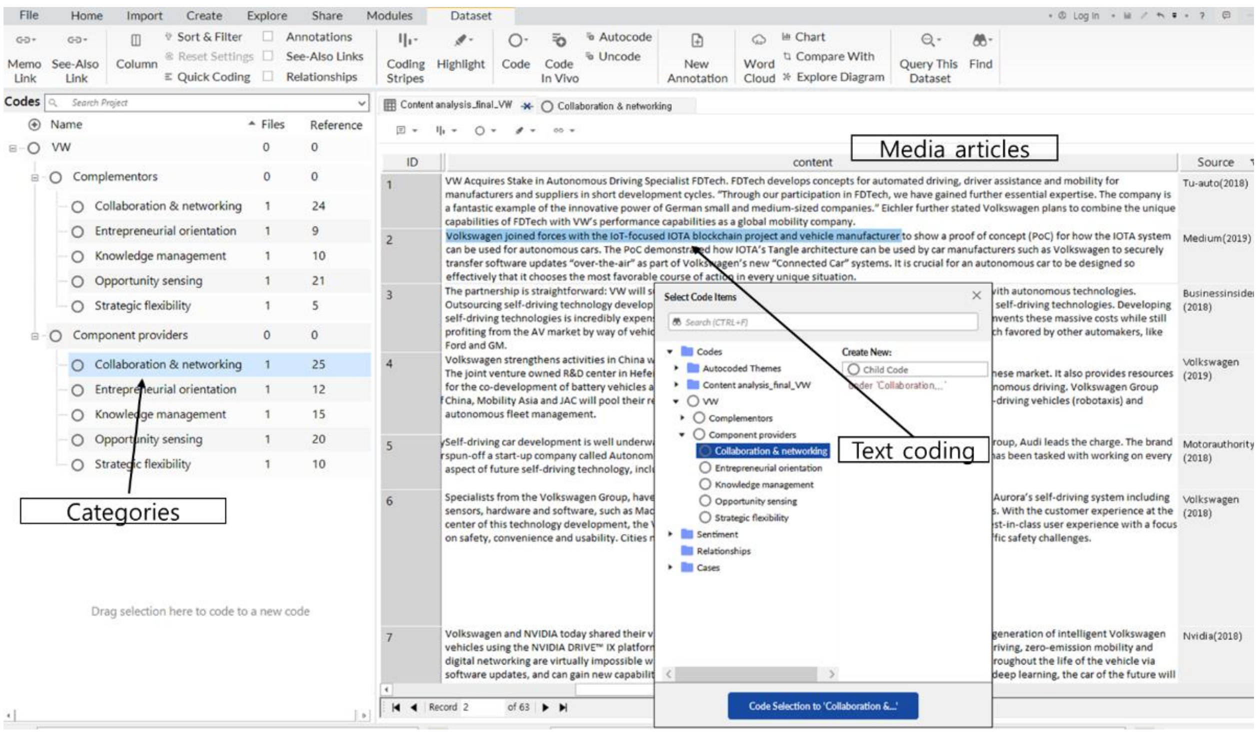


Figure 4. Qualitative coding of content analysis (NVivo).

Finally, research findings from the case study support and concretize the research framework initially built at the stage of the conceptual study. Figure 5 summarizes the overall research procedure and protocol.

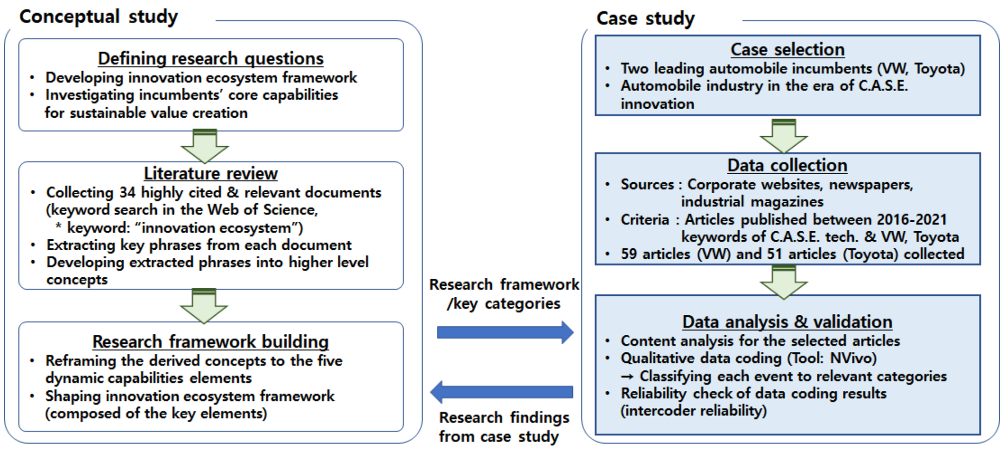


Figure 5. Research procedure and protocol.

5. Case Analysis

5.1. Case Description

So far, global automotive incumbents, including VW and Toyota, called original equipment manufacturers (OEMs), combined with extensive supply chains, mass production, and marketing capabilities, have maintained a stable position within the industry with little chance of being replaced by other companies [49,95–97]. No major component suppliers have succeeded in consolidating into OEMs, nor have many new entrants challenged the dominance of established OEMs [95,98].

However, digitization and new business models have revolutionized many other industries, and automobiles are no exception. In the automotive sector, these forces are driving four discontinuous technology-driven innovations: mobility services, autonomous driving, electrification, and connectivity [99–101]. These technology-driven innovations are significantly changing the position of existing players in the current mobility ecosystem, and multiple scenarios have become possible, either through partnerships between automakers and complementary companies or the emergence of new players outside the automotive realm [102].

While vehicles powered by internal combustion engines (ICEs) still dominate the market, EVs (electric vehicles) are considered to have the potential to overcome the environmental challenges posed by conventional vehicles, setting a new strategic path for the industry to move towards electrification [103–105]. Automotive connectivity, which allows vehicles to access the internet or other networks, will open new opportunities for business model innovation and new markets requiring software development capabilities [100]. Autonomous vehicles, which detect people, objects, and their surroundings, require the cutting-edge technologies of deep learning, real-time control software, and image data processing [100]. Since these technologies are beyond the existing capabilities of the incumbent automakers, they thereby require networking with multiple organizations capable of providing the autonomous driving solutions required [100,101]. Mobility services are another area of innovation in which high-tech companies can offer complementary solutions such as car sharing, carpooling, and self-service cars, thus contributing to the emergence of innovation ecosystems [106].

As the emergence of discontinuous technologies often challenges the incumbents' long-term survival, ecosystem activities at the inter-organizational level play an essential part in the incumbents' strategies to efficiently respond to radical technological change [107–110]. The incumbents compete and cooperate simultaneously to develop an ecosystem while exploring new opportunities [111]. In this context, incumbent automakers' analysis must consider a new partnerships approach for the mobility of the ecosystem [102].

5.2. Research Results

This section analyzes ecosystem actors and their activities around the two leading incumbents, from 59 events of VW and 51 events of Toyota extracted from media articles published between 2016 and 2021. The list of analyzed events is summarized in the Appendix A, and the content analysis result of the two automobile firms is described as follows.

5.2.1. Evidence from the Case—Ecosystem Actors

Case of VW

In the era of rapid technological advances led by C.A.S.E. innovation, VW has collaborated with diverse component providers and complementors to secure ecosystem-level resources and capabilities to manage the new innovation ecosystem. As for the autonomous driving platform, VW has accelerated technology internalization by acquiring startups with core technology. At the same time, it has developed novel solutions through collaboration with companies specialized in autonomous driving sensing, judgment, and control technologies, thereby shortening the release schedules. For the stable procurement of battery cells, the firm collaborated with stakeholders, jointly developing next-generation solid-state batteries. Regarding the EV platform, VW has pursued a shared strategy with other OEMs to reduce costs for future technology development and to extend networks and product lineups for regional sales. As the burden of investment cost increases in passenger cars and in the commercial vehicle market, where it is difficult to secure economies of scale, the company is pushing to share an electrification-only platform with other competitors to reduce operation costs and increase sales. In SW architecture, VW has established a software development division to maximize software scalability and developed a software architecture that considers commonality and connectivity, forming a collaborative ecosystem with external companies. In addition, VW has partnered with the component providers in developing semiconductors and communication functions for connectivity and autonomous driving solutions.

VW has also maintained direct and indirect relationships with complementors in the mobility service area to expand the service area of the ecosystem. By working with car-sharing and mobility solution companies, the incumbent firm invented and verified revenue models for the mobility businesses. Furthermore, VW announced a collaboration with universities to strengthen the software infrastructure further and transform it into a service-oriented firm to train its employees to acquire software capabilities and build a cloud platform. In addition, VW established a subsidiary in charge of the distribution and operation of electric vehicle charging infrastructure and formed a strategic partnership with complementary firms to provide charging services in public places and homes in each region of the energy charging system. VW also joined forces with diverse complementors to source the battery's raw material to secure a stable supply chain of the batteries and develop a battery management system to improve battery life and safety. Figure 6 illustrates the ecosystem actors in a wide range of technology fields that have been in relationships with VW during the period of interest in this study, which shows that the ecosystem actors are extensively linked beyond existing industry boundaries in the era of discontinuous innovation.

Case of Toyota

Toyota has also formed alliances with diverse component suppliers and complementary companies to strengthen capacities in C.A.S.E. and to lead an innovation ecosystem. Toyota has expanded cooperation with battery experts for relevant technology development and safe battery procurement, significant for battery electric vehicles (BEV)'s quality and price competitiveness. Toyota focused on investment/acquisition of external companies to complement its insufficient autonomous driving technology and mobility business capabilities at an early stage of development. As a result, the incumbent firm could secure a large-scale autonomous driving expert and utilize the accumulated autonomous driving data. In addition, Toyota jointly developed the EV platform and achieved economies of scale, allowing other OEMs to adopt the platform developed by Toyota. Moreover, Toyota has strengthened cooperation with telecommunication and IT companies to transmit and receive vehicle data, thus improving the connected cars' customer experience.

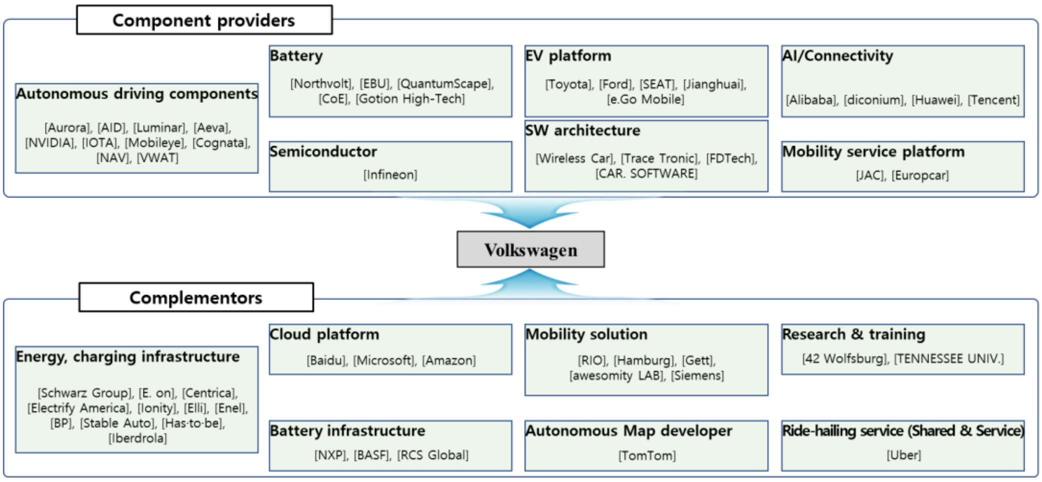


Figure 6. The ecosystem actors in relationships with VW.

Toyota has also built relationships with complementors to expand the C.A.S.E. ecosystem, including mobility services, charging infrastructure, and autonomous driving map developers. Toyota has improved the convenience of charging hybrid and electric vehicles by working with energy companies that develop a robust charging infrastructure. Through partnerships with mobility solutions and services platform companies, Toyota expanded its mobility service business by utilizing its know-how. Collaborating with universities could also accelerate autonomous driving research and joint development of sustainable mobility models. Toyota worked with complementary companies to diversify key materials' supply lines and construct a pilot production line for next-generation batteries for stable battery procurement. In addition, collaboration with autonomous driving map companies enabled real-time map updates, improving the autonomous driving experience. Figure 7 shows the ecosystem actors that have been in relationships with Toyota.

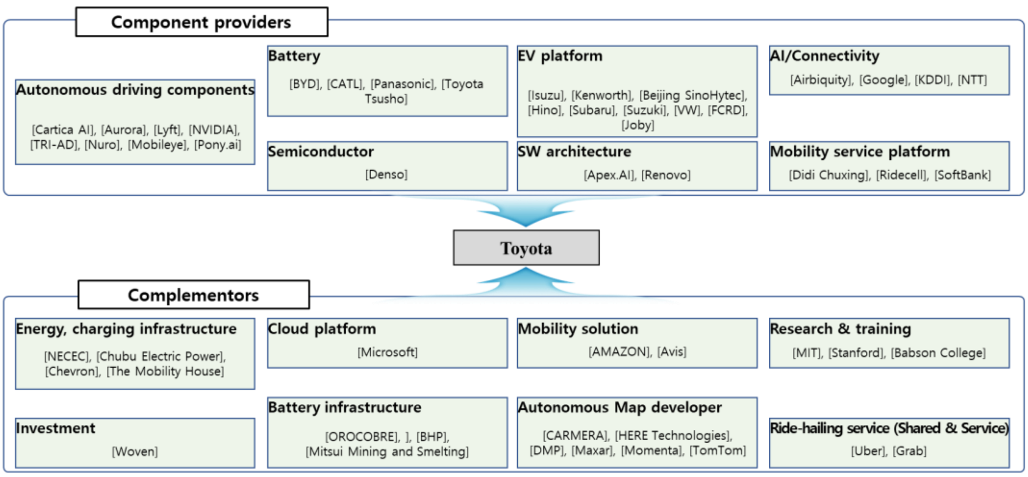
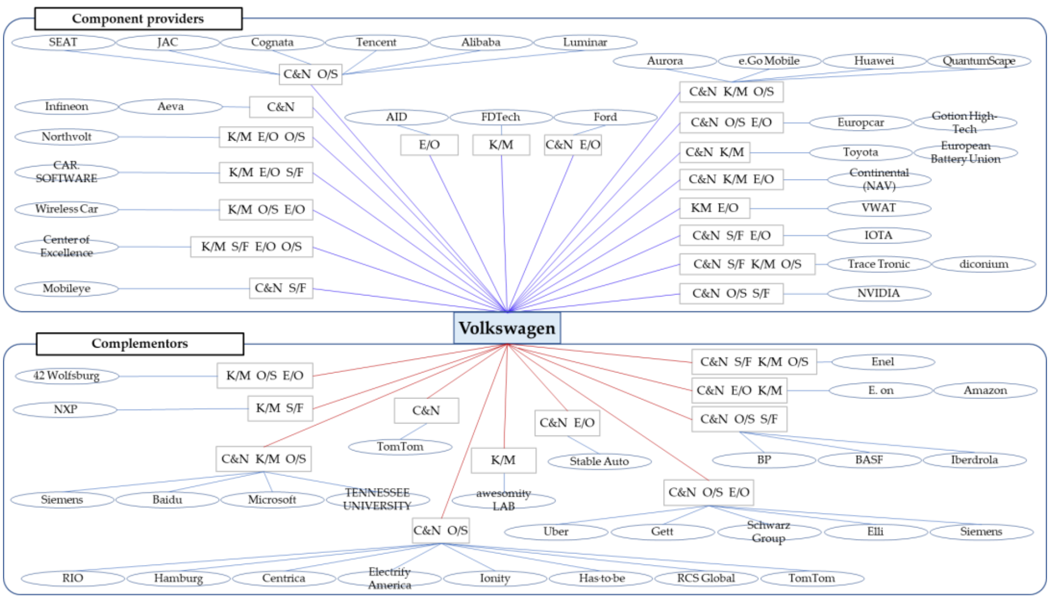


Figure 7. The ecosystem actors in relationships with Toyota.

5.2.2. Evidence from the Case—Activities

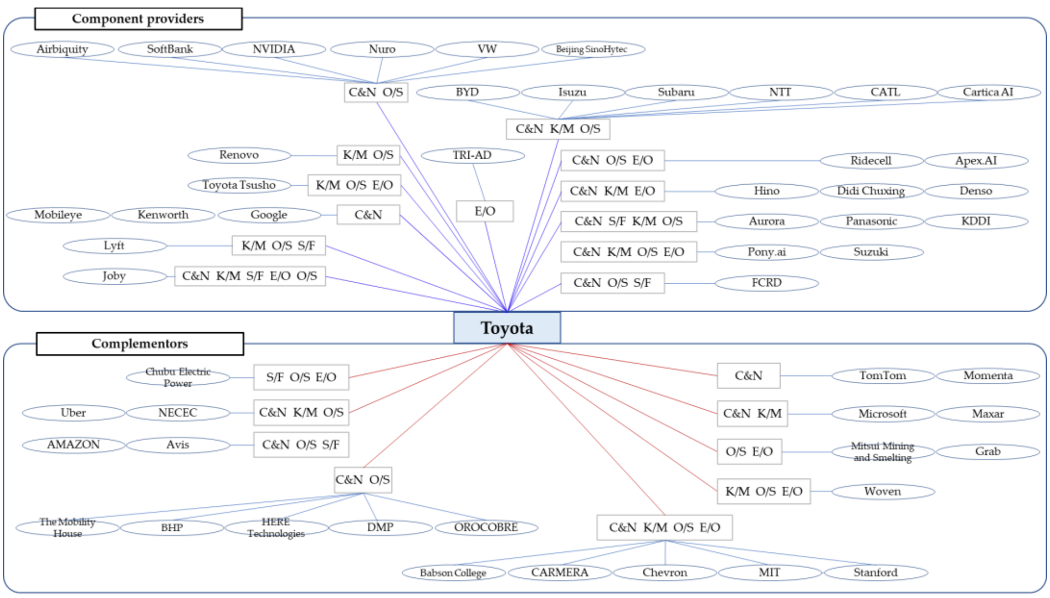
The diverse activities of the focal firms in the innovation ecosystem represent their capabilities and strategies in the phase of the industrial paradigm shift. Relevant events are extracted from the collected articles according to the dynamic capability categories of the research framework proposed in Section 3: collaboration and networking, opportunity sensing, entrepreneurial orientation, knowledge management, and strategic flexibility. We abbreviated the five dynamic competencies as C and N, O/S, E/O, K/M, and S/F.

The activities of the focal firms can be analyzed with corresponding dynamic capability categories in relationships with each ecosystem actor according to the coding process in Figure 4. Figures 8 and 9 summarize relationships with the ecosystem actors (accumulated from 2016 to 2021) and corresponding dynamic capabilities of VW and Toyota, respectively. The activities of VW and Toyota in relation to each ecosystem actor, e.g., component provider or complementor, were analyzed from one dynamic competency to four dynamic competencies and from one dynamic competency to five dynamic competencies.



※ C&N (Collaboration & Networking), O/S (Opportunity Sensing), E/O (Entrepreneurial Orientation), K/M (Knowledge Management), S/F (Strategic Flexibility)

Figure 8. Dynamic capabilities of VW in relationships with the ecosystem actors.



※ C&N (Collaboration & Networking), O/S (Opportunity Sensing), E/O (Entrepreneurial Orientation), K/M (Knowledge Management), S/F (Strategic Flexibility)

Figure 9. Dynamic capabilities of Toyota in relationships with the ecosystem actors.

Case of VW

Collaboration and Networking: Collaboration and networking are the most frequently found ecosystem activity of VW group, one of the world's leading automotive manufacturers, in the face of technological innovation discontinuities. The incumbent firm has joined forces with various component providers and complementors to establish extensive networks in the innovation ecosystem and thereby gain access to the infrastructure of partnering organizations. In 2018, VW announced the formation of the Networking for Autonomous Vehicles (NAV), with Aquantia, Bosch, Continental, and NVIDIA, to drive the ecosystem development required for the next generation Multi-Gig Ethernet networking in vehicles. The firm also planned to join China's Apollo autonomous driving consortium, to develop self-driving cars for the world's largest market. In 2019, VW worked with Microsoft on a cloud-based automated driving platform (ADP) to simplify its development processes, partnered with Alibaba A. I. Labs for Intelligent In-car Experience and signed a joint development agreement with Siemens to provide the charging infrastructure for the electric cars. In 2020, VW agreed to a three-year partnership with Centrica, the UK's biggest energy company, to provide home charging hardware solutions for new EV owners to accelerate EV adoption across the UK. In the same year, the firm collaborated with QuantumScape, a US battery specialist, in a joint venture to enable industrial-level production of solid-state batteries. In 2021, the giant incumbent bet on Europcar's vast international network in more than 140 countries, including a fleet of over 350,000 vehicles, as a way to sell lucrative mobility services. Besides, VW plans to accelerate the decarbonization of the economy and its enormous positive impact on the environment by collaborating with Iberdrola as the official energy partner supplying renewable energy to the electric vehicle chain.

Opportunity sensing: Such extensive collaboration and networking activities are based on timely sensing of upcoming opportunities, the second most frequently found activities of VW. The focal firm has consistently tried to identify critical cooperation partners in consideration of mutual benefits and compatibility of the strategy in the era of environmental change. In 2016, VW chose Tencent, a Chinese internet technology group, as the right partner to expand its product ecosystem for Chinese customers in a way that is tailored to their unique needs. In 2017, the firm expected that partnering with Ionity could satisfy the common goal of providing customers with fast charging and implementing a high-power charging (HPC) network for electric vehicles, significantly reducing charging times compared to existing systems. VW also found an opportunity for electric cars in Rwanda, announcing: "Rwanda has the potential to leapfrog the internal combustion engines into electric cars. Rwanda has a young and progressive population that appreciates individual and modern mobility". In particular, identifying potential bottlenecks and essential resources for a rapid breakthrough of the discontinuous technologies was a vital sensing capability of VW. The incumbent firm's management insisted on a simple and fast charging infrastructure that would be crucial for the efficient breakthrough of e-mobility and, therefore, the main pillar for VW's transformation. Electrify America was selected as an appropriate collaborator because the firm was, by 2020, the only open public charging network to offer chargers with power levels up to 350 kilowatts. Across the country, 96 percent of the population live within 120 miles of an Electrify America charger. "By adding three years of fast charging at no additional cost through Electrify America, we are eliminating all barriers for mainstream compact SUV buyers to go electric," said Scott Keogh, CEO, VW Group of America. In addition, VW forecasted that batteries are key success factors in electric vehicle development. Thus, its plants need to be kept running at full capacity to overcome any potential bottlenecks.

Entrepreneurial orientation: VW Group also shows entrepreneurial orientation in multiple events. The giant incumbent aims to become a world-leading mobility provider by 2025, alongside its pioneering role in the automotive business. At VW Group in 2018, Audi spun off a start-up company called Autonomous Intelligent Driving (AID), working on every aspect of future self-driving technology, including software, hardware, maps, calibration, and more. In 2019, VW strengthened a new software organization, Car.Software that bundles together VW Group's software competencies to create an ideal platform for pioneering software development in the VW Group. In the same year, VW established VW Autonomy (VWAT), in which the focal firm bundles expertise from the automotive and technology industries, combining the agility and creativity of a high-performance culture with process orientation and scalability. In addition, VW plays a pioneering role in Germany and Europe in green battery cells. "With the planned construction of a battery cell factory in Salzgitter, we are making a decisive contribution to establishing the core battery cell technology in Germany as well," said Thomas Schmall, Group Board Member for Technology and CEO of VW Group Components in 2021. Even though transformation to autonomy and electrification has proven to be incredibly expensive and difficult to get right, VW took bold and risky steps and conducted pilot projects to experiment on the uncertainties to innovate and break new ground.

Knowledge management: Another category of knowledge management capabilities centralizes VW's activities in the innovation ecosystem. VW has absorbed advanced external knowledge from diverse sources, integrating it with internal capabilities to create unique value. For example, in 2018, specialists from the VW Group intensively worked with experts from Aurora to integrate Aurora's self-driving system, including sensors, hardware, and software, such as machine learning and AI technology in VW Group's vehicle platforms. Furthermore, in the area of intelligent connected vehicles, Audi China in VW initiated a joint research program with Huawei to strengthen the skills of technology experts in automated driving and the digitalization of services. In 2019, VW could seize the opportunity to accelerate the delivery of safe and comfortable mobility services by combining its comprehensive expertise in developing connected driving solutions with Microsoft's cloud and software engineering know-how. Furthermore, as a member of the Institute for Advanced Composites Manufacturing Innovation in 2020, engineers in VW and researchers in the University of Tennessee created a novel composite liftgate for the VW Atlas, a mid-size crossover SUV model, that reduces weight by 35 percent, as well as reducing investment cost. Recently, VW called solid-state batteries "the end game," as the development of solid-state battery technology was important to enable the firm to hold a strong position in the field of batteries. Therefore, VW combined forces with QuantumScape to secure essential knowledge and gradually build up capacities to enable industrial-level production of solid-state batteries. Regarding this, Dr. Axel Heinrich, Head of VW Group Research, said in 2020, "We want to accelerate the commercialization of QuantumScape's solid-state batteries. Moreover, we combine forces to leverage VW's experience as a production specialist and QuantumScape technology leadership".

Strategic flexibility: We found evidence of strategic flexibility from VW's activities to cope with rapid environmental changes. The focal firm reconfigured the value chain structure to mitigate bottleneck challenges and better coordinate the innovation ecosystem. Thomas Schmall, the chairman of the board of management of VW Group Components, said in 2019: "We already develop and manufacture power electronics, battery systems, electric motors, and charging systems and are building up battery recycling know-how. With the integration of the battery cell business area, VW Group Components is on track to becoming a global leader in producing e-mobility components". In the same year, VW consolidated its development efforts into its subsidiary, Car.Software better coordinates among its brands, where each brand handles its work while collaborating on core functions such as detecting obstacles. In 2021, VW focused on exerting more control over key components in its supply chain, such as semiconductors and lithium. By doing this, it can overcome any potential bottlenecks and keep its plants running at full capacity, saying, "We need to move into vertical integration more strongly, procuring and securing raw materials." According to the situation, VW disintegrates part of its function, e.g., outsourcing self-driving technology development to Mobileye in 2018, to help VW avoid the incredibly expensive R&D costs needed to build self-driving technologies. In addition, the German carmaker expands its core business to offer customers a wide and convenient range of services in and around their vehicles, paving the way for more electric models and infrastructure. It provides the flexibility and scalability needed to meet the diverse needs of modern electromobility customers, whether they seek a compact car, a plug-in hybrid, or a luxury electric vehicle.

Case of Toyoda

Collaboration and Networking: Toyota has also striven to cope with the rapidly shifting environment by establishing extensive collaborative networks, shown in the content analysis result. In 2016, the giant Japanese incumbent entered a new business and capital alliance with KDDI Corporation, which has built relationships with more than 600 telecommunications carriers worldwide, so that they could jointly choose and procure communications networks in each country for next-generation connected cars. Afterward, during 2018–2020, Toyota teamed up with several complementors—CARMERA, TomTom, NTT Data, DMP, Momenta—to develop high-definition maps for automated vehicles, thus increasing the installed customer base. In 2021, to build a large-scale business in a low-carbon area that is complementary to Toyota's offerings, the firm partnered with Chevron to collaborate on a hydrogen-related policy that supports hydrogen infrastructure development. In the same year, Toyota joined NECEC's Strategic Partner Network, a membership network for global corporations focused on building strategic relationships across the Northeast cleantech ecosystem to incubate clean energy solutions for the entire region and affect relevant policy and innovation development. Sometimes, complex networks of the ecosystem actors are inherently coopetitive. For example, in 2019, Toyota and Suzuki worked together on overcoming new challenges surrounding the automobile sector by building and deepening cooperative relationships in new fields while continuing to be competitors. In 2020, Hino Motors, a subsidiary firm of Toyota, collaborated in developing electric trucks with Traton, a subsidiary firm of VW, a competitor of Toyota. Akio Toyoda, a president of Toyota, said in 2021, "It is important we compete and cooperate with rivals in the future."

Opportunity sensing: Toyota has identified that large-scale simulation tools for software validation and testing are critical for developing automated driving systems, and partnering with NVIDIA is important to realize this vision. In 2019, Dr. James Kuffner, CEO of TRI-AD (Toyota Research Institute Advanced Development), said, "Our vision is to enable self-driving vehicles with the ultimate goal of reducing fatalities to zero, enabling smoother transportation, and providing mobility for all." When charging up a partnership with Suzuki for electric cars in 2019, Toyota recognized that cooperation with Suzuki would help Toyota expand its presence in India, the world's fifth-largest passenger car market. It had struggled to grow sales due to lean demand for its lower-cost models. Although it was a far smaller firm, Suzuki was a dominant force in the fast-growing Indian market. After gauging the global EV market through a joint venture with Australian miner Orocobre, Toyota Tsusho, part of the Toyota Group headed by Toyota Motor Corp, planned to expand lithium production to 42,500 tons from 2021′s direction and for promoting their widespread adoption. In 2020, Toyota focused on increasing demand for its products in China, partnering with Chinese firms to develop fuel cell powertrains that meet China's performance and regulatory needs. Shigeki Terashi, operating officer at Toyota, said, "There is no other automobile market with such a sense of speed, and I am extremely confident that we will gain partners we can work with toward the shared target of expanding the use of fuel cell-electric vehicles in China." Besides, Toyota aims to clear emissions regulations and meet customers' demands increasingly aware of global warming. "Meeting the transportation needs of all consumers in the Northeast and providing them with clean transportation choices are important pillars of Toyota's overall strategy for reducing carbon emissions," said Robert Wimmer, director, energy and environmental research, Toyota Motor North America in 2021.

Entrepreneurial orientation: Toyota Group has invested aggressively in the future market to seize opportunities and drive innovation. For example, while traditional automakers are racing to team up with disruptive tech companies, Toyota agreed to buy a $1 billion stake in Southeast Asia's Grab in the biggest investment, into a ride-hailing firm in 2018. Later in 2020, Toyota Green Energy was established with an agreement with Toyota Motor

Corporation, Chubu Electric Power Co., Inc., and Toyota Tsusho Corporation to obtain and manage renewable energy sources in Japan and supply electric power from renewable energy sources to the Toyota Group in the future. In the same year, TRI-AD formed a new holding company called Woven Planet. This $800 million global investment fund supports innovative, growth-stage companies in mobility, automation, artificial intelligence, data and analytics, connectivity, and smart cities. In addition, Toyota has tried to bring the entrepreneurial management expertise of Babson college to develop mobility models to solve real-world problems. The Japanese incumbent also tapped the potential to revolutionize future transportation and life, taking up the challenge of air transportation with Joby, an innovator in the emerging eVTOL space. Recently, Toyota has been trying to secure leadership in the rapidly growing U.S. hydrogen market by fronting the initiative in developing hydrogen-related policies in the U.S. with local energy companies.

Knowledge management: Many events related to Toyota show innovation through knowledge integration of internal and external knowledge. In 2017, Toyota and KDDI jointly conducted R&D focused on telecommunication platforms that enable optimal communications between towns, homes, people, and cars as communication technologies evolve, including 4G, 5G, and 6G. In 2018, Toyota shared technology and expertise with NTT to create big data research projects using vehicle information collected from across Toyota's fleet of connected cars. In 2019, to build a next-generation intelligent transportation framework for sustainable cities, Toyota integrated its leading connected vehicle technology with expertise in AI-based large-scale mobility operations of DiDi. In 2020, Toyota launched a joint venture with BYD to conduct R&D in battery electric vehicles. New chairman Hirohisa Kishi said, "With the engineers from BYD and Toyota working together under the same roof, we aim to develop BEVs that are superior in performance and meet the needs of customers in China by merging the two companies' strengths and also through friendly rivalry." Recently in 2021, Toyota is planning to absorb the advanced technology of Silicon Valley startup Aurora on autonomous driving technology by bringing engineering teams together to develop and test driverless-capable vehicles equipped with Aurora's autonomous driving stack of software and hardware. Furthermore, Toyota could secure large-scale self-driving research personnel at once and utilize accumulated self-driving data by acquiring Lyft Inc's self-driving technology unit in 2021. As a result, its self-driving technologies and mobility business capabilities will be improved within a short period. In addition, Toyota struggled to develop its technology and assisted others in the ecosystem network to achieve common goals such as decarbonization, for instance, by providing a forum for leading companies.

Strategic flexibility: Finally, we found evidence of Toyota's strategic flexibility in several events. Toyota partnered with multiple firms to increase speed and flexibility toward a shared goal, partnering with Japanese energy firms, including Honda and Nissan in 2017, and several Chinese firms, including FCRD in 2020, for hydrogen fuel cell development of the electric platform. In partnering with Panasonic in 2020, Toyota invested in R&D to develop advanced solid-state batteries and planned to supply batteries to partners such as Suzuki and Mazda, securing competitive pricing and steady supply for its future EV models. As the Japanese incumbent develops autonomous vehicles, it opens up further potential for fleet management and air transportation. "We tap the potential to revolutionize future transportation and life," said Akio Toyoda, Toyota Motor Corporation President and CEO. In addition, in 2020, the FCEV (fuel cell electric vehicle) value chain was vertically integrated by establishing a joint venture between Toyota (fuel cell stack manufacturing), Ehwa Tong (FCEV system manufacturing), and Chinese OEM (FCEV vehicle manufacturing). As a result, investment costs were minimized through joint development of forwarding and backward collaborators, and it became easier to achieve economies of scale. Recently, Toyota has focused on developing partial self-driving vehicles capable of driver intervention while cooperating with Aurora for a fully autonomous driving system to ease the burden of expensive technology development and diversify its portfolio.

5.2.3. Discussion

In the previous section, we investigated the innovation ecosystem of the two major automobile firms from the perspective of the ecosystem actors and activities. Leading incumbents in the existing automobile ecosystem, VW and Toyota, are continuously confronted by the discontinuous challenge wave of C.A.S.E. innovation. Instead of fighting against the new wave and struggling to slow down the timing of technology substitution, VW and Toyota chose to ride the wave of innovation, showing dynamic capabilities to orchestrate the innovation ecosystem. Content analysis results of the two incumbents show their capabilities and strategies to transform into leading focal firms in the new ecosystem. We can discuss several research findings based on what we have described so far and Figure 10, which indicates the investigated events' frequency count concerning the component providers and complementors by the five dynamic capability categories.

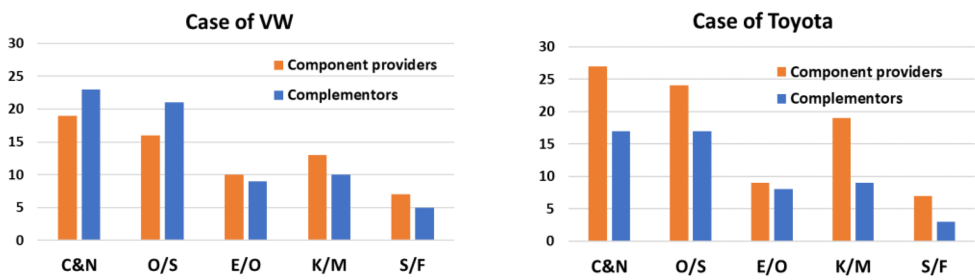


Figure 10. Frequency of events by the dynamic capability categories.

The case study results show that the activities of VW and Toyota have been closely linked with complementors and component providers beyond existing industry boundaries. While the traditional value chain in the industry has been mainly connected to the component providers and mostly led by incumbents, the new innovation ecosystem characterized with C.A.S.E. is open to diverse emerging experts holding key technologies to control the whole ecosystem [49]. As the end user's experience becomes important, the complementors such as local grid companies that provide charging infrastructure are also critical ecosystem actors. However, they do not have direct transactional connections with the automobile supply chain. Specialized complementary assets such as charging infrastructure and battery raw materials are critical and unique. They are not widely available on the open market, thus allowing incumbents to create inimitable value by securing them.

Although both VW and Toyota show preemptive, aggressive movement to take the lead in the era of C.A.S.E. innovation, there is a slight difference between them in the timing of EV market entry. VW entered the EV market earlier than Toyota, and in 2020, was ranked second in annual sales of EVs after Tesla, the EV-only manufacturer. However, Toyota has not launched a full EV model yet, as it has been more focused on the Hybrid EV lineup before. While comparing the content analysis results of the two incumbents indicated in Figure 10, the case of VW shows more complementor-related events than Toyota. VW has collaborated with diverse enabling technology developers to lay the foundation for the C.A.S.E. ecosystem, establishing the infrastructure of EV charging, raw materials of batteries, and mobility services. Toyota has focused more on partnership with component providers to accelerate its development and production of EV products to make up for lagging in EV production and sales.

As shown in Figure 10, the activities of each incumbent firm linked with component providers or complementors demonstrate all five ecosystem-related capability dimensions induced from the stage of conceptual framework building. VW and Toyota have centered their objectives on strong dynamic-capability-driven activities essential amid rapid technological change and serious uncertainties. The ultimate success of those incumbents in the innovation ecosystem experiencing C.A.S.E. innovation depends on how well they establish a sustainable value creation routine due to accumulated capabilities in relationships with diverse ecosystem actors. We argue that the two firms' struggle for sustainable value creation can be largely directed toward the following goals: technology internalization and dominant platform building.

First, VW and Toyota have absorbed core technologies, e.g., battery production and software architecture, necessary for breakthrough innovation from collaboration with diverse experts scattered around the world, or sometimes acquired external business units that possess specific assets. The absorbed knowledge is integrated with the inherent resources of the incumbents and thus internalized deep into the organizations. By internal development of valuable complements or components, the incumbents can reduce potential risks such as supply challenges in critical parts of the value chain and control the ecosystem, from raw materials to products. As previous studies propose, focal firms can improve innovation performance and sustain competitive advantages by internalizing and integrating external sources in the innovation ecosystem [7,32,41].

Second, VW and Toyota have led a consortium joining forces with extensive ecosystem actors to accumulate broader know-how on innovative technology and build standardized technology platforms. As more complementors and users join the technology platform, more actors and users are motivated to adopt the platform and join the innovation ecosystem. Previous studies emphasize that a platform leader has diverse strategic alternatives and thus can influence the overall technology trajectories in the ecosystem [41,63]. Thus, a platform leader of the innovation ecosystem can lead value creation in the innovation ecosystem, setting common goals and orchestrating ecosystem actors and product longevity through progressive continuous improvement.

Based on the arguments described so far, we can apply the innovation ecosystem framework in Figure 4 composed of actors-activities-artifacts to the case of automobile incumbents, as in Figure 11. The traditional dominators in the existing automobile ecosystem collaborate with new ecosystem actors to transform themselves into leaders of a new innovation ecosystem in the face of C.A.S.E. innovation, heading toward sustainable value creation via technology internalization and dominant platform building.

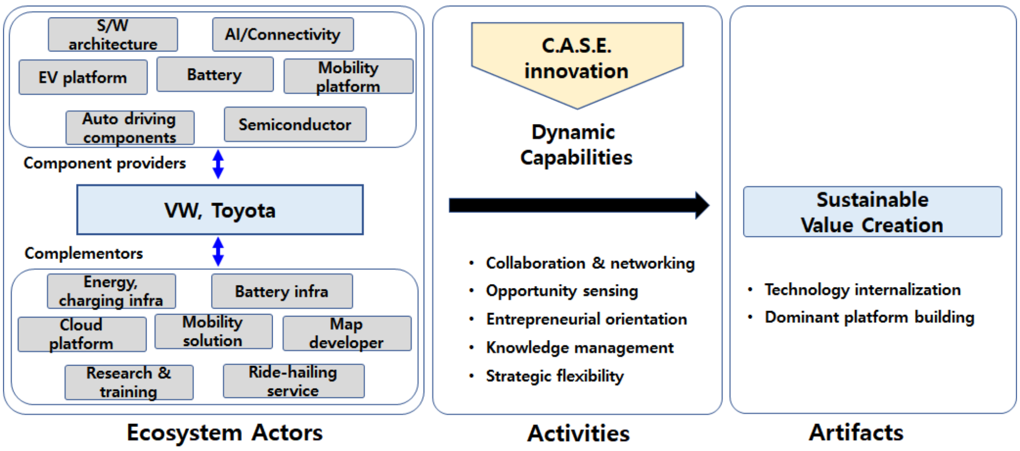


Figure 11. Innovation ecosystem framework of automobile incumbents in the face of technological discontinuities.

6. Conclusions

We have explored the innovation ecosystem construct of incumbent firms in a period of rapid technological change by both conceptual and empirical approaches. Although the innovation ecosystem approach is drawing attention from scholars and business management in the volatile modern environment, it is still at an early research stage and lacks sufficient conceptual and in-depth case studies. This study contributes to existing studies by combining a dynamic capability perspective with the innovation ecosystem approach to clarify key ecosystem-related capabilities essential for incumbents as focal firms to successfully navigate the innovation ecosystem, particularly in the face of technological innovation discontinuities. We established a innovation ecosystem framework that redefines and concretizes the actors-activities-artifacts framework proposed in Grandstrand and Holgersson (2020) through a literature review of dynamic capability and innovation ecosystem research and a case study of the two leading automobile incumbents.

We first conclude that in the era of discontinuous innovation, the ecosystem actors composed of incumbent focal firms, component providers, and complementors are extensively linked beyond existing industry boundaries, as in the case of the automobile innovation ecosystem. The value chain in the industry is not mainly connected to the component providers but open to diverse emerging experts holding key technologies to control the whole ecosystem. Next, by analyzing previous literature and activities of the two automobile giants, we defined five core capabilities of incumbent focal firms essential for their successful navigation in the complex innovation ecosystem—collaboration and networking, opportunity sensing, entrepreneurial orientation, knowledge management, and strategic flexibility. VW and Toyota have shown their strengths in the five elements of dynamic capabilities for transformation into successful focal firms orchestrating the innovation ecosystem. Finally, we highlight the strategy of technology internalization and dominant platform building as key artifacts of innovation activities for sustainable value creation in the innovation ecosystem. VW and Toyota have led consortium joining forces with extensive ecosystem actors for securing technology leadership while minimizing uncertainty in a volatile and fast-changing environment.

This study also provides the following practical implications related to the five suggested components of the incumbents' core capabilities. First, the management of the incumbent firm should build an extensive collaborative network covering component providers, complementors, and, if necessary, competitors. The more coordination there is with the partners with advanced technologies early in the development stage, the more difficult it is for rivals to overcome the established barrier. The focal firm can develop broader innovative solutions, coping with legislation and policy by bringing support from diverse stakeholders. Second, recognizing the right partners with resources and strategic fit is vital managerial capability. Identifying and collaborating with key stakeholders will be critical in resolving bottleneck challenges that constrain overall ecosystem performance. As discontinuous innovation often emerges outside incumbent firms and is led by new entrants, management of the incumbents should pay attention to external opportunities. In particular, by considering the growing importance of corporate social responsibility, e.g., developing eco-friendly technologies for the green economy, the firm can improve its reputation from the customer's point of view and thus increase customer loyalty [112–114]. Third, incumbent firms are vulnerable to rapid or disruptive environmental change because of their organizational inertia and Not Invented Here syndrome, an entrepreneurial culture of openness, experimentation, and risk-taking should be encouraged. By forming a subsidiary, for instance, specializing in developing cutting-edge technology, the incumbent firm can explore new technologies with agility, thereby occupying an advantageous position in building a technology platform in the innovation ecosystem. Fourth, internalization of core knowledge is a critical strategy for the incumbent to increase bargaining power and construct a routine of sustainable value creation. Acquiring external experts or business units with core knowledge can be a fast way to internalize the required technology. A knowledge management routine of absorbing external technologies through organizational learning, integrating them with internal resources to develop new knowledge, and sharing developed knowledge with other ecosystem actors to resolve the bottleneck challenges in the ecosystem should be organized. A solid knowledge management structure, starting with a creative idea and eventually yielding innovative products, is an important lever of firm profitability and sustainability [115,116]. Finally, as a discontinuous technology trajectory frequently destroys the existing competence of the incumbent, the overall strategy should be flexible and periodically reevaluated. According to the situation, today's best resources or strategies can be obsolete in a few years. Therefore, the overall value chain and allocated resources need to be reconfigured by judging which components to handle internally and which are better developed with external forces.

We will now consider some limitations of this study and suggest future research directions. First, as this study illustrates the ecosystem dynamics from specific incumbent firms' perspectives, the research outcome lacks activities or strategies of new entrants and other stakeholders. Future studies on the innovation ecosystem from the perspective of new entrants that challenge an incumbent ecosystem and coopetition among incumbents, new entrants, and complementors are expected to enrich future research. Differences of strategies and capabilities depending on the role within the innovation ecosystem, e.g., focal firm vs. participants, can be focused on. Second, as this study primarily investigates events of the past six years of technological transition, which is still in progress in the automobile industry, we still need to observe which firm will reap the most benefits, successfully sustaining the competitive position in the era of paradigm shift. Further studies are expected to analyze upcoming events within the dynamic ecosystem, linking capability elements to successful artifacts such as internalization of core competence or new platform building. We expect that this study's research framework, when supplemented by the suggested future research topics with the empirical evidence in the automobile firms, will be helpful to clarify complex ecosystem-level phenomena and systematically explore sources of modern firms' long-term survival in the face of technological discontinuities.

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Conflicts of Interest: The authors declare no conflict of interest.

Appendix A

Date	Actors	Title of Articles	Source
160524	VW, Gett	Volkswagen Group announces a strategic partnership with on-demand mobility provider Gett	Volkswagen (2016)
160911	VW, Tencent	VW's Audi steps up collaboration with Chinese tech groups	Reuters (2016)
171103	VW, Ionity	Launch of Pan-European High-Power Charging Network IONITY	Porsche (2017)
180104	VW, Aurora	Volkswagen Group and leading self-driving technology company, Aurora Innovation, announce strategic partnership	Volkswagen (2018)
180107	VW, NVIDIA	Volkswagen and NVIDIA to Infuse AI into Future Vehicle Lineup	Nvidia (2018)
180626	VW, Cognata	Audi partners with Israel's autonomous vehicle simulation startup Cognata	Reuters (2018)
180627	VW, awesomity LAB	Milestone in Africa: Volkswagen launches local assembly and Car sharing in Rwanda	Volkswagen (2018)
180702	VW, Continental (NAV)	Continental, NVIDIA, Volkswagen Join Hands, Forms Networking for Autonomous Vehicles (NAV) Alliance	News18 (2018)

Date	Actors	Title of Articles	Source
180710	VW, Huawei	Audi and Huawei sign memorandum of understanding for strategic cooperation	Finchannel (2018)
180904	VW, FDTech	VW Acquires Stake in Autonomous Driving Specialist FDTech	Tu-auto (2018)
181101	VW, Mobileye	VW and Mobileye are partnering on autonomous taxis	Businessinsider (2018)
181102	VW, Baidu	VW taps Baidu's Apollo platform to develop self-driving cars in China	Reuters (2018)
181123	VW, diconium	Volkswagen invests in digital specialist diconium	Volkswagen (2018)
181218	VW, Luminar	VW's Robo-Cars Get a Boost from Luminar's Lidar	Wired (2018)
181219	VW, Wireless Car	Volkswagen to take over telematics specialist WirelessCar from Volvo	Volkswagen (2018)
181227	VW, AID	Audi's AID subsidiary leads self-driving car development at	Motorauthority (2018)
190227	VW, Microsoft	Volkswagen to work with Microsoft on cloud-based Automated Driving Platform	Europe. autonews (2019)
190305	VW, e.Go Mobile	VW signs EV startup as the first partner for MEB electric platform	Autonews (2019)
190312	VW, TomTom	TomTom expands HD Map portfolio and completes deals with VW and FCA	Traffictechnologytoday (2019)
190321	VW, European Battery Union	Volkswagen forms European Battery Union with Northvolt	Volkswagen (2019)
190327	VW, Amazon	Volkswagen and Amazon Web Services to develop Industrial Cloud	Volkswagen (2019)
190514	VW, Infineon	Volkswagen partners with Infineon for electric vehicle	Roboticsandautomationnews (2019)
190527	VW, SEAT	Volkswagen strengthens activities in China with the market entry of SEAT and Smart City Project	Volkswagen (2019)
190606	VW, Elli	Volkswagen plans 36,000 charging points for electric cars throughout Europe	Volkswagen (2019)
190611	VW, Alibaba	Alibaba A. I. Labs Partners with Audi, Renault and Honda for Intelligent In-car Experience	Businesswire (2019)
190619	VW, Schwarz Group	Volkswagen and Schwarz Group to be strategic e-partners	Volkswagen (2019)
190712	VW, Ford	Ford-VW alliance expands to include autonomous and electric vehicles	Theverge (2019)
190731	VW, has·to·be cooperate	Volkswagen and software expert has·to·be cooperate for expansion of charging infrastructure	Volkswagen (2019)
190801	VW, Stable Auto	VW wants to test robotic EV chargers for self-driving cars	Theverge (2019)
190923	VW, CoE	Volkswagen Group starts battery cell development and production in Salzgitter	Volkswagen (2019)
191002	VW, RIO	RIO digitizes Volkswagen Group Logistics	Volkswagen (2019)

Date	Actors	Title of Articles	Source
191028	VWAT	Volkswagen plans to make autonomous driving market-ready	Volkswagen (2019)
191029	VW, Siemens	First for Africa: Volkswagen and Siemens launch joint electric mobility pilot project in Rwanda	Volkswagen (2019)
191121	VW, Car.Software	Volkswagen strengthens new software organization	Volkswagen (2019)
191207	VW, IOTA	IOTA and VW to Build Autonomous System Cars	Medium (2019)
191212	VW, Aeva	Aeva snags VW investment with smaller, longer-range lidar	Techcrunch (2019)
191216	VW, Hamburg	Volkswagen's Weshare launches new e-car sharing service in Hamburg	Erticonetwork (2019)
200117	VW, Tennessee Univ.	Volkswagen and University of Tennessee announce innovation hub collaboration	Volkswagen (2020)
200304	VW, Centrica	Centrica and Volkswagen announce EV enablement partnership	Centrica (2020)
200403	VW, E. on	E.ON and Volkswagen to make fast charging possible	Eon (2020)
200528	VW, Jianghuai	VW in final talks to seal big EV deals in China, report says	Europe. autonews (2020)
200529	VW, JAC	VW to take over the majority stake in JAC joint venture	Electrive (2020)
200529	VW, Guoxuan	Volkswagen intensifies e-mobility activities in China	Volkswagen (2020)
200610	VW, FORD	Ford and Volkswagen sign agreements for joint projects on commercial veheicle, EVs, autonomous driving	Ford (2020)
200616	VW, QuantumScape	Volkswagen increases stake in QuantumScape	Volkswagen (2020)
200625	VW, Siemens	Siemens provides its expertise to Volkswagen to develop digitized electric car production	Roboticsandautomationnews (2020)
200910	VW, RCS Global	VW partners with RCS on battery supply	Miningmagazine (2020)
200921	VW, Electrify America	Electrify America and Volkswagen of America Announce Agreement Providing Unlimited Charging Plan for Owners of the All-New 2021 VW ID.4 Electric SUV	Automotiveworld (2020)
201002	VW, Uber	Volkswagen partners with Uber to provide sustainable public transportation	Yahoo (2020)
201020	VW, NXP	Volkswagen Adopts NXP Battery Management Solutions for its MEB Electrical Vehicle Platform	Nxp (2020)
201028	VW, Toyota	VW's Traton, Toyota's Hino Agree Electric Truck Venture	Barrons (2020)
210315	VW, BP	Volkswagen Group and bp to join forces to expand ultra-fast electric vehicle charging across Europe	Bp (2021)
210316	VW, Northvolt	VW strengthens ties with Northvolt to expand battery capacity in Europe	Automotivelogistics (2021)
210316	VW, Enel	Iberdrola, Enel and bp form E-mobility power alliance with Volkswagen	Smart-energy (2021)

Date	Actors	Title of Articles	Source
210317	VW, Iberdrola	Volkswagen, Iberdrola, Enel, BP to install EV recharging stations and battery plants in Europe	Pv-magazine (2021)
210510	VW, 42 Wolfsburg	Volkswagen: A boost for the digital age—Programming school "42 Wolfsburg" starts operations	Volkswagen (2021)
210608	VW, BASF	Volkswagen Group, BASF, Daimler AG and Fairphone start a partnership for sustainable Lithium mining in Chile	Volkswagen (2021)
210729	VW, Europcar	Volkswagen makes $3.4 billion Europcar bet on mobility services	Reuters (2021)
210730	VW, Trace Tronic	Volkswagen and TraceTronic establish neocx—a joint venture for automated software integration	Volkswagen (2021)
160406	Toyota, Microsoft	Toyota expands Microsoft partnership in connected vehicle services	Reuters (2016)
160602	Toyota, KDDI	Agreement on New Business and Capital Alliance between Toyota Motor Corporation and KDDI Corporation	Toyota (2016)
170328	Toyota, NTT	Toyota and NTT to collaborate on connected car tech, including AI	Techcrunch (2017)
180313	Toyota, Avis	Toyota Connected North America Partners with Avis Budget Group to Enhance Customer Rental Experience	Toyota (2018)
180828	Toyota, Uber	Toyota and Uber Extend Collaboration to Automated Vehicle Technologies	Toyota (2018)
181004	Toyota, SoftBank	Toyota and SoftBank partner to develop self-driving car services	Venturebeat (2018)
181218	Toyota, Grab	Toyota develops "Total-care Service" Designed for Ride-hailing Companies	Toyota (2018)
190228	Toyota, CARMERA	TRI-AD and CARMERA team up to build high definition maps for automated vehicles using camera data	Toyota (2019)
190311	Toyota, Airbiquity	Toyota invests in $15M round for Airbiquity, a 22-year-old connected car startup in Seattle	Qeekwire (2019)
190318	Toyota, NVIDIA	NVIDIA and Toyota Research Institute-Advanced Development Partner to Create Safer Autonomous Transportation	Nvidianews (2019)
190320	Toyota, Suzuki	Toyota and Suzuki charge up a partnership for electric cars	Reuters (2019)
190423	Toyota, Kenworth	The Kenworth T680 with Integrated Toyota Hydrogen Fuel Cell Technology Starts at Port of Los Angeles	Bulktransporter (2019)
190510	Toyota, Babson College	Babson College and the Toyota Mobility Foundation Team Up to Accelerate the Future of Mobility-Partnership will leverage Toyota Mobility Foundation's know-how and Babson's entrepreneurial management expertise to develop mobility models aimed at solving real-world problems	Toyota (2019)
190624	Toyota, OROCOBRE	Toyota Tsusho to wait on EV market before Upping Lithium investment	Reuters (2019)
190710	Toyota, Denso	Toyota, Denso Form Venture To Create Advanced Chips For Self-Driving And Connected Cars	Forbes (2019)
190717	Toyota, CATL	CATL and Toyota Form Comprehensive Partnership for New Energy Vehicle Batteries	Toyota (2019)
190725	Toyota, Didi Chuxing	Toyota Expands Collaboration in Mobility as a Service (MaaS) with Didi Chuxing, a Leading Ride-hailing Platform	Toyota (2019)

Date	Actors	Title of Articles	Source
190903	Toyota, Cartica AI	Israel's Cortica teams with Toyota, BMW in autonomous AI car tech.	Reuters (2019)
190927	Toyota, Subaru	Toyota and Subaru Agree on New Business and Capital Alliance	Toyota (2020)
200115	Toyota, Joby	Toyota and Joby Aviation are Flying to New Heights Together	Toyota (2020)
200204	Toyota, PANASONIC	Toyota and Panasonic decide to establish a joint venture specialising in automotive prismatic batteries	Counterpointresearch (2020)
200226	Toyota, Pony.ai	Toyota leads fundraising for Chinese self-driving startup Pony.ai	Asia.nikkei (2020)
200310	TRI-AD	TRI-AD enables the successful creation of HD maps for automated driving on surface roads	Toyota (2020)
200310	Toyota, HERE Technologies	TRI-AD Enables Successful Creation of HD Maps for Automated	Toyota (2020)
200310	Toyota, TomTom	TomTom Partners with Toyota Research And DENSO to Demonstrate High-Speed HD Map-Building	Autofutures.tv (2021)
200312	Toyota, Maxar	Toyota hones in on maps for AVs	Autonews (2020)
200317	Toyota, DMP	TRI-AD and DMP kick off HD Map update PoC from April 2020	Toyota (2020)
200318	Toyota, Momenta	Toyota partners with China's Momenta on high definition maps for autonomous cars	Reuters (2020)
200402	Toyota, BYD	BYD, Toyota Launch BYD Toyota EV technology Joint Venture to Conduct Battery Electric Vehicle R&D	Toyota (2020)
200403	Toyota, Chubu Electric Power	Toyota Green Energy Established to Conduct Renewable Energy Power Generation Business	Toyota (2020)
200605	Toyota, Beijing SinoHytec	Six Companies Establish R&D Joint Venture for Commercial Vehicle Fuel Cell Systems for the Creation of a Hydrogen-based Society in China	Toyota (2020)
200609	Toyota, FCRD	Toyota partners with 5 Chinese firms on fuel cells	Motorauthority (2020)
200619	Toyota, MIT, Stanford	MIT and Toyota partner to advance autonomous driving research	Toyota (2020)
200817	Toyota, AMAZON	Toyota and Amazon Web Services Collaborate on Toyota's Mobility Services Platform	Toyota (2020)
200910	Toyota, Woven Capital	Toyota Research Institute—Advanced Development to Form Woven Capital, an $800 Million Global Investment Fund	Toyota (2020)
201006	Toyota, Hino	Toyota and Hino to Jointly Develop Class 8 Fuel Cell Electric Truck for North America	Toyota (2020)
201028	Toyota, VW	VW's Traton and Toyota's Hino to develop electric trucks together	Autonews (2020)
201210	Toyota, Mitsui Mining and Smelting	Toyota's game-changing solid-state battery en route for 2021 debut	Asia.nikkei (2020)
210210	Toyota, Aurora	Toyota Enters into a Strategic Partnership with Silicon Valley Startup Aurora on Autonomous Driving Technology	Futurecar (2020)

Date	Actors	Title of Articles	Source
210324	Toyota, Isuzu	Toyota and Isuzu to take a stake in each other to co-develop new vehicles	Toyota (2021)
210414	Toyota, Apex.AI	Toyota partners with Apex.AI to develop an autonomous platform	Electrek (2021)
210421	Toyota, Chevron	Chevron, Toyota Pursue Strategic Alliance on Hydrogen	Chevron (2021)
210427	Toyota, LyfT	Lyft sells autonomous car division to Toyota subsidiary Woven Planet in $550 m deal	Zdnet (2021)
210518	Toyota, Mobileye	ZF and Mobileye Safety Technology Chosen by Toyota	Autofutures.tv (2021)
210518	Toyota, The Mobility House	Toyota and The Mobility House extend long-standing partnership	Mobilityhouse (2021)
210525	Toyota, Nuro	Woven Capital Makes Its First Investment, Backing Nuro	Toyota (2021)
210527	Toyota, NECEC	Toyota Joins NECEC's Strategic Partner Network	Necec (2021)
210617	Toyota, Ridecell	Woven Capital Invests in Ridecell to Accelerate Global Growth in IoT-driven Automation for Mobility and Fleet Businesses	Toyota (2021)
210722	Toyota, Google	Toyota launches Google-powered voice assistant and interactive car manual named Joya	Voicebot.ai (2021)
210928	Toyota, Renovo	Toyota buys software firm Renovo to accelerate self-driving tech development	Reuters (2021)
211004	Toyota, BHP	BHP to supply nickel to Toyota-Panasonic battery venture	Reuters (2021)
211018	Toyota Tsusho	Toyota Charges into Electrified Future in the U.S. with 10-year, $3.4 billion Investment	Toyota (2021)

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