Industrial and Corporate Change, 2015, Vol. 24, No. 3, 603–611
doi: 10.1093/icc/dtv015
Advance Access Publication Date: 24 April 2015
Original Article

OXFORD

Introduction: knowledge generation and innovation diffusion in the global automotive industry—change and stability during turbulent times

Anja Schulze[1]*, John Paul MacDuffie[2] and Florian A. Täube[3]

[1]University of Zurich, Department of Business Administration, Swiss Center for Automotive Research (swiss CAR), Plattenstrasse 14, CH - 8032 Zürich, Switzerland. e-mail: anja.schulze@uzh.ch, [2]Management Department Wharton School, University of Pennsylvania, 3105 SH-DH, 3620 Locust Walk, Philadelphia, PA 19104, USA. e-mail: macduffie@wharton.upenn.edu and [3]Solvay Brussels School of Economics and Management, Emile Bernheim Chair of Entrepreneurship in a Global Context, Université libre de Bruxelles, Avenue F.D. Roosevelt 42, B-1050 Brussels, Belgium. e-mail: ftaube@ulb.ac.be

*Main author for correspondence.

Abstract

This introduction to this special section establishes the context within which automotive firms cope with turbulence caused by globalization, new governmental regulations, and advances in electronics, communication, and drive train technologies. While exploring change, the papers in the special section also report on stability, e.g. in the central role of Original Equipment Manufacturers in system integration and their resulting dominance over product architecture and supply chain dynamics. We apply the lens of change and stability to two stages of the innovation lifecycle: (i) knowledge generation; and (ii) the diffusion of innovations. The papers, organized along these dimensions, help us understand how and why automotive firms are changing their ways of innovating, but also why past patterns of innovative behavior persist. We close with an outlook on future research topics to complement this special section.

JEL classification: O33, O31, L62, O32, F23, L22, M13, L62, D43, L16

At the time of writing this introduction, there are rumors that Apple might be building an electric car by the year 2020. The rumors are not confirmed, but hires of engineering talent away from electric vehicle-maker Tesla and battery-maker A123 are. It is also a fact that Google has developed an autonomously driving electric car, building on its expertise in maps and navigation and utilizing widely-available sensor and communications technologies. While the emergence of the electric vehicle (EV) is a technological discontinuity that creates opportunities for new firms to enter a highly consolidated mature industry, entries by firms such as Google or Apple are quite unusual. Typically, new entrants to a mature industry are small firms building on a new technology that provides different functionality from incumbent products; Tesla fits this mold. Not only are both Google and Apple established giants. They also build on competencies that are part of an ongoing technology convergence between consumer electronics and mobility.

What does this mean for the global automotive industry? Are we on the verge of dramatic change in what has long been the very definition of a mature, traditional industry? Will we see a tipping point as an industry characterized by mechanical engineering since its inception over a century ago shifts its ecosystem from a physical one to a digital one, similar to many other disrupted industries? Or is this an evolutionary development reflecting the ever-increasing share of electronics inside the car and the entry of new suppliers who will come under the sway of the dominant automakers?

To begin addressing the future evolution of this industry, it will be helpful to take a step back in time before addressing current phenomena and theoretical discussions. We begin with a short historical background of the industry as an ecosystem characterized by dominant automakers (also known as Original Equipment Manufacturers, hereafter OEMs) acting as system integrators not only assembling the physical vehicle but also dealing with a wide range of stakeholder interests, from suppliers and distributors and individual vehicle owners to regulators, governments, and local communities. We will then turn to current drivers of the global, regulatory, and technical changes that the industry is experiencing and how it is responding to this environment via both novel and extant ways of innovating. This will establish the context for this special section and provide a framework for situating each of the six papers. Finally, we lay out possibilities for future research, based on what theories are either confirmed or challenged by the findings that follow.

1. The past—roots of the automotive industry's structure and innovation capacity

The auto industry has long been characterized as a capital-intensive industry with vertical integration and economies of scale. However, before mass production got its start, the early years saw many firms—peaking at 300 in 1910 (Rao 2009)—and product concepts competing for the dominant design. Once this was reached in the late 1920s, massive consolidation left only a few OEMs that succeeded in building crucial system-integration capabilities and scale, creating barriers of entry. This made evolution and stability rather than revolution and change a closer reflection of the industry's structure, products, and innovation processes until the turn of the century. While there has been almost continuous innovation at the component level, the dominant design has been quite stable at the architectural level, roughly up to the turn of the century. In other words, cars have an enclosed metal body, an internal combustion engine, a chassis providing both suspension and transmission, steering plus braking for vehicle control, etc. Once vertical integration began to taper off in the 1950s, suppliers obtained larger roles in the value chain, initially only in manufacturing but increasingly in design, with the largest suppliers also being innovative in their own R&D.

However, global OEMs are consistently at the top of the list on R&D expenditures, even for technologies that are largely designed and manufactured by suppliers; maintaining overarching technical knowledge for system integration and control remains an important goal and prerogative for OEMs (Brusoni, Prencipe and Pavitt, 2001). OEMs have the lead role in developing product architecture, designing platforms (all) and specific models (most), and setting primarily proprietary component specifications, thus facilitating their hierarchical control of suppliers.

The Japanese model of low vertical integration at OEMs coupled with close collaboration with *keiretsu* (business group) suppliers became increasingly influential from the 1980s on and by the late 1990s GM and Ford (still the most vertically integrated OEMs) did major spinoffs of component divisions, into Delphi and Visteon respectively. Meanwhile consolidation among first tier suppliers generated new "mega-suppliers" (also called Tier 0.5) who sought a larger system integration role (and more value-added to generate higher margins) for themselves vis-à-vis OEMs. On the one hand, this has meant more design responsibility for mega-suppliers and sourcing of innovative knowledge from their R&D efforts. On the other hand, OEMs still maintain tight control, resisting a move to industry-wide standard components in order to retain brand distinctiveness and to achieve better design integration—and arguably not taking full advantage of suppliers' innovation potential.

Final assembly remains fully under OEM control, given that automotive production requires both strong system-integration capabilities as well as scale economies. Unlike electronics and IT, contract manufacturing has never taken hold in the auto industry except on a very limited basis. This keeps OEMs in control of process innovations too, although extensive outsourcing of some activities, such as running assembly plant paint shops, can be observed at some firms. In this industry, product segment innovation typically comes from established OEMs who compete fiercely for advantage when launching new products.

Automobiles are large, heavy, fast-moving machines operating in public space (MacDuffie and Fujimoto, 2010). As a result, they are routinely regulated, in both developed and developing countries, around a consistent set of public policy issues: safety, fuel efficiency, emissions, etc. OEMs often view regulatory requirements as constraints that impede their ability to respond to consumer preferences, but in many instances, particularly for safety and fuel efficiency features, technology-forcing regulations have spurred high rates of innovation at OEMs and suppliers alike. Overall, OEMs seeking to export their products globally must be able to match the quality standards of developed country markets. This requires that all global OEMs achieve a similarly high level of system-integration capability and innovation capacity.

2. The present—faster-paced industry evolution in turbulent times

At the start of the 21st century, the automotive industry certainly looked like a mature industry displaying a highly stable structure and being quite predictable by extant theories: evolutionary innovation, consolidation, driven by the large incumbents, etc. But for over a decade now, the industry has been experiencing significant turbulence due primarily to changes in markets, regulatory requirements, and technologies.

- *Globalization* is ever more far-reaching, evolving over different phases developed country OEMs manufacturing in developing countries, followed by the reverse flow of foreign direct investment from developing to developed countries; the opening of Eastern Europe, Russia, and China's markets in the aftermath of a falling iron curtain as well as increased motorization levels and hence sales growth in emerging markets such as China, India, and Brazil; and now the increased prominence of Indian and Chinese new entrant OEMs, following in the historical footsteps of Japan and Korea. Yet capability shortfalls have often slowed, below expectations, the export growth of new entrant OEMs in countries with low factor costs, e.g. China and India, given the high bar of meeting both developed country regulations and consumer demands for vehicle performance.
- *Governmental regulations* on energy consumption, emissions, and safety place increasing demands on all OEMs. These requirements are driven by a complex socio-political agenda that combines an increasing desire for less oil dependency with concern about climate change, air pollution, and other negative externalities of the auto industry such as congestion.
- *Technological advances* in the area of electronics, communication, and internet technology are steadily infiltrating vehicle design, while a parallel set of both evolutionary and radical technology shifts are on the horizon in drive trains, from EVs to fuel cells to biofuels. As a result, new automakers (Tesla) but also suppliers from once-unrelated sectors such as chemistry and electricity generation enter the stage, e.g. Evonik (Germany) and LG Chem (Korea). These technologies are facilitating not only new product features but also new business models, e.g. as deployed by Lyft, car2go, and Uber, as consumer preferences move toward mobility as a service rather than vehicles as products.

Due to—but also in spite of—these forces for turbulence, we see a scale and scope of innovations that the automotive industry has rarely seen since the settling of the dominant design. We might therefore anticipate that the way innovation is generated and diffused would change too. Will such changes be transformative, making this industry unrecognizable within a decade or two? While we do anticipate important change in both the "who" and the "how" of innovation in the auto industry, we also believe there is good reason to be skeptical of pundits who predict fundamental and incumbent-displacing disruption like that affecting other sectors. This is due to the central role of automakers as system integrators, high OEM investment in R&D for all new technologies, and the continued relevance of accumulated capabilities in design, manufacturing, supply chain management, and distribution.

Against this backdrop of past and present developments, we have organized this special section to take stock of the state of innovation in the global automotive industry—including both the drivers of change and sources of stability. We recognize that stability can be further broken down into *persistence* (sticking with and improving legacy capabilities, business models, products, technologies) and *resistance* (avoiding or ignoring new sources of knowledge, not promoting diffusion of innovation, fighting against pressures for change from customers, suppliers, or regulators). Thus while the papers in this special section certainly pay attention to signs of change, they also seek to understand the sources and consequences of stability.

We seek to shed light on these questions:

- How do OEMs, suppliers, and other parties from inside and outside the industry interact to generate and diffuse automotive innovations in these turbulent times?
- Do their ways of innovating change, and if so—how?

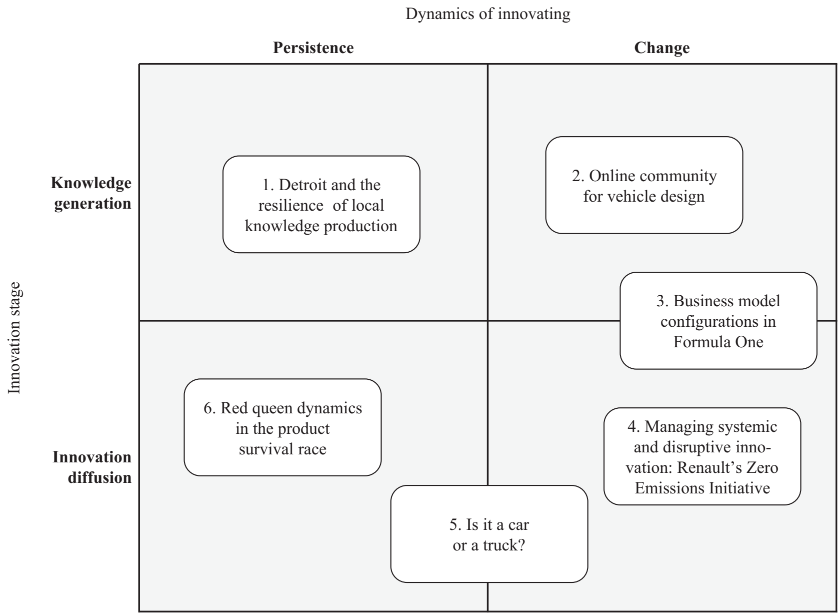

Figure 1. Overview of papers in this special section.

- Where innovation processes and outcomes remain stable in the auto industry, what factors underlie that stability? Does stability indicate persistence, resistance, or both?

Moreover, we apply the lens of change and stability to two major stages of the innovation lifecycle: (i) the sourcing and creation of knowledge needed to innovate; and (ii) the diffusion of innovations. Interacting two stages of the innovation cycle (knowledge generation and diffusion) with the innovation dynamics (change vs. stability) yields the following 2 × 2 table (Figure 1). Below we use this framework to categorize the papers in this special section.

2.1 Change and stability in knowledge generation and the diffusion of innovations

The papers in this special section illustrate, in various ways, the auto industry's particular mixture of change and stability for both knowledge generation and the diffusion of innovation. Given the environmental forces highlighted above (globalization, new regulations, technological advances), we anticipated considerable change in the "who" and the "how" of innovation and indeed we see such change—but we also see considerable persistence.

Geographic clusters are spatially concentrated ecosystems in which firms cooperate and compete at the same time. Knowledge flows have been found to be a driver of cluster competitiveness, both at regional or national levels (Maskell, 2011; Delgado *et al.*, 2014). However, there is a long and unresolved debate in economic geography whether specialization or diversity are more conducive to cluster performance. More recently, scholars have started to study *local* clusters and *global* value chains in combination and investigate whether local or non-local networks are more relevant for knowledge creation (Karna *et al.*, 2013).

In the first paper, Thomas Hannigan, Marcelo Cano-Kollmann, and Ram Mudambi provide evidence for the persistence of knowledge generation through an analysis of innovation activities in light of geographically shifting manufacturing activities. Their paper "Thriving innovation amidst manufacturing decline: The Detroit auto cluster and the resilience of local knowledge production" builds on the analysis of patent data from 1975 to 2009. The headline for this paper might well be "the fall and rise of Detroit" and as such, it would appear to be a story of change, given the frequency of accounts of the decline of Detroit as the indisputable hub of the US auto industry.

But a careful reading of the paper and its longitudinal tracking of patent data linked to the Detroit area shows, as the title states, a story of resilience instead. Even as Detroit was the manufacturing center of the US industry, it was also the R&D and product development center, going back to the industry's origin. And Detroit's role in this regard has, surprisingly, not changed but rather persisted. The Big Three (GM, Ford, and Chrysler) kept their primary R&D and product development activities in the Detroit area; foreign automakers (Japanese, German, Korean) put their primary US R&D facilities nearby in the corridor between Detroit and Ann Arbor; US suppliers expanded R&D activities in this cluster as their design role increased; and foreign suppliers followed the same locational logic as foreign OEMs in choosing the Detroit area for access to skilled labor and proximity to customers.

The flow of automotive innovations across national boundaries is also part of the industry's history; however, as this paper shows, the intensity and productivity of such interaction has increased based on the patent data trends. A final observation is that while the patents related to electronics linked to the Detroit cluster have increased over the period of the study, the increase was only from 14% to 18%, a level that appears disproportionately lower than the increase in electronics in the modern vehicle. Thus even as Detroit continues to be strong as a cluster around mechanical innovations, the jury is out on whether it is keeping up with trends in technologies that are far from its historic areas of strength—and, if it is falling behind, how it might catch up.

On the other hand, the second paper by Victor Seidel and Benedikt Langner undeniably covers a new phenomenon vis-à-vis knowledge generation for automotive innovations. It is entitled "Using an online community for vehicle design: project variety and motivations to participate" and gives clues about how automotive design knowledge is created by a global community of individuals, beyond incumbent firms' boundaries, using novel ways of organizing knowledge generation. A new entrant, Local Motors, hosts this community, builds on the community knowledge, and manufactures vehicles on a small scale. However, incumbents partnering with the firm, such as BMW or Peterbilt, source this community's knowledge, too.

Chesbrough (2003) prompted increased attention to how companies can open their innovation processes to crowd-sourced ideas, especially at the idea-generating front-end of product development (Schulze *et al*., 2014). However, this has not been a major concern for automotive firms which up to now have preferred the existing ecosystem, combining internal knowledge development at focal OEMs with increased (but not new) outreach to suppliers for innovative product and process proposals (e.g. Helper *et al*., 2000; Sako, 2004). Could this be changing?

Given that recent research has found open innovation models have made relatively few inroads into the automotive industry's product development process, this case study is instructive about how the crowd-sourcing of vehicle design might generate valuable knowledge in the future. What is novel here is the emergence of a design community, outside the automotive incumbents, that works for the advancement of the community's hobbyist interests but also provides knowledge for incumbents' innovation. At the same time, it shows that incumbents, who have been rather encapsulated when it comes to innovation processes, are being more receptive to an open innovation approach by sourcing knowledge not only beyond their own boundaries but even beyond their own supply chain. Finally, rather than competing for knowledge sources, this case shows how newcomers and incumbents can both benefit from collaboration when generating that knowledge through crowd-sourcing.

Historically, incumbents or new firms with inside-industry expertise have outperformed new entrants from outside the automotive industry (Klepper, 2002); this suggests that it might be challenging for firms like Tesla to succeed on a long-term basis. But the paper by Seidel & Langner could give us some answers to how activities such as product design might change due to the arrival of industry outsiders deploying methods well-established in digital industries. In a related development, Tesla opened up its patent portfolio recently in a strategic effort to share intellectual property with other firms interested in using its EV supercharging technology. While open innovation has experienced considerable resistance from incumbent firms, there are now at least two examples involving this approach at new entrants, one each for in-bound (Local Motors) and out-bound open innovation (Tesla).

In today's automotive industry, we observe that firms use multiple business models simultaneously, such as Daimler not only selling cars but also operating the car sharing service car2go via a subsidiary. Previous research has informed us about positive performance effects of business models' economic complementarities, from either jointly using fixed physical assets or paying cross-subsidies. The third paper, by Paolo Aversa, Santi Furnari, and Stefan Haefliger, titled "Business model configurations and performance in Formula One, 2005-2013," draws on longitudinal data from Formula One (F1) racing teams to examine how configurations of business models utilized by different teams link to race performance, illustrating the theme of change in both knowledge generation and innovation diffusion.

These authors find knowledge-based complementarities being beneficial for firm performance. The most common combination of business models that link to race performance involve F1 teams that sell key components (such as engines) to other teams and/or "lend" (for a fee) drivers developed within their driving talent system to other teams.

While these two activities would appear to be relinquishing important sources of advantage to competitors, they benefit the focal team by providing additional data.

In short, configurations of business models that promote learning for the focal firm are what bring the greatest likelihood of racing success, while other configurations that generate more revenues may not have the same positive learning effect. In this technology-driven context, it is the cross-fertilization of knowledge that allows business models to operate effectively in tandem. The relationship between business models, organizational learning, and innovation is not frequently explored, and here the authors use Qualitative Comparative Analysis to identify the multiple configurations that F1 teams bundle together to achieve high performance.

While the Formula One context is quite unique, with competitive dynamics resembling professional sports leagues more than automakers, it still provides lessons about how to organize both knowledge generation and innovation diffusion through creative application of multiple business models. At a time when many auto OEMs are beginning to experiment with mobility business models such as car-sharing and developing the infrastructure for EVs, they will benefit by keeping in mind the lessons from these F1 teams; the key is to generate valuable learning for the core business while not being overly distracted by the demands of the new business. The car sharing fleet will benefit from the new technologies that OEMS are able to offer to customers. Vice versa, the OEM gains knowledge from car-sharing about customers' preferences vis-à-vis the technology-in-use that can be fed into engineering and marketing for use in future vehicle development projects.

The fourth paper, by Felix von Pechmann, Christophe Midler, Rémi Maniak, and Florence Charue-Duboc, titled "Managing systemic and disruptive innovation: lessons from the Renault Zero Emission Initiative," highlights the dynamics of change and persistence that occur when established processes of managing product launch, sales, marketing, and customer support meet a new product technology—the electric vehicle—that embodies a rare and challenging combination of innovations. These authors deploy a theoretical framing that sees EVs as embodying both systemic and disruptive innovations. They argue that the literatures on these two types of innovations provide inadequate guidance to the challenges of managing this combination. They draw on qualitative data collected over a 7-year period to show how Renault initially persisted in efforts to create and maintain an ecosystem orchestrator role using established structures and processes, but then discovered the need to change its approach. Ultimately, the Zero Emission Initiative required substantial modifications in how Renault organized its product development, sales, and marketing activities in the transition to EVs. While there is no available performance metric for evaluating the success of Renault's efforts, its actions both internally and in the ecosystem provide insights for enriching what we know about managing different types of innovation.

Since the outcomes of this initiative are still emerging, amid a general slowdown in EV sales and other setbacks (such as the bankruptcy of alliance partner A Better Place), it is difficult to assess whether these changes went far enough in terms of placing Renault squarely and firmly in the ecosystem orchestrator role it sought. But what does seem clear is that if Renault had not been willing to change its traditional processes, it would have made substantially less progress—and learned much less—that what it has accomplished by its internal process innovations, structural changes, and market experiments.

Entry of Google and Tesla into new categories such as EVs or autonomous cars are consistent with extant theory, which presumes that new product categories are introduced by the product innovation of new entrant firms. However, there are few studies on the role of incumbents in market category emergence. The existing studies are typically found in technology strategy and, hence, focus on strategic determinants such as firm capabilities (Penrose, 1959; King and Tucci, 2002; Kaplan and Tripsas 2008).

The fifth paper, by Daniel Engler, titled "Is it a truck or a car?: managerial beliefs, the choice of product architecture and the emergence of the minivan market segment," steps back into automotive history to show that breaking open a new market segment cannot be reliably predicted by market characteristics, competitive pressures, or organizational capabilities. Instead the author finds that such segments emerge as a consequence of firms' cognitions, structures, and decision-making in the course of innovating. He studies the development and the commercialization of the minivan at Chrysler, Ford, and General Motors between 1970 and 1985. First of all, this case teaches us about the criticality of market segment-related decisions. While Chrysler understood the minivan as a novel segment of its *passenger* market and thus designed the first vehicle with a front wheel drive, Ford and General Motors understood the minivan as a new segment of its *truck* market and designed it with a rear wheel drive. Eventually, the latter failed to establish their models, finally deciding, years later, on a costly design change to implement front wheel drive as well. Second, the case identifies the interrelations among the factors leading to the respective market segment decisions, hence the product architecture choices and, ultimately, success or failure of the innovation diffusion.

Engler develops new theory for this phenomenon, building on past work on managerial cognition, firm capabilities, economic incentives, and organizational structure (Abernathy and Clark, 1985). This qualitative analysis offers insights that are applicable to the recent emergence of new market segments such as SUVs (Sports Utility Vehicles) and CUVs (Crossover Utility Vehicles) and to future prospects for product innovations like EVs and autonomous vehicles. While the minivan case study points toward the OEM persisting as lead innovator for new product categories—also a phenomenon in other industries, e.g. Corning and fiber optics (Cattani, 2006)—the recent examples of Tesla (successful EV in the luxury consumer market) and Google (autonomous vehicle prototype) suggest that this pattern could change in the future.

The role of competition is a central one to innovation, ever since Joseph Schumpeter theorized about temporal monopolies that would be competed away by imitators. However, research typically saw competition in an aggregate and monolithic way. Most extant theory does not take into account whether a firm introducing a new product was a leader or follower relative to its competition (e.g. Kapoor and Furr, 2014).

The paper "Do or die: competitive effects and red queen dynamics in the product survival race" by Berk Talay and Janell Townsend shows one downside of the persistence of innovation patterns in this industry by exploring the reciprocal relationship between the nature and duration of competition and innovation performance. Innovation is a common response to market competition and has been praised by scholars and practitioners alike as core to competitive advantage and long-term survival of the firm. However, from an industry perspective, it becomes apparent that product innovation triggers, in turn, the firm's rivals to introduce new products as well. This study, which builds on data of all light vehicle models offered in the USA from 1946 to 2008, helps us to better understand how actions and reactions escalate the overall competition in the market place. The authors find that the perpetually driven, reciprocal sequence of causality known as the Red Queen in evolutionary biology is a cardinal force behind the success of innovations. This paper highlights how competitive intensity can reduce—rather than spur—the overall innovativeness of new product offerings.

While the 'Red Queen' effect sees competition as a zero-sum game, it would be an interesting extension—especially for new product categories such as EVs—to study legitimacy-enhancing effects of innovation that build up an ecosystem. For instance, as mentioned above, Tesla as a leader in EV has recently offered to open up its patents on charging infrastructure to competitors. This might be clever strategy, with Tesla appearing to (deliberately) weaken its competitive position in order to help build a stronger EV ecosystem which would potentially establish it as the industry leader due to its standard-setting role.

While a number of the papers demonstrate change in the "who" and "how" of automotive innovation, perhaps a stronger thread through the full set of papers is persistence. As summarized above, structural characteristics explain much of the persistence of innovation behaviors at OEMs and in the ecosystem surrounding them. OEM persistence does not indicate high satisfaction by all constituencies; automakers are frequently criticized for everything from conservatism vis-à-vis technological innovation to outright resistance to demands from consumers (e.g. for better product quality) and regulators (e.g. for safety features such as seat belts and air bags). Yet from an industry architecture perspective, OEMs appear likely to retain their centrality regardless of how the current set of technological, business model, and regulatory uncertainties play out.

3. The future—extending current research and addressing new developments

This special section set out to investigate how automotive firms cope with turbulence caused by globalization, new governmental regulations, and substantial technological advances in communication and internet technologies. Particularly, the papers help us understand how and why firms change their way of innovating, but also why they persist in past patterns of innovative behavior. While we consider this essential and core to firms' competitive advantage and survival in these turbulent times, there are a number of other topics that call for further research, some of which we lay out below.

Theories related to *industry life cycle* predict a consolidation of firms as the industry moves from a growth to a mature stage. This has been witnessed in various industries, including the automotive industry. Indeed, we have seen a steady decline of car manufacturers from about 500 in 1910 to approximately 20 in the 1990s. The arrival of the

21st century, in turn, has brought another flourishing founding period and the number of new OEMs has risen substantially; China alone has more than 30 OEMs, many of them founded after 1990.

What seemed to contradict theory is actually just another proof of it. The (automotive) world became bigger as the iron curtain came down. It was much like starting the industry all over again with many firms competing and most likely crowding out and consolidating over time. Yet something is new. While industry life cycle-related theories suggest that entrants are small and medium in size, we observe large firms appearing on the scene. An example is Tata Motors starting to offer passenger cars in 1991. And these large firm newcomers have also started to acquire established brands (e.g. Tata's purchase of Jaguar-Land Rover from Ford; Geely's purchase of Volvo), a development that is hardly accounted for by extant theories that picture newcomers and incumbents as separate players.

According to the extant theory on disruptive technologies (e.g. Christensen, 1997), new entrants accumulate knowledge about new and inferior technologies by exploring new markets which are not attractive to incumbents. And indeed, we observe an armada of small entrants engaging in the production of EVs. Usually, disruptive technologies are truly novel. EVs, however, already existed around 1900 and even dominated the streets of New York in the 1920s. Here we see an old technology reappearing and challenging the dominant design.

Again, what seems to question extant theory actually supports it. The globe experiences incredible pollution which finally led society to change, with governments setting new emission regulations. This new set of boundary conditions cracked open the extant dominant design of drive trains and led to a rejuvenation of the industry. It restarted the battle of alternative technologies (EV, hydrogen, or even solar) with the dominant internal combustion engine.

Yet extant theory predicts small newcomers entering the game, often being underestimated by incumbents. And while we see firms like Tesla that fit this picture, it was incumbent Toyota that was the first to reach commercial success based on its accumulated competence in the hybridization of electric and internal combustion technologies. And even though the other incumbents were fast-followers with hybrids, it is them rather than new ventures driving the development of the new innovations that could threaten to displace the old technology.

In addition, collaboration between newcomers and incumbents (such as Tesla with Daimler or Toyota) remains to be studied. Extant theory sees newcomers and incumbents as rivals, first indirectly in adjacent markets and later directly in the same market.

In this vein, the real shake-up of the industry might yet arrive with autonomously driving cars. As theory predicts, the newcomers come from outside, building upon competencies that are distant to an established industry's core competencies. Automotive forays by Google and Apple, who seem not to ally with incumbents, confirm this. Again, what is rather unusual is the sheer size of these newcomers. Rather than small, as the theory describes it, it is giants entering the scene. This new way of potentially disrupting technology remains to be understood.

Overall, the automotive industry is undergoing a transition from being a product, sales and after-sales-service focused industry prioritizing customers and markets of developed economies to being a global sector for mobility, characterized by a larger variety of technologies, products, services, and business models than ever before. Rather than producing and selling cars, the emerging global mobility market offers many new services for people to get from A to B. Research questions to be answered by future studies include: How will novel business models generate competitive advantage? Will OEMs capture value from car- and ride-sharing services like Daimler's car2go, or will new entrants, e.g. Lyft, Uber, or Kuaidi Dache, dominate? And how can less cash-rich suppliers cope with these new technological developments, will there be a displacement of current suppliers from the ecosystem?

4. Conclusion

This special section provides articles exploring current issues of the automotive industry which have been under-researched so far and which are of significant academic and managerial interest.

The automotive industry is a mature industry that is now experiencing significant changes driven by globalization, new governmental regulations, and advancements in electronic, communication, and drive train technologies that shape (and are shaped by) shifting consumer preferences. At the same time, the industry displays stability in certain areas such as the persistent central role of OEMs in system integration. By researching these phenomena and mechanisms, this special section hopes to help scholars understand how mature industries in general and companies that are part of such industries cope with the mix of changes and structural stability in order to continue to innovate and thus stay competitive.

Funding

The first author's reseach is funded by the Swiss National Science Foundation. The second author's research is funded by the Mack Institute for Innovation Management at the Wharton School, University of Pennsylvania. The third author's research is funded by the Fondation Bernheim, which endowed the Emile Bernheim Chair for Entrepreneurship in a Global Context at the Solvay Brussels School, Université libre de Bruxelles.

References

Abernathy, W. J. and K. B. Clark (1985), 'Innovation: mapping the winds of creative destruction', *Research Policy*, **14**(1), 3–22.

Brusoni, S., A. Prencipe and K. Pavitt (2001), 'Knowledge specialization, organizational coupling, and the boundaries of the firm: why do firms know more than they make?', *Administrative Science Quarterly*, **46**(4), 597–621.

Cattani, G. (2006), 'Technological pre-adaptation, speciation, and emergence of new technologies: how corning invented and developed fiber optics', *Industrial and Corporate Change*, **15**(2), 285–318.

Chesbrough, H. W. (2003), *Open Innovation: The New Imperative for Creating and Profiting from Technology*. Harvard Business Press: Boston, MA.

Christensen, C. M. (1997), *The Innovator's Dilemma*. Harvard Business School Press: Boston, MA.

Delgado, M., M. E. Porter and S. Stern (2014), 'Clusters, convergence, and economic performance', *Research Policy*, **43**(10), 1785–1799.

Helper, S., J. P. MacDuffie and C. Sabel (2000), 'Pragmatic collaborations: advancing knowledge while controlling opportunism', *Industrial and Corporate Change*, **9**(3), 443–488.

Kaplan, S. and M. Tripsas (2008), 'Thinking about technology: applying a cognitive lens to technical change', *Research Policy*, **37**(5), 790–805.

Kapoor, R. and N. R. Furr (2014), 'Complementarities and competition: unpacking the drivers of entrants' technology choices in the solar photovoltaic industry', *Strategic Management Journal*, **36**(3), 416–436.

Karna, A., F. Täube and P. Sonderegger (2013), 'Evolution of innovation networks across geographical and organizational boundaries: a study of R&D subsidiaries in the Bangalore IT cluster', *European Management Review*, **10**(4), 211–226.

King, A. A. and C. L. Tucci (2002), 'Incumbent entry into new market niches: the role of experience and managerial choice in the creation of dynamic capabilities', *Management Science*, **48**(2), 171–186.

Klepper, S. (2002), 'The capabilities of new firms and the evolution of the US automobile industry', *Industrial and Corporate Change*, **11**(4), 645–666.

MacDuffie, J. P. and T. Fujimoto (2010), 'Why dinosaurs will keep ruling the auto industry', *Harvard Business Review*, **88**(6), 23–25.

Maskell, P. (2001), 'Towards a knowledge-based theory of the geographical cluster', *Industrial and Corporate Change*, **10**(4), 921–943.

Penrose, E. T. (1959), *The Theory of the Growth of the Firm*. Basil Blackwell and Mott Ltd.: London, UK.

Rao, H. (2009), *Market Rebels. How Activists Make or Break Radical Innovations*. Princeton University Press: Princeton, USA and Oxford, UK.

Sako, M. (2004), 'Supplier development at Honda, Nissan and Toyota: comparative case studies of organizational capability enhancement', *Industrial and Corporate Change,* **13**(2), 281–308.

Schulze, A., G. Brojerdi and G. von Krogh (2014), 'Those who know, do. Those who understand, teach. Disseminative capability and knowledge transfer in the automotive industry', *Journal of Product Innovation Management*, **31**(1), 79–97.