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Introduction to innovation in the East Asian automotive industry: Exploring the interplay between product architectures, firm strategies, and national innovation systems

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Abstract

East Asia is the origin and target market for an increasing number of technological innovations. We use the East Asian automotive industry as a focal point to discuss central questions of innovation research such as modularity, product architecture, and the dynamics of state sponsorship in national innovation systems. Two developments in the East Asian automotive industry are of particular interest to the broader innovation community: 1) East Asian firms and consumers are forerunners in the current transition to energy-efficient innovations and the future of automobiles. These technological developments will lead to a ‘hybridization’ of product architectures that need to be reflected in firm’s competitive strategies. 2) Particularly in China, the role of the state for national innovation systems is pronounced in the automotive sector. The way national and regional frameworks interact with broader technology trends shapes business innovation, and this understanding can inform firms in other sectors as well. Before highlighting the contributions of each paper of the special issue, we provide contextual background regarding the unique trajectories of the Japanese, Chinese, and Korean automotive industry, and summarize the current state of research. We conclude with an outlook on future research topics.

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1. Introduction

East Asia has emerged as the new center stage of automotive production and innovation: China alone accounted for three quarters of the automotive market growth in 2016 (IHS 2017). Japanese carmakers with their large number of patents are leading Thompson's yearly list of global innovators' (Sedgwick 2015). Key positions in emerging technologies such as automotive battery systems are dominated by Japanese, Korean and Chinese carmakers and their suppliers (Roland Berger 2017). Thus, there are strong indications that the geographic focus of innovation and competition is in the process of shifting. It is the aim of the special issue to shed more light on recent developments in the East-Asian automotive industry which are of high academic and managerial interest due to two main reasons:

First, the East-Asian automotive market can offer important insights in the current transition to energy-efficient innovations and the future of automobiles and its independence on fossil fuels. In late 2014, Toyota and Hyundai were competing to launch the first mass-produced fuel-cell vehicles, featuring what many experts assume to become a leading technology for future mobility (Nikkei 2014). Korean and Japanese makers of lithium-ion batteries dominate the world market (Lowe et al. 2010), as do Chinese suppliers of magnets and rare earths. China is expected to become a major lead market for new drivetrain technologies. Chinese carmakers launch an increasing variety of new hybrid and electric models each year and use new modularized drivetrain technologies to 'leapfrog' past Western and Japanese incumbents.

Second, East Asia is increasingly seen as a testing ground for "frugal innovations" – i.e., the development of lean, low-spec products for emerging markets (Economist 2012, 2010). Carmakers from Korea, India or China might have an advantage vis-à-vis their Western competitors to bring 'good enough' products quickly to their domestic and neighboring markets

(Leibowitz, Roth 2012). For example, Chinese firms like Longxin have used part development practices of “localized modularization” - broadly specified, supplier driven part development to overtake competitors (Brown, Hagel, 2005).

The special issues also offers some broader lessons. The automotive industry is exemplary of two phenomena that have shaped technology and innovation in recent years: First, the development of electric propulsion technology in China shows an extreme case of a push towards modularization of automotive product architecture. In this sense, the East Asian automotive industry showcases the competition between modular and integral product architectures. This is part of a broader discussion on the interplay between product architectures and firm strategies that is highly relevant for innovation in other sectors (Fujimoto 2008). Second, the current dynamics in the East Asian automotive industry illustrate the interplay between innovation and national institutional frameworks. National and regional frameworks interact with broader industry and technology trends to shape business innovation. This holds particularly true in the automotive industry, where both alternative propulsion technologies and autonomous driving are tightly linked to new infrastructure and regulatory frameworks, but also in the larger industry landscape, where the state/business interplay of investments in IT infrastructure and regulation will shape trends like connected manufacturing (“industry 4.0”).

Before we elaborate on these themes and the individual contributions of the papers in this special issue, the next section establishes the context of “East Asia”. The national innovation system of the three dominant regional players in the automotive industry, Japan, China and Korea, have followed distinct trajectories. These distinctions matter, since they shape the competitive positions of national players when they align their firm strategies to institutional frameworks and dominant product architectures. After a brief introduction of the concept of product architecture,

which we will use to guide the comparison, the next section provides an outline of each trajectory and briefly sketches the current state of innovation research on the automotive industry in East Asia.

2. Historical development of the East Asian Automotive Industry and current challenges

The emergence of the East Asian automotive industry needs to be understood in light of a country's dominant model of industrial innovation and production. Two basic types of product-process architecture can be distinguished (Fujimoto 2008), (1) "Integral architecture" with complex interdependence between product functions and product structures (such as automobiles, etc.), and (2) "Modular architecture" in which the relationship between a product's functional and structural elements have a simple and clear one-to-one correspondence (such as personal computers, etc.) (Ulrich 1995). While the automotive sector is often cited as a typical example of integral architecture, new developments such as electric propulsion systems and the stronger integration of the IT and automotive sectors have led to a hybridization of product architectures. The dynamics of the evolution of the product architectures in the automotive sector and how these are shaped by carmaker strategies, national innovation systems, and consumer markets is a leading theme of this special issue.

The Japanese innovation trajectory

Japan is the prime example of the East Asian economic catch-up. The post-war automotive industry in Japan was characterized by a number of product and process innovations, most prominently the Toyota Production System, which led to Japan's rise in industrial competitiveness (Clark, Fujimoto 1991; Song, Dyer 1995; Womack et al. 1990). Japanese companies enjoyed high

levels of productivity, especially for coordination-intensive products with an integral product architecture – such as automotive.

Several factors were driving innovations in Japan. The high-growth era of Japan in the 1950s and 1960s were characterized by resource scarcity, particularly concerning labour (Fujimoto 1999). The chronic labour shortage motivated firms to select long-term employment systems and build long term-relations with subcontractors, leading to the accumulation of coordinative capabilities within and between manufacturing firms and suppliers. This “economy of scarcity” may be the source of Japan’s industrial competitiveness and innovativeness, particularly for products with integral product architectures (Fujimoto 1999).

In the 1990s two major events challenged this competitive advantage: One was the entry of Chinese low-cost competitors into the global market. The other was the rise of the internet and other digital communication technologies in the mid-1990s which caused the rapid substitution of analog (relatively coordination-intensive) devices by digital (relatively coordination-efficient) ones. These changes made the competitive gaps in market performance between coordination-intensive goods (e.g. cars, machine tools) and coordination-efficient ones (e.g. bicycles, PCs) increasingly evident. For example, as TV sets became digital, Japan’s major TV manufacturers such as Panasonic, SONY, and Sharp suffered substantial deficits (Economist 2014).

For researchers on the Japanese automotive industry, the organization of automotive product development has traditionally attracted considerable interest (e.g. Cristiano et al. 2000; Ueki et al. 2010), including the integration of suppliers into the innovation process (e.g. Dyer, Nobeoka 2000; Dyer, Hatch 2006; Kotabe et al. 2003; Takeishi 2001). Another theme is the overseas transfer of process innovations. A high number of studies looked especially at the challenge to innovate by adapting existing business models to foreign environments (e.g.

Morimoto 2006; Saka-Helmhout 2010). Relatively few studies investigate how Japanese carmakers and their suppliers respond to ever increasing competitive pressures. Can they move towards more market-oriented relationships and still retain the system logic that made them innovative (see also Aoki, Wilhelm 2017; Aoki, Lennerfors 2013)?

The Chinese innovation trajectory

In the late 20th century, China adopted a Soviet-style national innovation system under the Communist Party regime in which industrial R&D activities were highly concentrated at the nation state level. As a matter of fact, manufacturing firms in China often did not have their own R&D function. The design of Chinese products tended to lag behind that of advanced countries. Thus, when China opened up its economy in the 1970s, many of the manufacturing firms, those in Southern coastal provinces in particular, had to license foreign technologies or copy foreign products (Fujimoto 2008). In order to rapidly catch-up, many of the Chinese firms, state-owned or private, bought licensed or copied parts as generic modules and started new manufacturing businesses by mixing and matching generic components. A “quasi-open architecture” thus characterized Chinese products such as motorcycles, trucks, air conditioners, TVs, and other digital consumer goods. About one hundred assembly makers for each product segment received copied parts from hundreds of local suppliers, leading to extreme price competition fueled by the use of temporary workers from low-wage regions of inland China. By the end of the 20th century, China became a major exporter of labour-intensive modular architecture goods.

Innovation studies have mainly focused on Chinese carmakers’ and suppliers’ competency building strategies for catching-up and leapfrogging (Zhao et al. 2005; Guo et al. 2014). Since the mid-1980s, some Chinese automobile firms have accumulated substantial internal resources

through international joint ventures (IJV) or domestic mergers (Nam, 2015). Some studies demonstrate the positive effects of IJV with foreign carmakers ([Gallagher, 2006](#); [Rui and Yip, 2008](#); [Zhao et al. 2005](#)) and collaboration with foreign parts suppliers ([Sadoi, 2008](#)) on knowledge transfer to Chinese automobile producers.

However, the intended knowledge transfer through these IJVs did not lead to the desired success and Chinese carmakers are still struggling to enter the highly competitive mature markets (Nam 2015). Even in the Chinese domestic market, Western incumbents continue to be dominant players, and Chinese carmakers reach market shares below 20% (Colum 2015; Economist 2013). Major reasons for the technology transfer problem seem to be the reluctance of foreign multinationals to transfer core technology to Chinese partners (Rui, Yip 2008) but also the local firms' low ability to absorb new knowledge (Hatani 2009).

Rules and incentives set by government policy are frequently cited as supporting factors for facilitating knowledge transfer from foreign MNCs to Chinese local firms. At the same time, strong differences in implementation success point at the importance of individual firm strategies (Nam 2015). In sum, the literature on knowledge transfer to Chinese automotive firms shows that although FDI, IJV and M&A are central strategies for the Chinese automobile industry to upgrade their technological base, much depends on the details of implementation. Effective knowledge transfer thus remains a challenging issue for the Chinese automotive industry.

The technological shift towards electric vehicles might, however, change these dynamics and accelerate the catching-up process of Chinese carmakers. Fully electric vehicles are characterized by a product architecture with less moving parts (e.g. gearbox, exhaust system, oil changes, combustion engine) and less need for integration (Klug 2013). These specific characteristics provide opportunities for Chinese carmakers to attack the incumbents' market

positions e.g. by using low-cost mix-and-match strategies or leapfrogging into high-end market segments (Rong et al. 2013; Wang, Kimble 2013). However, while the Chinese government grants substantial subsidies for electric vehicles by domestic producers (Roland Berger 2017, 2015), the political implementation is relatively fragmented with national and regional policy makers pulling into different directions. The relatively late technological catch-up of the Chinese automotive industry (Xiao et al. 2013) has led to a state of ‘fragmented liberalization’ where political actors at the local and national level set conflicting incentives (Oh 2013). Others have warned, that the strong political support can have negative side-effects, and may decrease an automotive firm’s competitiveness (Sun et al. 2010).

The Korean innovation trajectory

Korea has a young automotive industry, and major players such as Hyundai produced their first cars only in the mid 1970s. The 1970s and 1980s were characterized by a rapid technological catch-up as Korean firms drew strongly on external sources of technological knowledge, hired automotive design firms from Italy and production experts from Japan to learn about automotive design and production (Kim 1998). As latecomers in this period with an initial cost advantage and the strength of the large Korean business groups (*Chaebols*) behind them, Korean automotive firms pursued scale economics to strengthen their technological positions (Hu 2012). The strong top-down control by the founder-owners of Korean Chaebols led to quick decision-making on investments in capital-intensive processes. Korean export power is highly concentrated on capital-intensive modular architecture goods such as general purpose steels, DRAM, and CLD produced by large firms, many of which stem from Chaebols (Fujimoto 2008). Their latecomer position allowed Korean firms to match the technological levels of foreign competitors with lower capital

outlays by directly investing into newer production technology and by skipping phases in automotive technology, for example, by directly leapfrogging to the fuel-injection engine, skipping carburetor engines (Lee, Lim 2001).

In the 1990s, while car exports of Korean brands such as Hyundai and Daewoo increased strongly, they were still viewed as low-end products by Western consumers. Hyundai especially used exports to the more mature automotive markets of the US and Europe as a testbed and learning experience (Kim, Lee 2001; Kim et al. 2015). By the 2000s Korean companies made serious progress in competing against major automakers on the global stage and achieved major improvements of technology and globalization. Especially Hyundai began to heavily invest in design capabilities (Suh et al. 2014; Lansbury et al. 2006).

The catching up process was heavily supported by the Korean government who has pushed its automotive firms strongly towards the challenging export markets (Amsden 1992; Amsden, Singh 1994; Studwell 2014). Smaller players that could not keep up were encouraged to merge with larger competitors. In the 2010s, Hyundai Motor Corporation (HMC) remains the last player from this contest with strong technological competencies.

Studies on automotive innovation in Korea highlight attempts by Korean firms to increase the efficiency of existing structures. Korean firms have localized a higher share of component development and manufacturing, and invested aggressively in new technology acquisition (Poon, MacPherson 2005; Choi et al. 2014), as well as brand enhancement (Choi, Bok 2009). This rapid pace may be an effect of ownership-based leadership, enabling quicker investment decisions (Shim, Steers 2012).

3. Trends and emerging research gaps

From our review of the literature, our call for papers for this special issue highlighted the following main research gaps in research on the East Asian automotive industry, which a focus on Japan, China, and Korea:

- What are the institutional factors that enable radical innovations and leapfrogging in East Asia? What is the role of domestic consumers, governments and regulations, or home country knowledge sources?
- How does the internationalization of technology sourcing affect East Asian automotive firms and automotive suppliers?
- Which organizational processes account for the success of firms like Hyundai and Toyota in bringing innovation to the mass-production stage? How can more established firms manage the cost-variety tradeoff and improve the integration between design and mass-production?
- Are East Asian carmakers such as Hyundai (Korea) and Geely or SAIC (China) better equipped to design cars for emerging market consumers? How can cost-advantages in production be combined with innovative product development?
- How do Asian carmakers globalize their product development activities to create innovation for their local consumers?
- How do national innovation systems in East Asia interact with firm strategies and dominant product architectures?
- How can the diffusion of new technologies such as electric vehicles in East Asia inform us about the future of automotive in the rest of the world?

Almost all papers we received had a strong regional focus that highlighted specific developments in one East Asian national innovation system. While the majority of papers focused on the Chinese automotive industry, none of the submissions that reached us were dealing with the

Korean automotive industry. This is surprising, given the recent success of Korean carmakers in challenging traditional incumbents from the US-Europe-Japan triad.

4. Individual contribution of papers

In the following, we outline the main contributions of the papers that were accepted for the special issue. While some papers have a stronger focus on the role of the state and national innovation systems in East Asia, others focus more explicitly on firm strategies. These macro and meso-levels of analysis are connected through product architectures, as another major theme of our special issue.

National innovation systems

Local carmakers that received the highest level of governmental support in China have been the least successful. The paper by **Thun** sets out to explain this puzzle by asking why cost innovation can provide a foundation for upgrading in some sectors within the Chinese automotive industry, such as commercial vehicles and components, but not others, such as passenger vehicles. Each of these sectors can be broken down into market segments that corresponds to an income pyramid. Thun suggests that it is particularly important to understand the incentives for firms to engage in cost innovation in the middle segment, a delicate balancing act in an area where customers demand a high degree of ‘value for money’. While the lower-end segment offers natural protection from foreign firms with higher cost structures, the high-end of the market is often dominated by foreign firms with better access to technology and other strategic resources.

Through the use of interview data and extensive secondary data sources, Thun dives into three embedded case studies – Shanghai Auto Industry Corporation (SAIC) for passenger vehicles, SAIC-GM-Wuling (SGMW) commercial vehicles, and Yatai for component firms. The case of

passenger vehicles illustrates how the combination of tariff protection and restrictions raised prices out of the range of private consumers, and led to reduced incentives to innovate for firms. The commercial vehicle and component firms, by contrast, were better able to succeed in cost innovations in a manner that foreign firms had difficulty matching.

Thun's study bears substantial implications for policy makers: state intervention can inadvertently reduce the size of market segments which can create problems for local firms. While policies can be changed rapidly, organizational capabilities within firms develop slowly, and firm behaviour will not respond immediately to policy changes. Thun urges to differentiate stronger between market segments for a single product in emerging economies to better understand the inconsistent success of emerging market firms to compete with foreign competitors. While Chinese firms have struggled to compete with global firms in passenger vehicles, even in low-end segments, they were much more successful for commercial vehicles and components.

The paper by **Bohnsack** closely links to the paper by Thun by discussing the role of government and unexpected consequences of political action to support technological development in automotive markets. The study explores local and national protection mechanisms with a focus on policy-firm intersection and discusses competition within and across niches. Two distinctions are advanced to develop a conceptual framework that combines local niches and the firms that dwell in them: location dependency (open/closed) and technology relatedness (selective/unselective). The authors refine previous studies that look at the role of protective spaces for fostering innovation by showing that national boundaries matter less than the dynamics of a specific locality. Instead, location dynamics shape the size of protective niches which in turn shape the strategies of firm actors. The dominant discussion on automotive innovation in China may be conceptually misled, as it tends to treat China as a monolithic actor instead of analyzing the many

spaces that protect or impede innovation, depending on regional or even municipal dynamics. Highlighting the importance of these local dynamics is a key takeaway of the study. **Bohnsack's** study informs our understanding of the interaction between policy protection and market actors to shape a specific technological field with sometimes unexpected consequences.

Firm strategies

Globalization and intensified competition in the automotive industry call for increased dynamic variety, defined as the number of vehicles produced in a manufacturing plant over a period of time. While dynamic variety is closely linked to product development and innovation, it also affects mass-production and process innovation. The paper by **Aoki & Stäblein** studies the integrative capability between design and manufacturing for effectively managing dynamic variety and its underlying cost-variety tradeoff. This integrative capability is referred to as “monozukuri” which has long been regarded as a particular advantage of Japanese carmakers. The authors ask how monozukuri capabilities differ between the manufacturing-oriented Japanese approach with the more design-oriented focus of German OEMs, and how OEMs in Japan and Germany differ in their organization of the design-manufacturing interface. In order to answer this question they analyze production data and original case material.

The authors paint a complex picture that shows distinct trade-offs as solutions to common modern problems in automotive innovation such as how to deal with increasing variant complexity and how to organize modular production without sacrificing product originality. Aoki & Stäblein's study concludes that the gap between Japanese and German carmakers has in fact decreased: While Japanese carmakers began to put more emphasis on economies of scale and platform strategies, German makers focused on increasing dynamic variety. Revisiting the literature on the superiority

of the Japanese monozukuri capability over Western makers from the 1980s and 1990s (e.g. Clark, Fujimoto 1991; Womack et al. 1990), Aoki & Stäblein unveil a ‘hybrid approach’ to dynamic variety between Japanese manufacturing-oriented and German design-oriented ones. On a more general level, their study contributes to the literature on modularization but also organizational ambidexterity.

Complementing the German-Japanese comparison of the paper by Aoki & Staebelin, **Hertenstein and Williamson** compare supplier integration in product development between German and Chinese firms. As specialization increases, external sources of technology gain in importance. Suppliers have clearly played a large role in shaping both the technological development of local Chinese carmakers and the substantial transfer of product and process technologies by foreign carmakers to China. In this sense, an extreme case of supplier-buyer dynamics in technology development can be studied here. Hertenstein and Williamson compare Chinese and German firms’ interaction with key suppliers to show how product architecture influences product development approaches of Advanced Market MNEs (AMNEs) and Emerging Market MNEs (EMNEs) differently. The authors find a more cooperative, integrative approach by German carmakers in their interaction with key suppliers. This contrasts with a more modular approach, based on the assembly of externally available technological inputs by the Chinese firms, using rapid design iterations and market feedback.

While the paper by Hertenstein & Williamson compares the buyer-supplier interactions of Chinese firms to their competitors, the study by **Yakob, Nakamura & Ström** complements this view by exploring how a Chinese automotive company expanded its access to foreign suppliers and innovation systems. Their in-depth case study of Geely’s takeover of Volvo analyzes how

Geely leverages its strategic assets to global innovative capabilities. The authors look at the fit between host country innovation environment and the automotive market environment of Geely's home market, and assess how these push- and pull-factors interact in making such investments successful. The study explores how these linkages between home- and host-country strengths can create benefit not only for the acquiring firm, but also for the acquired firm. The authors argue that this fit to host-country spatial dynamics is especially important to create enduring links to host-country innovation networks that improve the firm's global innovation capabilities. The study proposes specific ways in which the acquiring firm can overcome the difficulties of such a marriage between unequal partners. A specific balance is required between local autonomy of the acquired firm and alignment to the strategic intent of the acquiring firm. The authors demonstrate this interaction by focusing on organizational routines that were established by Geely and Volvo in their joint entity CEVT.

Taken together, the papers of this Special Issue contribute to a more nuanced understanding of recent developments in the East Asian automotive market. We gain a better understanding of the unexpected consequences of government action (Thun), and learn that the nation level might not be an adequate level of analyses when talking about Chinese automotive innovation, but regional differences must be better accounted for (Bohnsack). Moreover, we find that superficial similarities between models of automotive organization of more mature carmakers can be misleading, and that differences in organizational responses can be entrenched in a path-dependent manner that goes against the idea of a convergence to one-best way models of automotive innovation (Aoki & Stäblein). Similarly, we find substantial organizational differences between German and Chinese carmakers' approaches to supplier integration in their innovation processes that can be related to differences in their product architectures (integral versus modular)

(Hertenstein & Williamson). Finally, we learn that the Chinese firm's acquisition of AMNE does not only serve asset augmenting purposes, but can actually help to create new strategic assets (Yakob et al.).

5. Outlook

Some gaps remain that deserve further investigation. For Chinese automotive firms, questions of technology transfer continue to dominate the discussion. Chinese carmakers face substantial challenges of technological upgrading and a real danger of losing a large part of value added to their suppliers and becoming low-tech assemblers in the emerging new division of labor. As Chinese carmakers move away from the role of systems integrators, the question of their value added in the automotive supply chain becomes more urgent. An answer for this may lie in demand side dynamics: New business models and highly targeted combinations of services and products may prove a way forward for Chinese firms to combine their domestic advantages into a competitive strength for electric vehicles that goes beyond the current mix of political support and subsidies.

A large gap concerns our current state of knowledge on innovation strategies of Korean firms that increasingly face limits to further scale-up their efficient innovation structures that helped them to master the technological catch-up in the past. The challenges of adapting these structures are especially prominent for automotive and electronic products, which both undergo a strong push towards an increasing role of software inputs into the R&D process and will challenge the current strengths in producing integral products – a challenge faced by both Korean and Japanese firms. (Fujimoto, Park 2012).

Finally, Japanese carmakers face the challenge to maintain organizational arrangements that have served them well in the past that were related to their highly integral, coordination-intensive product architectures. Main threats to these arrangements are technological trends that increase the modularity of automotive product architecture, as they are already visible in the Chinese market. In particular, Japanese carmakers face three main problems: First, a growing number of software in modern vehicles conflicts with the traditional focus of Japanese carmakers on mechanical/electronic integration (Fujimoto, Park 2012). Second, the long-standing success model of generating innovations through their closed networks of long-standing (Japanese) suppliers might need to be adjusted. Through continuous consolidation, European system suppliers like Bosch and Continental have gained a dominant technological position in future key areas such as automatic driving and connected cars that is unmatched by their Japanese rivals. Finally, external engineering service suppliers help carmakers in Europe and the US to master the trade-off between maintaining strong in-house R&D competencies and profiting from external resources. This trend of a stronger reliance on external development and testing competencies is likely to increase as carmakers move into new and uncertain technological territories such as automatic driving. Whether Japanese carmakers can maintain their dominant position in this competitive industry will be determined by the question whether they can master these challenges while maintaining the key strengths of their traditional internal innovation models .

The research presented in this special issue can serve as a starting point for the further exploration of these important challenges that will continue to dominate the discussion on innovation in and beyond the East Asian automotive industry.

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