An Examination of Inter-Organisational Learning and R&D Capability through Open Innovation

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Abstract: This study illustrates how Toyota, one of the world's largest automobile companies, emerged as a leading research and development (R&D) company in the rechargeable battery business in Japan. This study examines the 1990s–2000s period, during which Toyota accumulated substantial R&D capability in rechargeable battery technology. Several automobile companies, such as Toyota and Nissan, have engaged in research on rechargeable battery systems that are adaptable to electronic vehicles. Compared to Nissan, Toyota collaborated with several external partners. A time-series analysis of patent data comprising 631 samples spanning from 1998 to 2003 shows that Toyota accumulated its R&D capability over time, absorbing technical expertise from partners and ultimately evolving into a leading company. Patent citation data (N = 353) between 2006 and 2009 can trace these patents back to the technologies of Toyota's former partner, Panasonic. These results confirm that Toyota gained technological expertise from its partners and eventually initiated internal R&D. Earlier studies on open innovation focused on how partnership influences technological output alone. This study sheds light on the specific inter-organisational aspects of learning via open innovation. Although open innovation is considered a direct outcome of technological output, open innovation for inter-organisational learning broadens the theory regarding indirect outcomes for R&D capabilities and direct outcomes. From theoretical and practical perspectives, a company must exploit open innovation for the long term with respect to partnerships because it takes time for such partnerships' influence on R&D activity to take effect. By cross-correlating lagged patent data for Toyota and Nissan, this study documents the following. First, inter-organisational learning effects are delayed, significant and persistent. Second, open innovation through partnerships for basic research and supply chain research generates learning effects. Finally, R&D capabilities gleaned from a core partnership and a long-term partnership can lead to internal R&D enhancements.

Keywords: Open Innovation, Inter-Organizational Learning, Partnership, Delayed Effect, R&D Capability

1. Introduction

Japanese automakers Toyota and Nissan began to research rechargeable batteries in the early 1990s in anticipation of producing electric vehicles (EV). The rechargeable battery was a new technology for them, and both companies struggled to become self-sufficient as researchers. Although Toyota and Nissan were at virtually the same level until the early 2000s, Toyota started to surpass Nissan in the late 2000s. This is because Toyota took advantage of open innovation (Chesbrough, 2003) to a greater extent than did Nissan.

Chesbrough (2003) introduced the concept of open innovation in which companies make the most of both external and internal knowledge. In this case, Chesbrough (2003) defined knowledge as consisting of technologies as well as ideas. In order to promote open innovation, partnership is the most important measure, *i.e.* creating an alliance (Gerlach, 1992; Nooteboom, 1999) and cooperation (Dyer, 1996; Gomes-Casseres, 1996; Powell *et al.,* 1996) with partners. Although management style and research and development (R&D) governance for open innovation previously attracted the attention of researchers (*e.g.* Bergman *et al.,* 2009; Chesbrough and Appleyard, 2007; Dyer, 1996), this study focuses on the output variable. Previous research has examined other topics, such as technological output (*i.e.* innovative products or technology) as an output variable (Chesbrough, 2006; Laursen and Salter, 2006), but this study also considers inter-organisational learning effects (see Section 2.2). Indeed, the direct output of open innovation is, in fact, itself, an innovative product, but indirect outputs, such as inter-organisational learning effects, are also important. Inter-organisational learning generates additional R&D capability as well as dynamic capability (Teece *et al.*, 1997). Companies with sufficient R&D capability are then able to research and develop innovative technologies independently, rather than rely on partners or alliances to make such advancements.

Among open innovation theories in the literature that have been discussed for many years is the paradox of openness (Arora *et al*., 2016; Laursen and Salter, 2014). Too much openness sometimes erodes a company's performance and capabilities (Enkel *et al*., 2009; Laursen and Salter, 2014). When too much depends on a partner, it also decreases the company's R&D capabilities. Therefore, there seems to be a trade-off between promoting open innovation and initiating internal R&D. However, Toyota made the most of their partnerships

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and reached the status of becoming a leading R&D company in the field of the rechargeable battery. This case, apparently, is a counterexample to the mainstream of previous research. However, from the perspective of inter-organisational learning, Toyota gained their technological-base knowledge from their partner, as well as improved their R&D, and was able to then independently conduct research using their own capabilities. Nissan, who never aggressively promoted open innovation, slowed down their R&D on the rechargeable battery in the late 2000s, while Toyota aggressively formed partnerships with various companies and embarked on establishing their own research ability.

This study reveals some facts on Toyota's outstanding partnership management. Toyota formed partnerships for basic research as well as for research on cooperation of R&D, although previous studies have suggested that simultaneous partnerships for basic research and supply chain research might be less effective (e.g., Stefan and Bengtsson, 2017; Haus-Reve *et al.*, 2019). That is a second counterexample to the previous theories. This study employs a time-series analysis and reveals the reason why Toyota succeeded to becoming a top R&D company by means of its partnerships.

2. Theoretical background

2.1 The concept of open innovation

Large manufacturers have been devoted to in-house R&D and usually disparage external R&D as 'Not-Invented-Here', which is a strong bias against outside technology (Katz and Allen, 1982). As a counterargument to the Not-Invented-Here attitude, Chesbrough (2003) proposed that combining internal and external knowledge should be known as 'Open Innovation'. Open Innovation is a paradigm that assumes that firms can and should use external ideas as well as internal ideas, and internal and external paths to market, as the firms look to advance their technology (Chesbrough, 2003). Under the open innovation paradigm, partnership is an important strategical measure (Lee *et al*., 2010). In the process of open innovation, companies are often confronted with some managerial problems. At first, company must search adequate partners, and prepare to merge the R&D activities of their own company with those of their partner (Laursen and Salter, 2006; Enkel *et al*., 2009). Subsequently, in the next stage, the company must combine internal and external knowledge (Enkel *et al.*, 2009; Van de Vrande *et al.*, 2009; West and Bogers, 2014; de Felice *et al.*, 2019). Finally, the company must develop innovative products (West and Bogers, 2014).

During the searching process, the topics of the importance of intermediary market (Chesbrough, 2006) and the role of innovation community (Ficher, 2009) have been introduced by previous studies. However, the governance of partnerships remains an unsolved problem. Felin and Zenger (2014) discussed the fact that a company's governance mode—either open or closed—should be driven by innovation problem type. In this context, innovation problems often concern issues such as communication channels, incentives and property rights. Therefore, open innovation doesn't always work well. Laursen and Salter (2014) reveal curvilinear relationship between open innovation and performance. Dahlander and Gann (2010) postulated that relying on outside too much incurs additional costs and hurts a company's capability. Therefore, too much openness can hurt a company's performance.

However, here are two problems to be solved; one is a management of each stage of open innovation, the other is a matter of criteria regarding the outcomes of open innovation (Huizingh, 2011). At one stage, a company must form a partnership in spite of the openness paradox; at another stage, it must handle R&D independently through internal R&D. Thus, it is certain that there is no contradiction between these two governance modes (Maegawa and Miyamoto, 2009). A key success factor is handling the two governance modes according to the stage of development. Therefore, this study employs a time-series analysis. Previous studies on open innovation has mainly examined the direct effects of partnership (*i.e.* innovative technology and R&D efficiency), but partnership, as one measure of open innovation facilitation, provides inter-organisational learning opportunities to *both* companies (Doz and Hamel, 1998; Inkpen, 1998). Thus, this study posits that inter-organisational learning is an indirect effect of open innovation. Inter-organisational learning via partnerships is a difficult, frustrating and long-term process (Inkpen, 1998) because it requires a common knowledge base and shared dominant logic (Lane and Lubatkin, 1998). It can, therefore, be supposed that the effects of inter-organisational learning might appear later than do the direct effects.

2.2 R&D capability and inter-organisational learning

Teece *et al*. (1997) defined dynamic capability as the exploitation of existing internal and external company-specific competences in order to address changing environments, company's ability to integrate, build and reconfigure internal and external competences to address rapidly changing environments. By referring Teece *et al.* (1997), Zollo and Winter (2002) discussed a company's dynamic capabilities, defined as routinized activities, as directed toward the development and adaptation of operating routines. They emphasize the accumulation of experience, the articulation of knowledge and the codification of information during the evolution of operational routines. The argument can be made that dynamic capabilities are shaped by the coevolution of these learning mechanisms. Then, the management of R&D capabilities—whether accumulated internally (Helfat, 1997; Kim, 1999) or obtained externally (West and Bogers, 2014)—is crucial. In addition to internal accumulation and external transfer, inter-organisational learning has been considered (Figueiredo, 2002). Inkpen (1996) discussed the partnership from the view point of alliance learning and inter-organisational learning.

Although the importance of inter-organisational learning has been confirmed, there are still a few arguments regarding the management of the learning process. Indeed, bridging distant or diverse knowledge gaps should serve to enhance creativity (Audia and Goncalo, 2007); hence, a broader recombination with various partners leads to an increase in economic value (Kaplan and Vakili, 2015). But a significant negative interaction is still possible in scientific and supply chain partnerships (Haus-Reve *et al.*, 2019). Thus, seeking partnerships for the purpose of conducting both basic and supply chain research at the same time can actually decrease a company's open innovation performance. Partnership for basic research has a positive impact on innovation performance (Tomlinson, 2010). Other studies has pointed out that partnership for basic research enhances the novelty of a company's R&D, while partnership with suppliers enhances its effectiveness (Stefan and Bengtsson, 2017). Seeking both simultaneously, however, can have a negative impact, depending on the specific innovation process being engaged (Jensen *et al.*, 2007). However, the case of Toyota is a counterexample because Toyota formed a successful partnership for both basic research and supply chain research at the same time.

The relationship of R&D capability with its performance can be measured using the criterion of a company's patents (Coombs and Bierly, 2006; DeCarolis and Deeds, 1999). Therefore, this study analyses R&D capability by using patent data as a proxy for open innovation partnership success. Data regarding patent applications illustrate the status of research partnerships by confirming the head applicant and co-applicants. This study obtains information on partnership and inter-organisational learning vis-à-vis an analysis of patent data. This study uses lagged time-series data to compare the results of Toyota's and Nissan's individual approaches to open innovation.

2.3 Research question

As mentioned in Section 2.1, previous studies on open innovation paid more attention to its direct effect. Then partnership is the practical management measure of open innovation. Partnership might be considered as having two different aspects; indirect effects (rather than direct effects), as well as delayed effects. If so, open innovation has an effect on the outcome as a direct effect at that time, as well as indirect and delayed effects that become apparent at a later time.

The main research goal of this study is to reveal the reasons why Toyota was able to become a top R&D company in the field of rechargeable battery technology, a technology area with which Toyota was previously unfamiliar. Therefore, this study formulated three hypotheses:

H1: Open innovation exerts both delayed and long-term effects on inter-organisational learning.
H2: The time lags for partnerships on basic research and suppliers differ. When time lags are considered, partnerships on basic research and supply chain research increase a company's internal R&D capability and performance.
H3: After their partnership expired, Toyota was able to accelerate their internal R&D by leveraging the positive effects gained through inter-organisational learning.

3. Analysis

3.1 Toyota and Nissan

During the mid-1990s, Nissan sought more patents than Toyota. Toyota began to pursue open innovation in approximately 1997; between 1998 and 2003, it had established a core partnership with Panasonic, a follower company in the rechargeable (lithium-ion) battery business. Nissan collaborated only intermittently with Sony, a leader company in rechargeable battery technology at that time, and had no core partner. In addition, Toyota formed longer-term partnerships than Nissan. Figure 1 compares trends in patent applications for rechargeable batteries for Toyota and Nissan.

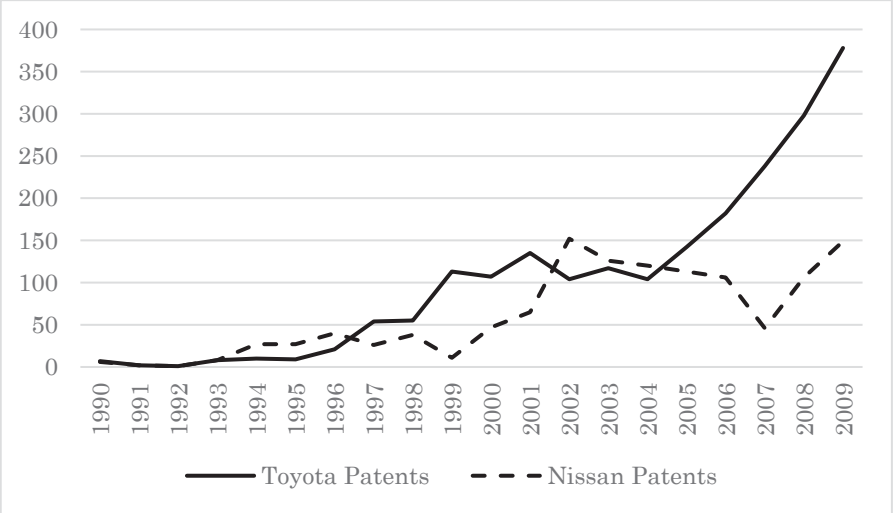

Figure 1: Number of patent applications for rechargeable battery for Toyota and Nissan

Toyota surpassed Nissan in patent applications between 1997 and 2001 (Figure 1), but the number of patents as a head applicant (main inventor) indicates Toyota and Nissan were at a similar level (see Figure 2). Until about 2004, Toyota and Nissan applied for approximately the same number of patents related to rechargeable batteries. Toyota has far surpassed Nissan since 2005 although Toyota had already dissolved partnership with a core partner at that time.

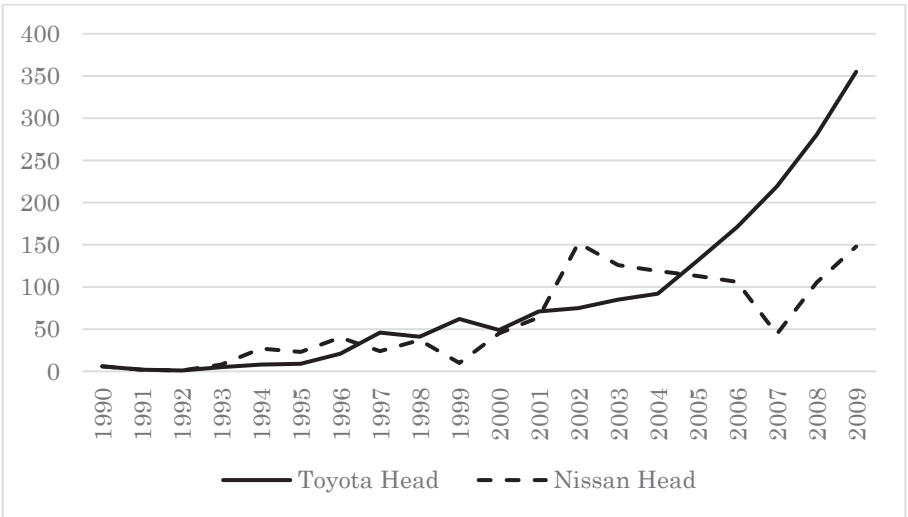

Figure 2: Number of patents as a head applicant

Table 1 lists the details regarding Toyota's and Nissan's patents when both companies were at a similar level. Toyota sought 45.3% of its patents with partners and Nissan 2.7%. Almost 30% of Toyota's total patent applications involved a core partner.

Table 1: Ratio of Patents with Partners

<Toyota> Patents: 1998–2003	Patents with partners	Patents with a core partner
631 (%)	286 (45.3%)	179 (28.4%)
<Nissan> Patents: 1998–2003	Patents with partners	Patents with a core partner
439 (%)	12 (2.7%)	0 (0.0)

Before 2005 Toyota applied for many patents every year, but almost half of patents were the result of collaboration with partners. Since Toyota applied for far more patents as a head applicant since 2005 (see Figure. 2), Toyota was able to initiate research on the rechargeable battery using its own R&D capability since that date. It is confirmed that Toyota was intent on engaging in open innovation, but relied on improved inter-organisational learning in the meantime (1998–2003). In the next section, this study observes and verifies the learning effect of its partners.

3.2 Time-Series analysis (1): Partial autocorrelation function

By employing time-series patent data of Japanese patent office website (J-Plat Pat), this study calculates partial autocorrelation function (PACF or Partial ACF); partial correlations between an observation in a time-series with observations at prior times with shorter lags were also calculated. Figure 3 shows the partial correlations with all lags of Toyota's patents in the time-series. The partial correlation function of a one-year lag is the highest (PACF: 0.743). This means that Toyota improved their R&D capability every year at a steady pace. Since Toyota's R&D capability of one-year ago enhances their R&D capability the next year, their R&D capability was being accumulated annually. The reason for this will be discussed in Section 3.3.

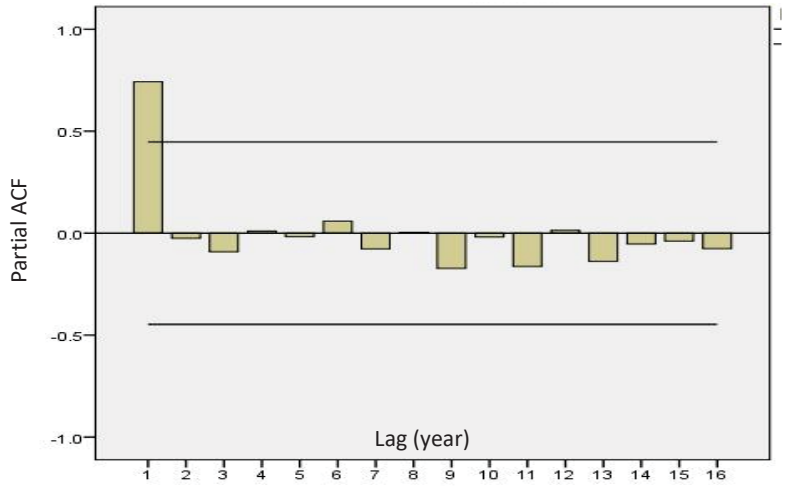

Figure 3: Partial Autocorrelation of Patents by Toyota

3.3 Time-Series analysis (2): Cross correlation function

Table 2 explains cross correlation. The first row indicates cross-correlated time-series for all patents and all types of partnership. The results indicate that the effects of partnership on inter-organisational learning were delayed but persistent. The second row shows cross-correlated time-series for all patents as well as patents submitted with suppliers. The inter-organisational learning effect from suppliers have a short duration. Figures for four years later are considerably small. Thus, the effect of suppliers lasts less than four years. The third row shows cross-correlated time-series for all patents along with patents submitted with a core partner in basic research. The greatest effects of inter-organisational learning appear after four years and decline at eight years. Note that the effect at four years is greater than that at two years. Although the effect of partnerships with suppliers disappears after a short time (less than four years), the effect of partnership lasts four years. It is supposed that this time-lag has been responsible for misleading previous studies.

Therefore, since the effects of partnership, especially with a core partner, are long term, partnerships must be long-term to be the most effective.

Table 2: Cross-Correlation by Type of Partnership

Type of Partnership	2 years later	4 years later	6 years later	8 years later
Patents * All partnership	0.949	0.761	0.513	0.233
Patents * with Supplier	0.480	0.064	--	--
Patents * with Core Partner	0.739	0.763	0.442	0.068

4. Discussion

On the basis of PACF, it has been confirmed that Toyota has been steadily accumulating R&D capability. there still remains a question regarding the theme: how can Toyota become the top R&D company in rechargeable battery technology? From Figures 1 and 2, the number of patent applications by Toyota increased dramatically in around 2005, when their partnership with their core partner expired. This is because the inter-organisational learning effects from this partnership had a delayed effect (see Table 2).

In addition, Toyota's management of their partnerships was excellent. Toyota formed partnerships more aggressively than did Nissan. However, Toyota also prepared for this period of partnership in advance. In accord with the absorptive capacity (Cohen and Levinthal, 1990), this study illuminates the fact that Toyota had researched rechargeable battery to some extent before commencing their core partnership. This experience through trial-and-error enabled Toyota to have a knowledge base of absorptive capacity (Lane and Lubatkin, 1998; Helfat, 1997). Toyota was then able to make the most of the inter-organisational learning effects from their partnerships.

In Table 2, the delayed effects of inter-organisational learning can be seen, in support of Hypothesis 1. The term during which the effects of a supplier partnership and a core partnership (basic research) are observable is different; the effects from a core partner can be seen for a longer time period than those of supplier partnerships. Thus, by focusing on the effect term lag, this finding can offer a solution to the trade-off problem indicated by previous research. Thus, Hypothesis 2 is supported. In terms of partnership governance, it was crucial whether Toyota maintained a long-term partnership or not, since long-term inter-organisational learning promotes more significant learning effects. Moreover, because the learning effect is delayed, Toyota patiently maintained its partnership and improved its own R&D capability for the long term.

From 2005, Toyota independently researched the rechargeable battery using their internal R&D capability, which had been brought about via inter-organisational learning through partnerships. Evidence for this fact can be seen below in Table 3. The term during which Toyota increased their patent applications is between 2006 and 2009. This study extracts high-value patents from all patents for which Toyota applied, using the criteria of patent registration with the patent office and patent citations by other companies. For extracted patents, this study analyses each patent's forward citation, from which the knowledge source of each patent can be confirmed. Table 3 presents patent citation data (knowledge source), by which it can be observed that Toyota acquired more knowledge from a previous core partner, Panasonic (a follower company), than from leader company Sanyo. Therefore, during this time period, Toyota's capability to initiate internal R&D and become a top R&D company was derived from its previous long-term partnership experience with a core partner. The information in Figures 2 and 6 indicate that Hypothesis 3 is supported.

Table 3: Details of High-Value Patents by Partners

High-Value Patents (Cited by others and registered)	Core Partner (Follower) Panasonic	Non-Core Partner (Leader) Sanyo
353 (%)	97 (27.5%)	65 (18.4%)

In summary, the findings of this study are illustrated in Figure 4. At first, Toyota independently researched to accumulate absorptive capacity. Subsequently, Toyota embarked on a partnership with a core partner to promote inter-organisational learning, since Toyota was not familiar with the new rechargeable battery technology, the lithium-ion battery. Finally, Toyota initiated independent internal R&D as a top R&D company in the rechargeable battery industry.

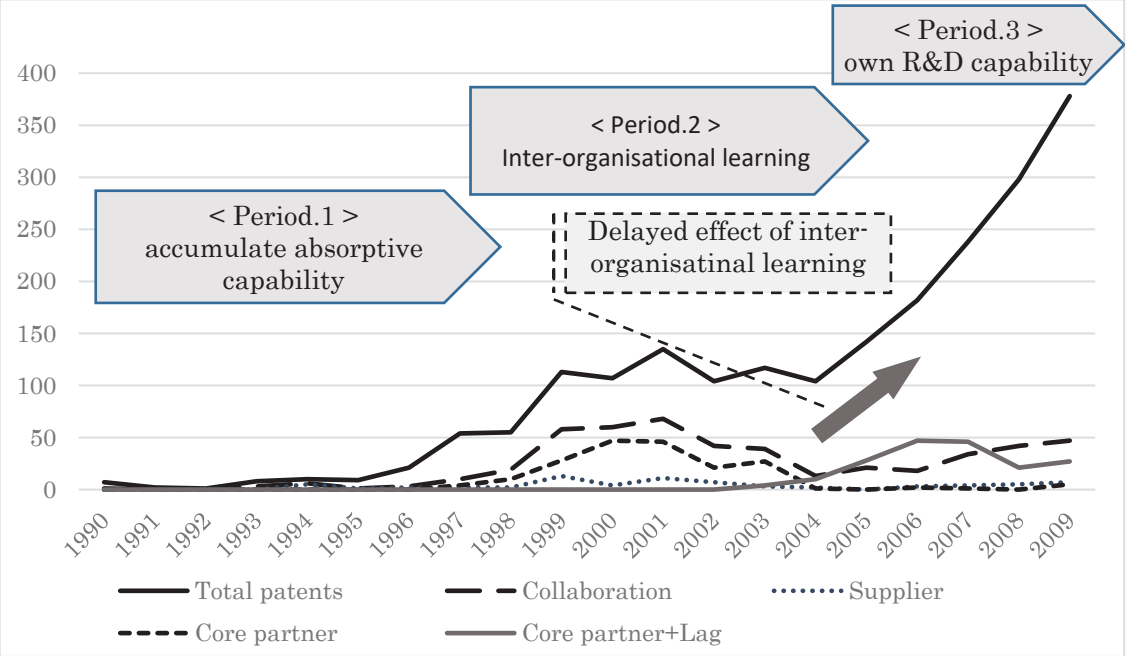

Figure 4: Summary of Findings

To test the validity of these findings, this study compares the management of Toyota and Nissan (see Figure 5). At first, during Period 1 in Figure 4, both Toyota and Nissan promoted internal R&D, which led to their knowledge bases in the next stage. Then in period of 2, Toyota formed a partnership with a core partner, whereas Nissan did not. Moreover, Toyota formed partnerships with more partners than did Nissan. Finally, in Period 3, Toyota initiated internal R&D and established itself as a leader in rechargeable battery technology R&D.

	Toyota	Nissan
Absorptive Capability; Preparation for Partnership (Period 1)	○	○
Long-Term Partnership with a Core Partner (Period 2)	○	×
Partnership for Basic Research and Supply Chain Research (Period 2)	○	△
Performance; Delayed Effect from Inter-Organisational Learning (Period 3)	◎ (Top R&D company)	×

Figure 5: Comparison with Toyota and Nissan

5. Conclusion

By cross-correlating lagged patent data for Toyota and Nissan, this study documented the following. First, open innovation via partnerships for the purpose of both basic research and supply chain research generates learning effects. Second, those learning effects are delayed, significant and persistent. Third, our findings counter claims to previous studies from organisational learning. Previous studies ignored time lags for learning from partnerships of basic research and supply chain. Therefore, Hypotheses 1 and 2 are supported. Fourth, this study documented the importance of a core partner and a long-term partnership. Toyota's core partner (Panasonic) was familiar with rechargeable battery, and Toyota, which had accumulated sufficient absorptive capacity through their previous independent research, ultimately benefitted from that long-term partnership several years later. From the data on patents as a head applicant (Figure 2), Toyota increased their patent applications as a head applicant rapidly since the year 2005, before their partnership with Panasonic expired. This is because Toyota was steadily accumulating R&D capability (see Figure 3); by around 2005, the company had accumulated enough capabilities to initiate their own independent internal R&D. This significant increase in their capabilities ultimately led to Toyota becoming a top R&D company in the industry. Therefore, Hypothesis 3 is also supported.

Because Toyota is an automobile company, Toyota was not familiar with rechargeable battery technology in the 1990s. Actually, from the 1990s to the middle of the 2000s, Toyota and Nissan were at the same rechargeable battery R&D level. However, during this time period, Toyota was proactive to open innovation for the purpose of inter-organisational learning, and Nissan seemed to be less so. Management of open innovation gave rise to significant differences between the development of the two automobile companies' R&D capabilities. Previous studies on open innovation has illuminated the direct effects of open innovation, such as the development of innovative technologies, but this study reveals the existence of other indirect effects, such as the enhancement of inter-organisational learning. By utilizing open innovation, Toyota Toyota increased their number of patent applications as a direct effect of promoting open innovation, but the company also increased their R&D capabilities through the inter-organisational learning enhancements that occurred as an indirect effect.

The practical implications of this study include the following. The term of a partnership is an important factor on determining the success of open innovation efforts. A company that plans to advance into a new technological area should wait for the delayed effects of inter-organisational learning. Moreover, the originality of this study is in describing the process from pre-partnership to post-partnership via verification of this delayed effect. Toyota was proactive to open innovation, although Nissan was not. This difference in management of open innovation gave rise to significant differences between the two automobile companies (see Figure 5). The main contribution of this study to the research is in terms of changing perspectives, namely, considering the inter-organisational learning process as an effect of open innovation as well as the fact that it is a delayed effect.

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