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Strategic alliance with Frenemy in Electric Vehicle Industry for Commercialization

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Eco-friendly technologies are crucial for firms to sustain their competitiveness as well as properly cope with international agreement which encourages reducing greenhouse gases. Electric vehicle (EV), in terms of this view, is significant since it would be dominant mobilities in the future by allowing firms to have competitiveness and solving for environmental problems. Hence, it is pivotal for firms to commercialize relevant technologies. In order to this, we used patent analysis to identify firms' strategic characters and core technology in electric vehicle industry. The analysis of strategic characters was carried out via patent portfolio analysis by calculating patent indicators regarding technology commercialization. Plus, network analysis was carried out to identify the core technologies of firms. With the two results, the final strategic framework for commercialization was established. The framework could be used for choosing appropriate collaboration partners and avoiding useless competition.

Keywords: Strategic Alliance, Technology Commercialization, Electric Vehicle, Patent Analysis, Network Analysis

Introduction

With the increasing pressure on firms to reduce greenhouse gas, eco-friendly technologies are crucial for firms to capture competitiveness. One of exemplar of them is electric vehicle (EV) since EV has played an important role in solving environmental problems but also it has changed the paradigm to profit from the existing industry[1].This makes the boundaries of EV industry blur. In commercializing and profiting from EV industry, therefore, many firms should find proper partners in technological and business aspects. Given this circumstance, most of firms need to pursue strategic alliances with players in order to reduce uncertainty in new technology and new market[2]. Although existing studies have examined commercialization and strategic alliance based on patent analysis, they are likely to be skewed to mathematical analysis. To improve such limitations, we carried out patent analysis focusing on two aspects. First, in order to define firms' strategic characters in EV industry, we used the concept of patent portfolio by calculating patent indicators regarding commercialization capacity and the indicators are classified into four groups. Second, we conducted patent network analysis in order to identify core technologies of selected firms. The results are combined to yield strategic framework which indicates the firms' strategic characters and core technologies and business areas.

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Strategic alliance for commercialization

In current business areas, convergence is pivotal to create new drivers of growth and technological innovation across all industries[3]. This convergence is so comprehensive in EV that is changing most of elements in value creation[4]. Compared to traditional value creation, for example, IT firms, which are strangers in existing vehicle industry, can have opportunities to expand their business by providing charging service[5]. Given this value-creation in EV, it is difficult for firms to profit independently[6]. For successfully commercializing firms' potential resources, they should make a strategic alliance, such as partnership, with diverse players[7]. Also, it is important to examine the firms' capacity in research and development (R&D) or strategic characters and their core technology areas[8]. In order to achieve above goal, patent analysis is appropriate for identify firms' strategic position and core technologies in EV. Among patent analysis, patent portfolio analysis makes it possible to figure out the competitor or partners' R&D activity, how much concentration on certain technologies or technology trajectory[9]. In terms of EV commercialization, patent analysis is more suitable due to two reasons. First, this industry has still high uncertain in technology and market. Predicting R&D activity of competitors and potential partners gives them business opportunities, such as partnership between firms with whom technologies are compatible[10,11]. Patent data primarily is reliable and comprehensive information as a proxy of R&D activity, which is helpful to elicit other players' status and strategy. Second, EV industry shows low rate of consumer adoption (less 10% of total vehicles)[12] and still has not arrived at main-stream market, which means that there has not yet been domain design[13]. In this circumstance, it is more effective to analyze firms' side, such as R&D status, rather market side, such as sales or target customers.

Research Method

Overview and Research Model

The goal of this paper is to build a framework for commercialization for firms to build strategic alliance. For this, we carried out patent analysis for finding strategic characters of firms and their core technology areas, and then represented the two results as a form of framework through combining them in vertical axes and horizontal axes. A specific empirical analysis is as following. First, in order to find strategic characters of firms, we carried out patent portfolio analysis. It is required to calculate patent indicators regarding commercialization, and we selected eight patent indicators, which are most relevant in R&D and commercialization capacity. Afterwards, factor analysis and cluster analysis were conducted to classify these indicators certain groups based on their similarity. These groups have unique characters of R&D and commercialization, and they make firms discernable and find strategic characters of firms in EV industry. Second, in order to find core technologies of these firms, we carried out network analysis based on patent data. Network analysis can represent the link (linked if there is citation or possession the patent regarding the technology) between firms or firms and technologies. By doing this, we could find core technologies of firms, but also their core business area in complex industry, EV.

Data Collection and Preprocessing

In order to reflect the strategic character of the players in EV industry, we collected 3,296 units of patent data related to EV and then removed noise data, which is not useful or meaningful for identifying firms' strategy characters or core technologies. After removal of noise data, we finally obtained 2,714 units of patent data which are issued to and publicized by the United States Patents and Trademarks Office (USPTO) using WIPSON database. The period of patent registered is between January 1st, 2010 and January 1st, 2016. About 74 firms possessed the patent data respectively, but approximately 50 percent of data belong to top 30 firms. Thus, we selected 30 firms patent data since the other firms' patent data cannot be analyzed significantly due to negligible amount of data. In brief, 1,271 units of patent data was used to analyze 'patent portfolio' and 'network analysis' as subjects.

Patent Portfolio Analysis

In order to understand firms' strategic characters in EV industry, we carried out patent portfolio analysis. Patent portfolio indicates that firms' R&D direction and thus decision makers can discern which firms have specific capability and influential power on EV industry through patent portfolio. The analysis is as following steps. First, we selected patent indicators related to R&D activity and influence on other firms. We calculated each

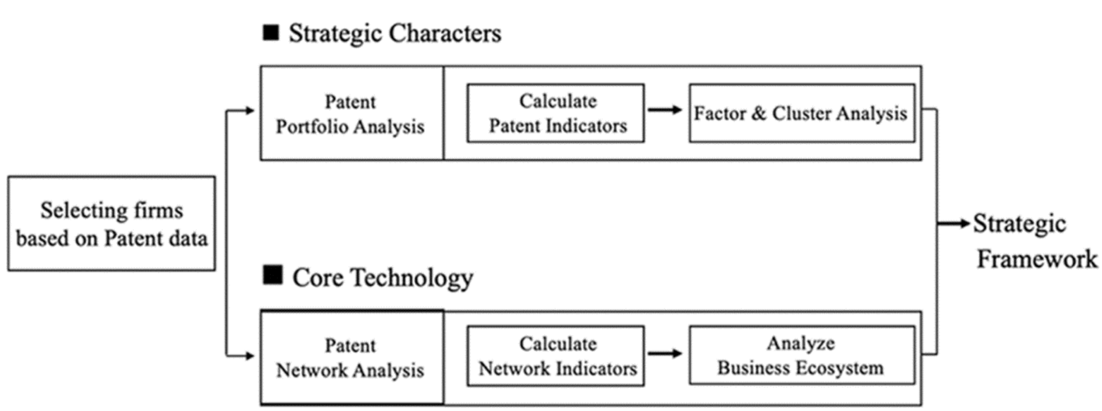

Fig. 1 — Research Model

of eight indicators for 30 firms. The definition of these indicators is described in table 1.

Second, we carried out factor analysis to classify the patent indicators based on similarity. Factor analysis classifies these indicators based on covariance and correlation among them. For analysis, we standardized these indicators as normal distribution. With standardized indicators, we calculated correlation and covariance among these indicators. Afterwards, eigen-value and factor loading were calculated to determine the number of factors. The result of factor analysis classified patent indicators into a few of factors based on similarity and this result can explain the strategic characters of firms. Lastly, we implemented cluster analysis in order to classify the 30 firms to make the firms classified based on similarity. The clusters were determined based on factors which derived from above factor analysis. Cluster analysis consists of two steps, which are hierarchical and non-hierarchical analysis. Firstly, we did hierarchical analysis through dendrogram to obtain the number of clusters, and did non-hierarchical analysis to determine specific number of clusters using analysis of variance (ANOVA).

Network Analysis

The purpose of network analysis is to identify selected 30 firms' core technology area. As above mentioned, since firms in EV industry are different from traditional automobile industry, it is required to identify their core technology. Previous studies used

Table 1 — Measurement of Patent Indicators

Indicator	Definition and Measurement
NP (Number of Patents)	A variable that shows a company's R&D activity results. It analyzes the progress of applications and growth rate, and can identify the interest and focus for a certain technology. However, it cannot reflect the technology's qualitative aspects. (Ernst 2003; Tseng *et al*. 2011; KIPO 2012) [Measurement] Calculated in person
NC (Number of Citation)	The number of times the patent was cited. It is directly related to the patent's value, and it can be used for the company's strategic decision making. (Harhoff *et al*. 2003) [Measurement] Calculated in person
PCPA (Percentage of Company Patents in the Area)	An indicator that shows the value from number of particular patents in a certain industry divided by number of a company's total patents as a ratio. It identifies the company's core technology area, enabling strategic decision making (Schmoch 1993; Tseng *et al*. 2011) [Measurement] $\frac{Number\ of\ Particular\ Patents}{Number\ of\ Total\ Patents}$
CI (Citation Index)	The mean value of the number of the patent's post citations. It is related to the patent's quality such as the technological value and its market potential. It shows the value of the R&D's primary result, which is the patent's innovation. (KIPO 2012; Tseng *et al*. 2011) [Measurement] $\frac{Number\ of\ Cited\ Patents}{NP}$
CII (Current Impact Index)	The degree of how many times the patent was cited in the last 5 years. It is derived by comparing the actual number of citations and the expected number of citations. When the value is high, it can be seen as having a large impact on other technologies and agents (Huang *et al*. 2003; Narin 1995; Tseng *et al*. 2011) [Measurement] $\frac{\sum_{1st\ year}^{5th\ year}(degree\ of\ citation * NP)}{\sum_{1st\ year}^{5th\ year} NP}$
TS (Technology Strength)	An indicator that combines the CII indicator and the NP indicator and quantitatively derives the technological impact index that a certain patent or technology has. It identifies the technological strength of a certain patent and shows the patent's impact by adding the strength of the impact on the industry and the economic agents as well as the NP as weight value (KIPO 2012; Tseng *et al*. 2011) [Measurement] CII * NP
SL (Science Linkage)	The degree of the patent's linkage to scientific knowledge. IT can examine the potential for having impact on basic and advanced sciences and related technologies. It is also deeply related to the patent's innovativeness, and can later be used for disruptive innovation or as a new driver of growth in the industry (Tseng *et al*. 2011; KIPO 2012) [Measurement] $\frac{Number\ of\ Citing\ non-Patents}{Number\ of\ Citing\ Patents}$
SS (Science Strength)	An indicator that multiplies SL and NP, and reflects the qualitative aspect of the patent's innovativeness possessed by the agent that owns the patent (Tseng *et al*. 2011) [Measurement] SL * NP

standard classification of patents (IPC or UPC) code for identifying firms' technology and business area. However, this method cannot reflect implicit aspects of firms due to complexity of EV industry. So, we used the concept of business ecosystem to find proper area for each firm. The analysis is as following steps. First, we set the firms and IPC as "node" and if the firms have the IPC (patent), make a link between them. This node and link build a network. Also, we calculated network indicators, such as the degree of centrality, which is how much a certain node has positive relationship between other nodes. By doing so, it is possible to find firms' core technology area. Second, we applied this result to the concept of business ecosystem to overcome limitation of only using IPC or UPC in order to match core technologies to business areas. The element of business ecosystem of EV is Zulkarnain's study (Manufacturers, Battery suppliers, Charging infrastructure, Regulators, End-users). The study includes specific business areas and major players of EV industry, thus it should be useful in indicating the element of business ecosystem of EV. Among them, we selected manufacturers, battery suppliers, and charging infrastructure since EV industry has not formed main stream market yet. The result of firms' IPC and the degree of centrality was applied to the business ecosystem to match core technology areas. This step was qualitative analysis through comparison the patent name, claims, applicants' career, etc. to the patent itself.

Empirical Results

Patent Portfolio Analysis

After calculating patent indicators of 30 firms, factor analysis was carried out. Before factor analysis, the KMO test and Bartlett test was done in order to examine the fitness of patent indicators. With suitable results of KMO value and Bartlett p-value, we concluded that these patent indicators are proper for factor analysis. We used principle component analysis (PCA) for factor analysis. Result of PCA, we should qualify these indicators to a few of factors and we used Eigen-value which more than 1 value means these factors can include patent indicators. Three factors have Eigen-value of more than 1. For the three factors, we did factor loadings to decide which factors should include patent indicators based on correlation. As a result, three factors were selected including eight patent indicators. As a result, Factor 1 indicates strong correlation with and includes five patent indicators, such as NP, TS, SS, NC, PCPA. Given this, Factor 1 can be labeled as Patent Activity, which is relevant with the quantitative activity of R&D and have many patent rights related to EV industry. Also, Factor 2, having high factor loading in CI, CII, was labeled as Patent Quality, which indicates the high degree of citation and strong influence on other firms. Lastly, Factor 3 was labeled as Innovative Patent, which means that high potential due to the relation to science areas. This factor mainly relates to basic science, technology and potential patent.

In addition, we carried out cluster analysis to classify 30 firms to certain groups based on the similarity of them. Cluster analysis was done as 2 stages of hierarchical and non-hierarchical analysis. Specific steps are as below. First, hierarchical analysis was carried out using the Ward's Linkage method, which measuring the Euclidean distance among 30 firms. This analysis determined possible the number of clusters. However, there should be the suitable number of clusters and it normally decided by ANOVA. As a result, the number of four clusters shows the highest F-value, which validates the number of clusters. Therefore, the suitable number of clusters for 30 firms are four. The 30 firms can be classified into each four clusters based on K-means clustering method. These clusters itself classify 30 firms functionally not significantly, hence, it is required to explain what each cluster explains strategic characters. In order to explain the character of each clusters, we used factor score. The result of comparison with factor score is described in Table 3.

All clusters are explained by factors and labeled indicating the characters of the clusters as below four groups.

1) Technology Leading: firms in cluster 2 can be explained by Patent Activity (factor 1) showing more active patent applicants and R&D activity.
2) Technology Quality: cluster 3 has the highest value on Patent Quality (factor 2), showing high impact on the industry due to a high number of cited patents.

Table 2 — Factor Loadings

Variables	Factor1	Factor2	Factor3
NP	9281	-.0025	-.1977
TS	7415	.0629	-.0442
SS	7430	.0750	.5873
NC	7526	.5986	-.0339
PCPA	3373	-.4219	-.6418
CI	1745	.8932	.1788
CII	0951	.9334	.1344
SL	-.0329	.0787	.9428

3) Technology Potential: cluster 4 has the best score in Innovative Patent (factor 3), meaning that has potential technologies in the future, thus labeled as Technology Potential.
4) Technology Steady: cluster 1 has no higher factor score in every single factor, however, this means that firms in this cluster are still hesitating on R&D and have timid action in commercialization.

Table 3 — Result of cluster characteristics using average of factor scores

Factors	Cluster	Average of Factor Score
Patent Activity (NP, TS, SS, PCPA, NC)	1	-0.85
	2	**1.47**
	3	-0.29
	4	0.04
Patent Quality (CI, CII)	1	-1.06
	2	0.18
	3	**0.58**
	4	0.48
Innovative Patent (SL)	1	-0.09
	2	-0.43
	3	-0.82
	4	**1.17**

Network Analysis

In order to identify the core technology of 30 firms, IPC and the firms are connected as a network. This network indicates core technologies which are cited and possessed by the firms. For this, we use digraph package in R and Fruchterman-Reingold algorithm to visualize and analyze the degree centrality of IPC as nodes. As a result, eight IPC code represent high degree centrality, which means that these technologies are core for the firms. The criteria for selecting crucial IPC code is that high centrality of IPC is over 50 since the average of high degree centrality is 5.12. Selected IPC should be regarded as core technologies in EV industry. After network analysis, we applied the eight core technologies of the firms to the concept of business ecosystem to identify which business areas can include the core technologies. Comparing patent qualitative aspects such as claims, applicants (person) with business ecosystem's elements (manufacturers, battery suppliers, charging infrastructure), we assorted core technologies of the firms in relevant areas. Finally, we could match the core technologies of firms to business areas based on three elements of business ecosystem; EVM (electric vehicle manufacturers), Charging Infrastructure, and Battery suppliers.

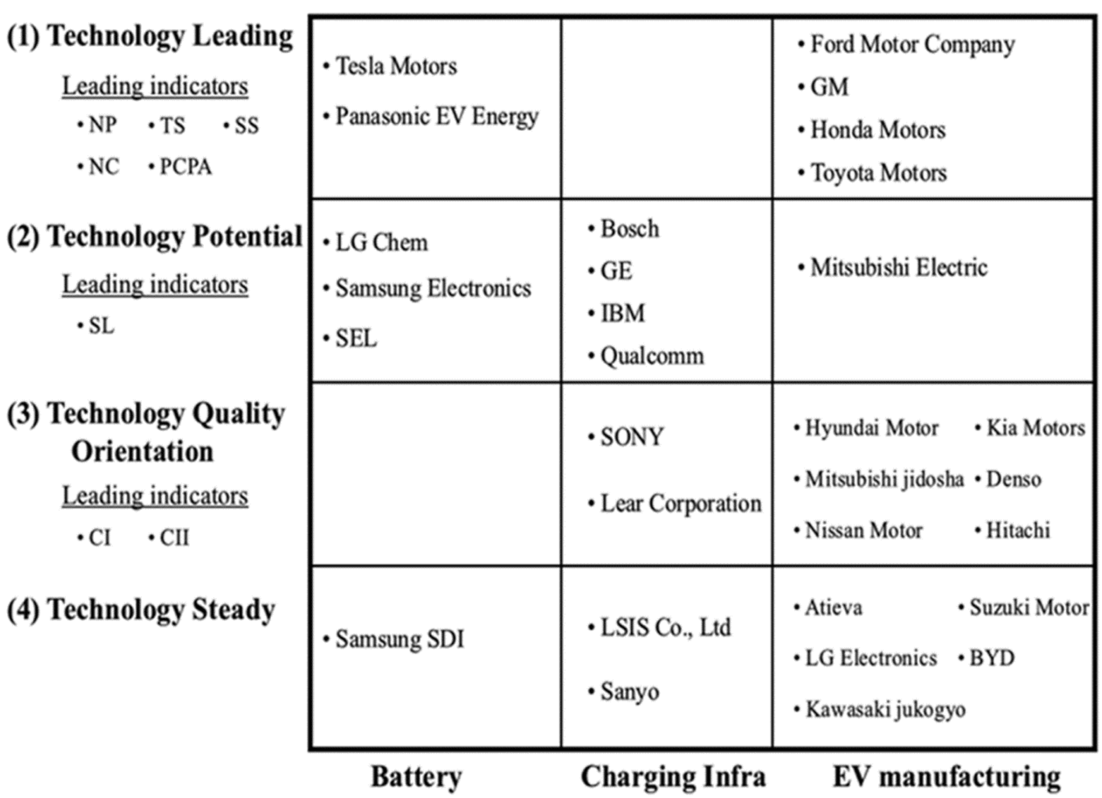

Fig. 2 — Strategic Framework for commercialization

Strategic framework for commercialization

As a result, we obtained two things. First, firms' strategic characters of commercialization (patent portfolio). Second, core technologies and their specific areas as business ecosystem elements (Network analysis). With these two results, we made a strategic framework for firms to understand the competitors and potential partners' strategic characters and their core technologies' areas based on elements of EV business ecosystem. With this strategic framework, firms can understand major firms' strategic characters in R&D and commercialization, also recognize their capacity in EV industry. Plus, core technologies of the firms based on EV business ecosystem guides firms to find which firms and core technologies are relevant in manufacturers, battery suppliers and charging infrastructure. These information helps firms to decide strategy for alliance which firms have potential in the future or can develop essential technologies.

Conclusion

This study examined strategic characters and core technologies of major firms in EV industry for successful commercialization. The crucial implication of this study is providing useful information about strategic alliance with major firms and this can reduce the risk of incompatible technologies with other firms and it is effective for both of incumbent firms and newly entering firms, such as ICT firms based on charging service. They should form positive strategic alliance to commercialize their technologies and resources and select proper firms using this strategic framework. However, we should admit some limitations of our study. This study mainly focuses on major firms and their technological side in terms of commercialization. Potential rising firms which have small patent can be influential, but, in this study, only major firms are considered. Also, even though the consumer-sided information has not been significant yet, further study should consider the market information such as preference, income level. Plus, the new trend of EV is sharing service. This aspect could be considered in the future by using SNS data or extracting useful data from online-platform.

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