Entry Conditions, Firm Strategies, and Their Relationships on the Innovation Performance of Emerging Green Industry

Gunno Park* and Jina Kang**

*Technology Management, Economics, and Policy Program, Seoul National University
599 Gwanak-ro, Gwanak-gu, Seoul, South Korea (gunno_park@hanmail.net)

**Department of Industrial Engineering, Technology Management, Economics, and Policy Program, Seoul National University
599 Gwanak-ro, Gwanak-gu, Seoul, South Korea
(Corresponding author: profkang@snu.ac.kr)

Summary

This paper examines the multidimensional effects of entry conditions and firm strategies in the emerging solar cell industry. It extends prior research on entry conditions, which have been separately examined by entry timing and entry size. There has been a noteworthy lack of empirical evidence on the relationship between entry conditions and firm strategies. To fill the gaps in extant research on entry conditions, this paper investigates whether entry timing and size have any effects on innovation performance, and how firm strategies, such as collaboration and technology portfolio after entry, strengthen or weaken these effects. Results suggest that entering the market earlier than competitors consistently works more beneficially for innovation performance than firm size. Furthermore, empirical results reveal that, after market entrance, the collaboration strategy of the firm is positively related to innovation performance. However, the positive effect of collaboration is relatively diminished for early entrants. In contrast, the effect holds true for late entrants who require aggressive collaboration. Building technology portfolio has a negative relationship on innovation performance, and such influence is more evident in late entrants.

Keywords: entry timing, entry size, collaboration, technology portfolio, solar cell industry

1. Introduction

Growing interest in green technologies, as the engine for future growth and new solutions to pollution and energy, has been reflected in the number of studies on emerging green industries (Shum and Watanabe, 2007; Citigroup, 2008). When potential entrants consider entering the emerging industries, fundamental strategic decisions such as “when” and “what scale” have to be tackled (Ayal and Zif, 1979). This brings up critical questions for potential entrants, such as “Do early entrants possess competitive advantage over late entrants?” and “Do large-sized entrants with rich resources have competitive advantage over small-sized entrants once they enter the emerging industry?”.

Many studies have been to solve these questions, and these efforts have been established as an important research field relating to entry conditions. Research on entry conditions affecting firm performance has been developed as two separate streams of research. One research field aims to explore effects of entry timing on firm performance. Since the research of Bain (1956), industrial economists have been interested in how and why entry barriers are built and maintained. A recent important stream of this research field was initiated by Lieberman and Montgomery (1988), who began using the term “first-mover advantage,” and investigated how and why early entrants have relative advantage over late entrants. The second research field involves entry size effects. Since the emergence of Gibrat’s law, which assumes that firm survival is independent of size, research on entry size has been conducted to determine the true relationship between firm entry size and firm growth (Agarwal and Audretsch, 2001). A large body of evidence suggests that the likelihood of firm growth and survival is not independent of entry size. Specifically, most studies have found that entry size is positively related to firm growth, enhancement of market share, and the likelihood of firm survival (Audretsch, 1991; 1995; Geroski, 1995; Sutton, 1997; Caves, 1998; Agarwal and Audretsch, 2001).

However, although the need for the integrated perspective has been mentioned by researchers such as Kerin, Varadarajan, and Peterson (1992), each research area has been independently developed. A few studies have been focused on the effects of entry timing in conjunction with entry size (Mascarenhas, 1997; Rodriguez-Pinto, Gutierrez-Cillan; Rodriguez-Escudero, 2006). Another limitation of previous research on entry conditions is that there is no consideration of firm strategies to enhance performance after entering the market. Moreover, there is a noteworthy lack of empirical studies on the relationship between entry conditions and firm strategies (i.e., collaboration and technology portfolio). The aforementioned two types of limitation interfere with further application of theory for practitioners and researchers.

To fill the gaps found in the previous research on entry conditions, this paper examines whether entry timing and size have effects on innovation performance, and how firm strategies after market entry strengthen or weaken these effects. The three objectives of this paper are as follows: i) to identify the joint effect of initial entry conditions, such as entry timing and entry size, on innovation performance; ii) to test moderating effects of entry conditions at the point of entry and firm strategies after market entry on innovation performance; and iii) to devise customized firm strategies aimed to increase innovation performance based on different entry conditions.

This paper conducts empirical research through analysis of data collected from the worldwide solar (PV, photovoltaic) cell industries. With the growing interest in green technology and as the new momentum to development, the solar cell industry has recently gained much attention (Shum and Watanabe, 2007; Citigroup, 2008). Many firms are actively involved in the solar cell industry; therefore, information associated with market entry is relatively abundant. Hopefully, results of this paper can help firms that have plans to enter the solar cell market in the near future.

We begin with a review of past research on entry conditions, firm strategies, and their relationships on innovation performance. Based on these reviews, we present eight hypotheses. Next, we discuss the current solar cell industry and its technological characteristics to help readers understand the industry dynamics and subsequent contribution of our research. Analyses and results from empirical test of worldwide solar cell manufacturers are then described. Finally, we propose several firm-specific strategies depending on entry conditions.

2. Extant Literature and Hypotheses Development

2.1 Entry Conditions: Entry Timing and Entry Size

The impact of market entry conditions on firm performance is one of the main research topics in strategic management (Lieberman and Montgomery, 1988; Agarwal and Gort, 1996; Klepper and Simons, 2000; Helfat and Lieberman, 2002). Since the seminal work of Bain in 1956, this research area has gradually received greater attention from both the industry and academia. In recent years, with the growing competency of the enterprises from the developing Asian countries and their expansion into high-tech industries (in particular, semiconductor, display, and mobile industries), the importance of entry conditions has been recognized (Schnaars, 1994; Mathews and Cho, 2000).

Research on entry conditions can be divided into two large research streams. The entry conditions comprise entry timing, which is the point when the firm enters the market, and entry size, which is the size of the firm at the point of entry. Research stream of "entry timing" has been established from Bain (1956), and through Lieberman and Montgomery (1988), who suggested the concept of first-mover advantage. Research stream of "entry size" has been formed by economists, who were stimulated by Gibrat's law.

Previous research on entry timing reveals that it has significant impact on the performance of firm and new products in many areas of study, such as economics and marketing (Crawford, 1977; Lieberman and Montgomery, 1988; Robinson, 1988; Lambkin, 1988; Carpenter and Nakamoto, 1990; Agarwal and Gort, 1996; Dutrenit, 2007). More specifically, on the average, early entrants maintain higher market shares (Robinson and Fornell, 1985; Urban, et al., 1986; Lambkin, 1988; Robinson, 1988; Mitchell, 1991; Mascarenhas, 2006) and have higher chances of survival in a market than subsequent entrants (Lambkin and Day, 1989; Mascarenhas, 1997; 2006). This positive performance relationship arises for various reasons. Early entrants have the first choice of locations, employees, agents, and customers. They may be able to obtain inputs at lower market prices than late entrants. Customers may view early entrants as prototypical of the new product category. Early entrants can create and exploit buyer-switching costs, such as contract renegotiation and penalties (Lieberman and Montgomery, 1988). According to these studies, there is a discernible difference in the performance according to the order of entry, and early entrants usually display higher performance than late entrants. A relatively small number of studies have commented on the advantages associated with late entrants (Lilien and Yoon, 1990; Golder and Tellis, 1993; Schnaars, 1994; Shankar, Carpenter and Krishnamurhti, 1998) Entry timing is also considered a key factor, and the relevance of the decision on this variable is reflected in a large number of papers that have attempted to evaluate the connection of entry timing with firm performance.

Entry timing is not the only important factor for decision making when entering new markets. Other variables can also affect the outcomes. In the present research, in addition to entry timing, another dimension of the entry condition is analyzed: entry size. Previous research on entry size has empirically shown that the size of the firm at the point of entry is not independent of its survival rate, and has indicated that larger size works more favorably to the probability of survival (Geroski, 1995; Sutton, 1997; Caves, 1998; Agarwal and Audertsch, 2001; Rasiah and Gopi, 2008). Sutton (1997) specified that size in the entry year is linked to firm growth in the subsequent time period. The major theoretical interpretation of the positive relationship between firm entry size and the likelihood of survival builds on the "noisy selection model" introduced by Jovanovic (1982), which was improved upon by Pakes and Ericson (1998). The central implication of the model is that firms may enter at a small, even suboptimal, scale of output and then expand, if merited by subsequent performance (Agarwal and Audertsch, 2001). Successful entrants operating at a suboptimal scale of output will grow, whereas unsuccessful ones will remain small and may ultimately be forced to exit from the industry. Similarly, the greater the entry size in a given industry, the less the cost disadvantage imposed by an inherent size disadvantage, and the greater the likelihood of survival confronting the new entrant.

However, prior research has failed to fulfill the necessity of taking both of these conditions into account, as firms do when making decisions on the entry into new market. Mascarenhas (1997) and Rodriguez-Pinto, Gutierrez-Cillan, and Rodriguez-Escudero (2006) agreed with this lack and suggested the necessity of research jointly investigating entry timing and entry size. In this paper, the individual factors (i.e., entry size and entry timing) are referred to as entry conditions. Through joint analysis of both factors, the paper attempts to provide a more integrated view that has been missing in extant research. Based on the above discussion, two hypotheses are suggested.

Hypothesis 1: The earlier the entry timing, the higher the innovation performance.

Hypothesis 2: The larger the entry size, the higher the innovation performance.

2.2 Firm Strategies: Collaboration and Technology Portfolio

Entry conditions measured at the time of entry are not the only factors that explain innovation performance of entrants; therefore, other factors should also be considered. Although many studies have analyzed the effects of entry timing and size on performance, other dimensions, such as firm strategies, have largely been ignored (Rodriguez-Pinto, Gutierrez-Cillan, and Rodriguez-Escudero, 2006). What, then, are some of the meaningful strategies for entrants to overcome the disparities in innovation performance arising from different entry conditions?

To answer this question, this paper selects two major strategies as variables, collaboration and technology portfolio, and explores the effects of these strategies on innovation performance. First, collaboration strategy with external firms is a viable option when the firm lacks internal resources. From knowledge-based views and open innovation concepts, each firm has different knowledge and resources that can be used for innovation. Collaboration can help bridge deficiencies. This view suggests that firms possess different knowledge, and collaboration with external organizations provides a channel that facilitates resource allocation. Through collaboration, a firm can absorb the deficient internal knowledge from the partner firms (Leonard-Barton, 1995; Mowery, Oxley and Silverman, 1996). Innovation is constantly required in technology-intensive and early-stage industries, such as in the solar cell industry, because sustaining competitive advantage solely through internal technology and knowledge is difficult. Consequently, exploiting external knowledge through collaboration is especially important in such industries (Chesbrough, 2003; Teece, 2007; Gulati, 1998).

Although positive effects of collaboration activities have been proven by prior research, some researchers suggest negative aspects of collaboration activities. On a view of Transaction Cost Economics (TCE), collaboration usually entails higher transaction cost (e.g., negotiating, bidding, and monitoring) than internal R&D activity. Another negative effect is that collaboration processes relatively absorb much managerial time and energy. During collaboration process, the attention of top managers and managing functions may be diverted from internal activities (Hitt, Hoskisson, and Ireland, 1990). Although the aforementioned negative effects of collaboration strategy are mainly associated with financial and operational aspects, the negative relationship of collaboration with innovation performance and capability of knowledge creation, as covered in this paper, may be difficult to recognize. Therefore, we maintain the view that collaboration strategy could have positive effects on innovation performance. Building on these discussions, a hypothesis regarding the contribution of the collaboration activity on innovation performance can be elicited.

Hypothesis 3: After market entry, collaboration activity has a positive relationship on innovation performance.

Second, Building the technology portfolio of a firm is another important strategy for enhancing performance. When a firm faces technical uncertainty, building technology portfolio could reduce risks of uncertainty. To clarify the concept of technology portfolio strategy, we review the paper of McGrath (1997), which described and extended the real options theory. Our paper posits that real option concept can be explained in terms of “processes,” from technology development to commercialization. The technology portfolio strategy used in this paper could be explained by relating it to the initial step of real option, except for the commercialization step. According to McGrath (1997), technology portfolio strategy is used in terms of “technology option”. However, we redefine the concept of “technology option” as the “technology portfolio” to obtain its precise meaning.

The usefulness of technology portfolio under high technological uncertainty has been suggested by previous research (Trigeorgis, 1993; Dixit and Pindvck, 1994; McGrath, 1997). Dixit and Pindyck (1994) suggested that technical uncertainty highly relates to the likely probabilities of attaining technical success. Although technology uncertainty exists, to secure the benefits (e.g., positive feedback effects of scale, path dependence, and network externality) of leading firms, the firm should invest in new technologies more quickly than competing firms. Technical uncertainties create pressure on the firm to invest immediately. A firm reduces technical uncertainty only through investment in other technologies (Dixit and Pindvck, 1994).

High technological uncertainty also exists in the solar cell industry. According to the recent research conducted by Mckinsey & Company (2008), solar cell products made from silicon-wafer-based PV technology holds over 90 % of the market. However, there is a technical limit to the efficiency of the conversion of the energy and its cost. Competition against thin film PV technology is expected in the near future. Under high technological uncertainty, some solar cell firms are displaying concurrent development of both thin film and silicon-wafer-based technologies (Lorenz, Pinner, and Seitz, 2008). As such, building a technology portfolio can be a useful strategy to reduce the risk under the circumstances of technology uncertainty (Bowman and Hurry, 1993; Huchzermeier and Loch, 2001; Miller and Arikan, 2004). However, due to the lack of dominant and standard technology, developing various technologies at once disperses the resources and, consequently, has negative effect on the accumulation of profound technologies. Adopting two technologies with different technology bases is expected to generate less synergy effect.

The absence of accumulation knowledge and synergy effect has negative impacts on improving innovation performance. Evidence for this can be found in previous studies on knowledge learning. Cohen and Levinthal (1990) suggested and defined the concept of “absorptive capacity,” and identified two primary factors regarding effective absorption and production of knowledge: accumulations of related prior knowledge and R&D effort. Applying such view on the effect of the technology portfolio on innovation performance, the lack of accumulated prior knowledge and similarity between the technologies indicate that absorption and utilization of external knowledge will be difficult, leading to deterioration of innovation performance. From the resource-based view, failing to allocate the tangible and intangible resources into a specific technology will result in the difficulty of concentrated R&D activities. Therefore, with the absence of dominant technology in the early stage of technology-intensive industry, building technology portfolio is not expected to bring about a positive effect on innovation performance.

Hypothesis 4: After market entry, building a technology portfolio has a negative relationship on innovation performance.

2.3 Interactions between Entry Conditions and Firm Strategies

Previously we examined literature on the impact of entry conditions and firm strategies on innovation performance. However, asserting that the performance of a firm is absolutely dependent on the entry conditions or firm strategies would be unrealistic. As evidenced by Visa Card, Reebok, Google, and Samsung, there are cases in which late and small-sized entrants have outperformed early and large-sized entrants. Some scholars have proven that early entrants do not always hold the advantage over late entrants (Cooper, 1979; Schnaars, 1994; Golder and Tellis, 1992). Related research has revealed that early entrants are expected to show sound innovation performance following relatively rapid accumulation of knowledge and technology.

However, there are downsides, such as formation of inertia, to the stand-alone internal research over a long period (Lieberman and Montgomery, 1988). Kerin, Varadarajan, and Peterson (1992) showed that the effect of entry timing is difficult to measure, as its relations to performance are affected by the size of market, strategies of the firm, the industry characteristics, and others. Similarly, the effect of entry timing can be offset by rich resources or high internal capacity, according to the research by Moore, Boulding, and Goodstein (1991). As for entry size, even small- and medium-sized firms with relatively few resources can promote innovation performance through utilization of external resources, which are becoming increasingly diverse (Timmons, 1999). In summary, the effects of entry conditions are relatively dependent on various factors. In particular, the result of Kerin, Varadarajan, and Peterson (1992) indicates that firm strategies set after entrance may alter the effect of entry conditions. Effects of entry conditions on firm innovation performance are better explained using a contingency approach in order to account for the moderating effects of firm strategies, such as collaboration and technology portfolio. Therefore, in this paper, the following hypotheses to verify the moderating effects are drawn from the above discussion.

Hypothesis 5: The effect of entry timing on innovation performance varies depending on collaboration activity.

Hypothesis 6: The effect of entry timing on innovation performance varies depending on building technology portfolio.

Hypothesis 7: The effect of entry size on innovation performance varies depending on collaboration activity.

Hypothesis 8: The effect of entry size on innovation performance varies depending on building technology portfolio.

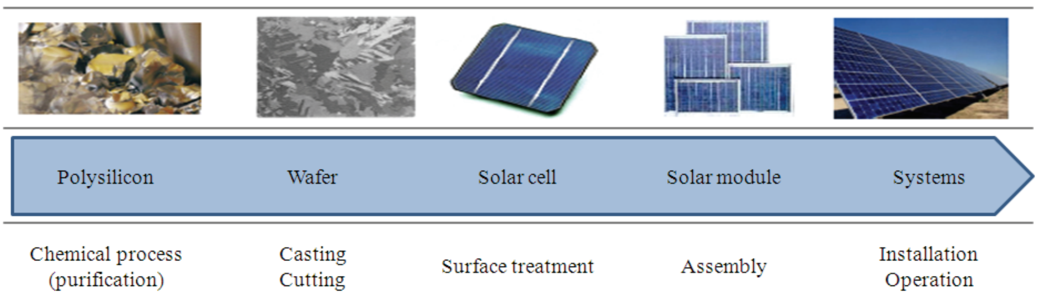
In the next section, we describe the solar cell industry used for the empirical test. We explore questions related to entry conditions, firm strategies, and their relationships by examining entry cases in the solar cell industry. To understand what a solar cell is, why the solar cell industry has entry issues, and what technology is used in manufacturing solar cell, some background knowledge is necessary.

3. Overview of the Solar Cell Industry

3.1 Emergence of the Solar Cell Industry

As energy resources and global environment issues emerge domestically and abroad, the importance of carbon-saving renewable energy, such as solar cell, is increasing. Unified statistical data or prospect is not available at present as the solar cell industry is still in its infant stage. The survey on installed capacity shows discrepancies of 3.4–5.5 GW (gigawatt) among institutions with inconsistent prospect on the long-term market growth rate. However, the solar cell industry is anticipated to grow by over 50 % in 2009 compared to the previous year. By 2010 and 2011, the demand is expected to sharply grow in most nations. From a long-term perspective, the industry and the technology are still in their early stages and the market size will grow to nearly 2000% by 2020 (Shum and Watanabe, 2007; Lorenz, Pinner, and Seitz, 2008; Citigroup, 2008).

A solar cell is essentially a photodiode, or a type of semiconductor device. Two fundamental technologies exist for manufacturing solar PV modules: crystalline silicon (x-Si), currently used in 90% of all solar PV modules manufacture, and the next generation thin film modules. In general, cells are built on either silicon or, in the case of thin film technology, glass (most commonly), plastic, or steel. Figure 1 shows a basic process flow schematic for silicon-based solar PV systems. In the case of a thin film module, the process up to the module level is different; however, it is similar from the module through the system level.



Source: Citigroup (2008).

Figure 1: Process Flow for Silicon-Based Solar PV Installation

Cells are assembled into modules (or panels), which are in turn assembled into an array (or system). The degree of vertical integration varies across the industry. Some firms only produce cells. Others produce cells, assemble them into modules, and install them at the customer site. Other players specialize in simply installing PV systems. The overall supply chain is heavily concentrated in Germany (due to the long-standing government subsidies), and to a lesser degree, Japan and the US (Shum and Watanabe, 2007). Among cell and module makers, China has the heaviest concentration due to significant recent investment and relatively little barriers to entry, whereas Taiwan and Korea, albeit major forces in the semiconductor industry today, remain relatively small players in the solar cell industry.

3.2 Specification of Solar Technology

Through the PV effect, sunlight is converted into electricity. When light hits a PV cell, it can be refracted, absorbed, or allowed to pass. Only the absorbed light generates electricity. The energy of absorbed light is transferred to electrons in the PV cell. Therefore, improvements in the solar energy conversion efficiencies are important factors for commercial diffusion. According to Citigroup (2008), silicon-wafer-based PV products display the highest efficiencies and accounts for approximately 95% of total cell production today. Several types of materials can be used for wafer-based PV; however, silicon is by far the most common. Two layers are juxtaposed: one with an abundance of electrons (which carry negative charge) and the other with an abundance of "holes" or vacancies where there would normally be an electron (this carries a positive charge). Sandwiching these together creates an electrical field that acts as a "diode," allowing electrons to flow from one side to the other, but not the other way around.

When energy from sunlight, in the form of photons, hits this cell, the energy frees electron-hole pairs and further creates an imbalance of electrons and holes. An external current path allows the electrons to flow through and back into their original side, refilling the holes. A cell is encapsulated with a number of other materials, including an antireflective coating (silicon is a shiny material and would otherwise reflect many of the photons and prevent them from being converted into usable energy). There are also contact grids on the back and, in most cases, on the front side, as well as a cover glass plate.

Silicon-wafer-based PV typically has better conversion efficiencies; however, given the high cost of polysilicon, it can be costly. Due to key material shortages, namely, polysilicon, there is a growing need to directly build diodes using various semiconductor materials on a substrate, such as glass or steel. This is called "thin film" PV, which accounts for approximately 5% of worldwide PV cell production today (Citigroup, 2008). Whereas the traditional crystalline silicon cell is 165–180 um thick, a thin film layer is only 2–3 um thick. Theoretically, thin film solar cells consume only 1% of silicon consumed by the existing solar cells, leading to a significant cost reduction. In addition, the price of the latest thin film silicon solar cell is said to be merely 30% of its counterpart. Although different semiconductor materials are being explored, the most commercial types include amorphous silicon (a-Si), Cadmium Telluride (CaTe, commercialized most successfully by First Solar), Copper Indium Selenide (CIS), and related materials (CIGS) (J. P. Morgan, 2008).

3.3 Increasing Competition in the Solar Cell Industry

Japanese enterprises such as Sharp, Kyocera, and Mitsubishi have dominated the solar cell industry until recently. With the increasing attention on green technology, enterprises from other nations are gaining increasingly larger shares of the global solar cell market. Supported by government policies and invigoration of their domestic market, Germany, China, and Taiwan have shown noticeable progress in the solar cell market. The competition is expected to further intensify with the recent announcements of participation plans by other global enterprises (Samsung, LG Electronics, and Hyundai Heavy Industry). With the escalation of competition in the solar cell industry, both early and late entrants are seeking to strategically reinforce their competitiveness for the future. Some have increased their investment on thin film and next-generation solar cell technologies, whereas others have strengthened ties with other firms or expanded either up or down stream.

4. Data and Methods

4.1 Sample and Data

As previously mentioned, this paper focuses on the solar cell industry, which has exhibited rapid growth. The solar cell industry has been noted as the next-generation growth momentum addressing global environmental problems and the issue of energy dependency of nations (Shum and Watanabe, 2007; Citigroup, 2008). Technological uncertainty is prevalent in the industry, with the absence of dominant and standard technology (Lorenz, Pinner, and Seitz, 2008). Incumbent firms from electronics, energy, and other heavy industries have announced their plans on future involvement, with other firms following this trend. Therefore, data collection for testing entry matters is comparatively straightforward, provided vigorous entrance and various entry conditions are present. The industry data is appropriate in evaluating the mutual interactions between entry conditions and strategies of individual firms, as firms display high variation in its technology portfolio.

The database was collected in two steps. First, we used the Thomsonone database for brokerage reports and searched PV-related news and articles to extract a list of 73 solar cell manufacturing global firms. Of the 73 selected, 11 were American, 18 European, 8 Japanese, 12 Chinese, 7 Taiwan, and 17 firms were from India, Korea, and other regions.

Table 1: Solar Cell Firms Broken Down by Regions

US	EU	JP	CH	TW	ROW	Total
11	18	8	12	7	17	73

Unlike the semiconductor industry, an independent category for the solar cell industry has not been formed in most of the databases. To extract firms focused primarily on solar cell manufacturing, we excluded firms providing silicon, ingot, installation, and services in the supply chain. Such exclusion was accounted for by the fact that incumbents in silicon or ingot industries, which have been supplying the semiconductor industries, may easily convert their destination of supply, resulting in ambiguous entry points. As for installation and service firms, the low requirement on innovation renders them inappropriate for the current research. Financial data from the database of DataStream and the patent data from US Patent and Trademark Office (USPTO) were used for the listed firms.

4.2 Variables

To measure the dependent variable, innovation performance, the total number of patents applied in 2008 was used. Previous empirical studies on market entry have focused on financial success or survival of a firm (Crawford, 1977; Lieberman and Montgomery, 1988; Robinson, 1988; Lambkin, 1988; Lilien and Yoon, 1990; Geroski, 1995; Sutton, 1997; Caves, 1998). This paper uses technological success or innovation as the proxy for firm performance variable.

In emerging markets, such as that of solar cells, empirical analysis using financial data is difficult owing to lack of accumulated data. Another factor that invalidates financial data as the proxy is internal capacity, such as the technological capacity of the industry, which is not accurately reflected in the financial data. The validity of the technological capacity of the industry is compromised because extensions of the facilities are planned and supported by governments. The solar cell industry displays high technology-intensive features, and improvements in energy conversion efficiency are crucial. Therefore, technological success is a vital factor (Citigroup, 2008; J. P. Morgan, 2008), as supported by Hagedoorn (1993) and Agarwal (1998), who illustrated that there is a strong propensity to focus on producing knowledge during the initial stage of technology-intensive industries to attain competitive advantage. The development of innovative capability is vital for the growth of firms in technology-intensive industries (Agarwal, 1998). Therefore, using technology innovation as the proxy for firm performance is appropriate in the solar cell industry.

The entry timing in Hypothesis 1 is measured by the number of years from the year when the first revenue is realized until 2008. For most of the cases, the point of first revenue realization differs from the alleged point of entry announced by firms in practice. Therefore, the first point of revenue realization was used to measure entry timing for consistency. To measure the entry size in Hypothesis 2, the number of employees at the point of first revenue realization was used. The patent data from USPTO was used to check the collaboration and building technology portfolio, as well as the innovation performance. Collaboration strategy in Hypothesis 3 was marked “1” if a firm has co-assigned patents and “0” otherwise. Co-assigned patent applications are typically considered outputs of R&D collaboration.

Consequently, the presence of co-assigned patents can be used as a proxy of collaboration strategy. The technology portfolio in Hypothesis 4 was checked by inspecting the types of technologies in the patents (including patent applied). If there are more than two technology types related to the solar cell, the value of technology portfolio was assigned as “1.” In contrast, if the firm focuses on one kind of technology, the value of technology portfolio was measured as “0.” For example, a mark of “1” means that a firm holds both silicon- and thin film-based technologies.

In addition, considering the variables of collaboration and technology portfolio as the firm’s activities after market entry, firm strategy variables were measured with patent data from the year following entry. We also assumed a one-year time lag between firm strategies and innovation performance. Hypotheses 5 to 8 tested the relationships between entry conditions and firm strategies. The interaction (moderating) effects between entry conditions and firm strategies were analyzed according to the four modes of interaction variables, which can be measured by multiplying two variables from entry conditions and two variables from firm strategies. Table 2 provides a summary of variables with corresponding measurement.

Table 2: Variable Information and Measurement

Variable information					Measurement
Independent variable	Entry condition	H1	Entry timing	AGE	Post entry active period until 2008 AGE=2008-year at entry
		H2	Entry size	SIZE	Total number of employment at the point of entry
	Firm strategy	H3	Collaboration	COLL	1 if co-assigned patent has been applied through R&D collaboration, 0 otherwise
		H4	Technology portfolio	TECH	1 if holding patents based on other technologies, 0 otherwise (e.g., 1 if holding both silicon- and thin film-based technologies, 0 otherwise)
	Interaction effect	H5 H6		AGE * COLL AGE * TECH	Entry condition variable times firm strategy variable
		H7 H8		SIZE * COLL SIZE * TECH	
Dependent variable	Innovation performance			INNO	Number of granted patents in year 2008
Control variable	Specialized firm			SPEC	1 if firm only specialize in solar cell products, 0 otherwise

4.3 Empirical Method Specification

In this paper, the number of patents was used as the dependent variable. The patent application is a discrete event having a positive integer. The likelihood of error is high for such variables if multiple regression analysis is used based on standard distribution assumptions. Poisson regression or negative binomial regression based on discrete distribution is more appropriate. Table 3 shows the result of descriptive statistic and correlations. The average of the dependent variable innovation performance (INNO) is 5.88, with its standard deviation reaching 10.21, which violates the basic assumption of Poisson distribution that the average and the distribution are identical. Therefore, the negative binomial regression was used in this research for analysis.

Table 3: Descriptive Statistics and Correlation Matrix

Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	Mean	Std dev.
(1) AGE	1.000								9.34	8.79
(2) SIZE	0.724	1.000							10.03	24.13
(3) COLL	0.657	0.499	1.000						0.55	0.50
(4) TECH	0.734	0.594	0.664	1.000					0.41	0.50
(5) AGE*COLL	0.979	0.721	0.782	0.763	1.000				5.06	9.44
(6) AGE*TECH	0.974	0.736	0.663	0.842	0.667	1.000			4.42	9.53
(7) SIZE*COLL	0.725	0.692	0.501	0.596	0.723	0.737	1.000		6.94	2.09
(8) SIZE*TECH	0.725	0.701	0.501	0.596	0.722	0.737	0.328	1.000	7.07	21.12
INNO									5.88	10.21

5. Results

The results of the analysis are presented in Table 4. The value of AGE variable (representing the entry timing) has significantly positive value. Thus, Hypothesis 1 is supported. Earlier entry timing yields better innovation performance. The solar cell industry displays high technology-intensive characteristics, and is currently in between the initial and growth stage. Firms in industries with such characteristics vie with one another for competitive advantage (Agarwal, 1998). Under such circumstances, early entrants have had relatively longer period to accumulate technological capacity, and this in turn, is followed by the enhancement in the innovation based on prior technological knowledge and expertise. As the result of Hypothesis 1, the first mover advantage exists in this industry.

The EMP variable, representing entry size, shows no statistical significance. Consequently, Hypothesis 2 is rejected. Such results imply that the amount of resources at the point of entry does not affect the innovation performance, a dubious result from the resource-based view.

This can be accounted for by the peculiarity of early markets in technology-intensive industries, as addressed by Agarwal and Audersch (2001). The study has empirically shown that the survival rate is less affected by the entry size in high-tech industries than in low-tech industries. Based on the results of Hypotheses 1 and 2, early entrance favors innovation performance, whereas firm size during entry is irrelevant. Therefore, firms planning to enter the industry should start investing at the earliest possible moment, although the investment may be small in size, to accumulate relevant knowledge and technology. The result can also be interpreted for the large firms as well. Even for firms with rich internal resources, rapid entry, rather than taking time to accumulate large resources, is advisable for the enhancement of innovation.

Table 4: Result of Negative Binomial Regression Analysis

Models variables	Model 1		Model 2		Model 3		Model 4	
	Coef.	S.E	Coef.	S.E	Coef.	S.E	Coef.	S.E
AGE	0.162***	0.039	0.474*	0.361	0.157***	0.033	0.698*	0.409
SIZE	-0.001	0.000	-0.001*	0.000	0.000	0.003	0.004	0.004
COLL	1.820***	0.624	5.436**	2.431	2.918***	1.208	9.244***	3.443
TECH	-2.049**	0.828	-3.986***	1.394	-3.021***	1.179	-5.506***	1.600
AGE*COLL			-0.593*	0.392			-0.882**	0.423
AGE*TECH			0.285**	0.157			0.342***	0.110
SIZE*COLL					-0.037	0.047	-0.047	0.067
SIZE*TECH					0.036	0.046	0.042	0.066
SPEC	0.841*	0.525	0.811*	0.501	0.875*	0.498	0.841**	0.340
Log likelihood	-48.286		-46.466		-44.901		-40.246	
Pseudo R^2	0.189		0.219		0.245		0.324	
LR Chi^2	22.44		26.08		29.21		38.51	

Notes: ***means under p- value 0.01, **means under p- value 0.05, *means under p- value 0.10.

The COLL variable, representing collaboration strategy, statistically shows positive value at significant level, supporting Hypothesis 3. Firms in the emerging market either make internal efforts to attain distinguished technology or collaborate with other firms to make the most out of their capacity and resources. Given the volatile nature of technology in the solar cell industry, attaining competitive advantage solely through internal knowledge, resources, and capacity is difficult. Therefore collaboration, transfer, and sharing of knowledge with other firms can benefit firms in technology-intensive industries, such as the solar cell industry, by promoting innovation performance.

The TECH variable, representing technology portfolio strategy, displays negative value at significant level, indicating that Hypothesis 4 is supported. The implication is, rather than building technology portfolio containing both of the two primary technological branches in the solar cell industry, focusing resources and capacity on one single technology would be more advantageous. With the absence of standards for technology, diversification may help reduce the risk. However, diversifying the capacity by investing on various technologies in the industry has negative influence on innovation performance.

The variable measuring interaction between AGE and COLL in the negative binomial regression analysis displays negative value at the significant level. This indicates that COLL has negative moderating effect on innovation performance with AGE, supporting Hypothesis 5. This result demonstrates that a firm with large value of AGE (i.e., an early entrant) is bound to be under negative influence if it collaborates with others. There is the benefit of reducing risk by collaborating; however, the firm is exposed to the leakage of knowledge and opportunistic behavior by the partner. Early entrants usually have accumulated knowledge and thus possess higher technological capacity. Therefore, the likelihood of the early entrants suffering from opportunistic behavior by the partner firm is high. The likely loss of technology appropriability following the leakage of technology is greater than the benefit.

The interaction variable for AGE and TECH has positive value at the statistically significant level. This indicates that TECH has positive moderating effect on AGE and innovation performance. With the accumulated technology and expertise, early entrants are likely to possess dispensable resources for technology diversification. Diversification with the available resources would help enhance innovation performance. This is consistent with the balance of exploration and exploitation from March (1991). Inertia may appear in firms that exploit one specific technology over a long period of time, restricting firms from shrewdly addressing the change in technology and new possibilities. Proper level of exploration on new technology provides variety and flexibility to the firm. With the interaction variable showing statistically significant level, Hypothesis 6 is supported. Table 5 summarizes the results of the hypotheses.

Table 5: Summary of the Hypotheses and Results

Hypotheses			Test results
Entry condition	H1	The earlier the entry timing, the higher the innovation performance	Supported
	H2	The larger the entry size, the higher the innovation performance	Not supported
Firm strategy	H3	After market entry, collaboration activity has a positive relationship on innovation performance	Supported
	H4	After market entry, building technology portfolio has a negative relationship on innovation performance	Supported
Interaction between entry condition and firm strategy	H5	The effect of entry timing on innovation performance varies depending on collaboration activity	Supported
	H6	The effect of entry timing on innovation performance varies depending on building technology portfolio	Supported
	H7	The effect of entry size on innovation performance varies depending on collaboration activity	Not supported
	H8	The effect of entry size on innovation performance varies depending on building technology portfolio	Not supported

6. Conclusion and Implications

This paper has examined entry conditions, firm strategies, and their relationships using the emerging solar cell industry, which has recently gained much attention. We have examined the impact of entry conditions and firm strategies on innovation performance. Furthermore, we have examined the interactions between conditions and strategies, as well as their combined effects on innovation performance. This study has three major contributions. First, it contributes to personalized strategy planning to firms. Whereas previous literature has provided insights into entry timing and size separately, this research provides firms with a more integrated view of entry timing and entry size. Second, the study analyzes both dynamic and static factors on the impact of entry condition. Lieberman and Montgomery (1988), Helfat and Lieberman (2002), and other researchers provided important insights on the impact of entry problem on the innovation performance of firms. In practice, however, the impacts of entry conditions are adjusted by the firm strategies, which subsequently follow (Kerin, Varadarajan, and Peterson 1992; Timmons, 1999). This paper provides empirical evidences of such view. Finally, this paper provides empirical analysis and strategic significance on an industry that, comparatively, has been less studied.

To sum up, in emerging industries such as the solar cell industry, entry timing has significant influence on innovation performance, whereas size at the point of entry provides little relevance. The result has implications on investment decision making of real option strategy. For example, firms that appropriate real option strategy invest in various technology and products to reduce technology uncertainties, and then select and focus based on the feasibility of realization and profitability. As firms are faced with limited resources, they experience difficulty in deciding the point of investment time and its size. The result of this paper indicates that the initial size of the investment is rather irrelevant to the innovation performance. Firms considering entry into emerging technology-intensive industries should invest at the earliest possible moment to exploit the advantage of early entry, however small the investment may be.

The strategies planned and executed by firms after entry have significant effect on innovation performance. Building a technology portfolio has been shown to have a negative impact on innovation performance. However, the analyses on the interactions of entry conditions and firm strategies show that the effects of firm strategies differ according to entry timing. For early entrants, the benefit of collaboration on innovation performance appears to be low, as well as the risks from building technology portfolio. In contrast, the collaboration has positive effect for late entrants; however, technology portfolio has negative effect. To enhance innovation performance, empirical research suggests that an early entrant firm should restrain itself from collaborating while building technology portfolio to reduce risk. A late entrant firm should aggressively utilize collaboration strategy while restraining itself from diversifying its resources.

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