Determinants of the Technology Commercialization of the Government-Sponsored Firms: Empirical Evidence from Korean Manufacturing

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Abstract—Understanding how scientific knowledge is transformed into commercial products in the market place and how to profit from technological innovations are important research issues. A key management challenge is how to transform promising technologies into economic returns by their commercialization. This study investigates the commercialization of government-sponsored firms and analyzes the relationship between their performance and determinants of the successful commercialization such as their internal and external capabilities. The empirical results show that the innovative capabilities, the investment on external R&D as the open innovation activities in the internal capability, and government funding for R&D and its commercialization in the external capability have significantly positive impacts on the commercialization. Moreover, it is found that the determinants of successful commercialization performance in the large sized firm are different from those of the small and medium sized firm. This study is expected to contribute to the firms’ formulation of their commercialization strategies to profit from their technological innovation and, in addition, the policy formulation to raise the firms’ performance of technology commercialization.

I. INTRODUCTION

Understanding how scientific knowledge is transformed into commercial products in the market place and how to profit from the technological innovations are important research issues [6][7]. The recent studies considered the technology commercialization as a key factor for the competitive edges of technology-based firms. A major management challenge of the firms is how to transform their promising technologies into economic returns. The technology commercialization is an essential and significant step for profiting from the technological innovations, especially in technology-based companies. The technology commercialization could be defined as an activity or a process to profit from the technological innovations, and encompasses a broad range of activities including the ideas or inventions toward specific objectives, evaluation of these objectives, downstream transfer of R&D results, and the eventual broad-based utilization outcomes [9]. Reference [14] defined the technology commercialization as “the process of acquiring ideas, augmenting them with complementary knowledge, developing and manufacturing saleable goods, and selling the goods in a market.”

Governments support firms’ technological innovations through providing technology infrastructures, public goods and services. Governments are also involved in the provision of services that leverage the technological innovation by stimulating private sector R&D and facilitating technology transfer and commercialization [13]. For example, the US Federal Government has actively pursued policies aiming at facilitating the technology transfer and commercialization. The Bayh-Dole Act was legislated to allow the universities and small business to appropriate the ownership to inventions resulting from federal government-funded research. The Technology Transfer Commercialization Act of 2000 was legislated to make it easier for federal agencies to license their inventions. The technology licensing has expanded remarkably in the US since the Bayh-Dole Act of 1980 [8][15]. In addition, the SBIR (Small Business Innovation Research) program has funded private sector R&D projects to help accomplish the government’s mission to enhance private sector R&D and to complement the results of the federal R&D. The SBIR program was begun by the NSF (National Science Foundation) and has encouraged the US small firms. Because of the success of the program at the NSF, the Small Business Innovation Development Act of 1982 has promoted the private sector’s commercialization [1][13].

The Korean government also legislated the law on Facilitate Technology Transfer of 2000 and amended the law on Facilitate Technology Transfer and Commercialization Act of 2006 to provide the infrastructure and to facilitate the technology transfer and commercialization of the national R&D outputs. The Ministry of Knowledge Economy in Korea supports the R&D and commercialization of advanced technologies through facilitating R&D center for firms, universities, and research institutes. Although the government has supported the firms to facilitate their technology transfer and commercialization, the level of technology commercialization to profit from their technological innovations in Korea is still very low. Therefore, this study investigated the performance of government-sponsored firms in their technological innovation processes, the determinants of successful technology commercialization, and their relationship.

Some previous studies focused on the appropriability regimes and the type of complementary assets as important factors affecting the choices of commercialization strategies. In resource-based viewpoint, innovative capability is required to successful technology commercialization in technological innovation processes [2][7][21][25]. Based on the previous studies, this study analyzes the commercialization performances, focusing on the comparison according to the firm size. This study empirically analyzes the impacts of the determinants on the technology commercialization in the manufacturing firms in Korea using data of the 1192 firms supported by the government programs regarding the
technological innovations. In order to examine a variety of determinants, this study combines two streams such as internal and external capabilities and their effects on the technology commercialization. This study is expected to provide a valuable reference to formulate S&T policies for technology transfer and commercialization by analyzing the determinants of the successful technology commercialization.

The remainder of this paper is organized as follows: Section 2 reviews the literature related to the determinants for the commercialization success; Section 3 provides the research model and explains the research method; Section 4 shows the results and discussions of the empirical analysis on the performance of technology commercialization; Section 5 concludes this paper with the political implications, and suggests directions for future research.

II. THEORETICAL BACKGROUND

A. Appropriate regimes

Reference [21] identified appropriability regimes and the type of complementary assets as important factors affecting the commercialization strategies. Some previous studies considered the protection of intellectual properties as an important factor for formulating the commercialization strategies. The firms with the strong appropriability regimes can threaten their competitors or potential partners with an independent market entry. The firms set up their commercialization strategies depending on the strength of patent positions and the ownership of complement assets [7][10][21][22]. The firms, therefore, need to consider the appropriability regimes to acquire competitive edges in market entry and to maintain its strong patent position to profit from its technological innovation. This study assumes that the appropriate regime is an internal capability for the commercialization, and analyzes its effect on the performance of technology commercialization.

B. Innovative capability

Innovative capabilities refer to firm's capabilities, based on the processes, systems, and organizational structure, which can be applicable to the product or process innovation activities. From the resource-based viewpoint, the firms can leverage their internal resources and capabilities and explore external resources which are essential but week or not already possessed [2]. The resource-based view suggests that a firm with strong innovative capabilities can lead to its successful technology commercialization. Successful technology commercialization requires strong and varied innovative capabilities to create new products and introduce them to the market in a timely manner and profit from innovation [23][25]. The firm with innovative capability has competitive edge by reducing costs, improving quality, absorbing new technologies and their performance. This study examines innovative capability based on the process, organization, marketing innovations as internal resources for commercialization, and assumes that these innovative capabilities affect their commercialization performance.

C. Open innovation activities

The open innovation is defined as “the use of purposive inflows and outflows of knowledge to accelerate internal innovation, and expand the markets for external use of innovation” [4]. The open innovation paradigm involves a wide range of internal and external technology sources, and is related to corporate R&D. A set of studies on the commercialization argued that strong protection of the technology leads to a cooperative commercialization strategy [6][7][10][11]. In addition, there is currently a broad awareness of the open innovation; the firms can use external ideas as well as internal ideas and technology to acquiring complement assets for technology commercialization to profit from innovation [5][12]. In these days, technology changes are radical and uncertainty increases in market. The firms need to respond to rapidly these changes and to satisfy customer’s needs considering the cost, speed, quality, and new technology. In this aspect, the firms should set up their cooperative commercialization strategies to access to external resources. This study expects that the open innovation activities affect the performance of the successful technology commercialization as the internal capability for the commercialization.

D. Technology uncertainty

The speed of technological changes increases a competitive landscape that is characterized by a high degree of uncertainty. In the uncertain environments, firms feel the pressure to develop new products and commercialization in order to create new business opportunities [24]. The technological uncertainty is defined as the technology’s range of functions or its changes. The technology uncertainty refers to the probability of unexpected changes in technologies [3]. The technology uncertainty has a negative impact on new product development, and thus the firms decide hierarchical cooperation under the uncertain circumstances [17]. To acquire competitive edges of technology more rapidly than competitor, the firms need to predict the technological changes and to maintain their technological competency responding to the technological changes.

E. Government support

The principal goal of most government-funded R&D is to develop new technologies for public purposes and search for fundamental knowledge through basic research [20]. However, the recent studies emphasized the role of government support as an entrepreneur and the importance of successfully and expeditiously commercializing government-sponsored R&D [13]. The role of S&T policies is important to decide the direction of the national innovation system and intended to influence the behavior of both public and private organization the development and commercialization of new technology [18]. The Korean government tries strategically to establish an R&D network to expedite information-sharing
and commercialization and collaborate with universities, companies, and research institutes conducting R&D. In addition, the government tries to expand financial support and tax reduction for developing and commercializing technologies and intrinsically enhances companies’ ability to self-innovative. This study examines the effect of the financial support and tax reduction by analyzing the commercialization performance of government sponsored firms.

III. RESEARCH METHOD

This section describes the conceptual framework, and deals with the data and variables for the empirical analysis.

A. Conceptual framework

Fig. 1 shows the conceptual framework of this study. The framework indicates that the commercialization performance of a firm is affected by its determinants of successful commercialization combining internal capability and external capability. Furthermore, the R&D investment and firm size are considered in the research model to reduce the bias arising.

B. Data

The data on the technology innovation activities of 1192 Korean manufacturing firms during the period 2005-2007 are derived from the Korean Innovation Survey (KIS) on the manufacturing sector of the Science and Technology Policy Institute (STEPI), Republic of Korea, in 2008. The KIS was approved for designated statistics, the Statistics Korea, and its major concepts and survey methodology are defined according to the Oslo manual [16][19]. In this study, a data set of 1192 firms is supported by the government programs in the technological innovation processes and includes 156 large sized firms and 1036 small and medium sized firms.

C. Variables

This subsection discusses the factors that are expected to influence the success of technology commercialization. The variables of this study are classified into four types: (i) performance of technology commercialization; (ii) internal capability; (iii) external capability; and (iv) control variables. The performance of technology commercialization indicates the results of the firms’ commercialization activities of their technology innovations (Table 1). This study measures the performance by success or failure of the firms’ market introduction of their products. This introduction includes commercialization of improved products as well as that of new products.

<table>
<thead>
<tr>
<th>Variable</th>
<th>Description</th>
<th>Mean</th>
<th>SD</th>
<th>Skewness</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Performance of technology commercialization</strong></td>
<td>Product commercialization</td>
<td>Success 1; Failure 0</td>
<td>0.336</td>
<td>0.472</td>
</tr>
<tr>
<td><strong>Internal capability</strong></td>
<td>Appropriability</td>
<td>Accumulated patent applications</td>
<td>28.1</td>
<td>250.8</td>
</tr>
<tr>
<td></td>
<td>Process innovation</td>
<td>Process innovation 1; or 0</td>
<td>0.408</td>
<td>0.492</td>
</tr>
<tr>
<td></td>
<td>Organizational innovation</td>
<td>Organizational innovation 1; or 0</td>
<td>0.363</td>
<td>0.481</td>
</tr>
<tr>
<td></td>
<td>Marketing innovation</td>
<td>Marketing innovation 1; or 0</td>
<td>0.242</td>
<td>0.429</td>
</tr>
<tr>
<td></td>
<td>Open innovation activity (I)</td>
<td>External/total R&amp;D investment</td>
<td>0.058</td>
<td>0.145</td>
</tr>
<tr>
<td></td>
<td>Open innovation activity (II)</td>
<td>Technology transfer 1; or 0</td>
<td>0.083</td>
<td>0.276</td>
</tr>
<tr>
<td><strong>External capability</strong></td>
<td>Technology uncertainty</td>
<td>Life span of core product (months)</td>
<td>59.3</td>
<td>74.5</td>
</tr>
<tr>
<td></td>
<td>R&amp;D-commercialization funded</td>
<td>Unit: million Korean Won</td>
<td>430.2</td>
<td>3,577.8</td>
</tr>
<tr>
<td></td>
<td>Tax reduction for R&amp;D</td>
<td>Unit: million Korean Won</td>
<td>178.7</td>
<td>1,858.1</td>
</tr>
<tr>
<td><strong>Control</strong></td>
<td>R&amp;D investment</td>
<td>Unit: million Korean Won</td>
<td>4,675.2</td>
<td>36,540.8</td>
</tr>
<tr>
<td></td>
<td>Firm size</td>
<td>ln (employees)</td>
<td>1.771</td>
<td>0.630</td>
</tr>
</tbody>
</table>
The **internal capability** represents the intramural capacity and ability of the firms for raising the probability of the commercialization success. This study considers six factors representing the internal capabilities: appropriability regime; process innovation capability; organizational innovation capability; marketing innovation capability; open innovation activity (I); and open innovation activity (II). First, the appropriability regime implies the internally accumulated technological ability. The capacity is a significant factor to profit from the technological innovations and their commercialization, because the firms need to maintain strong patent position to protect their technology from their competitor. This variable is measured by the number of the accumulated patent applications. Second, the commercialization of the technological innovations is influenced by not only appropriability regimes but also other supporting functions. This study considers three types of innovative capabilities: process innovation capability, organizational innovation capability, and marketing innovation capability. These innovative capabilities represent the firm’s competencies in the aspects of production, organization, and marketing innovations, respectively. Furthermore, this study additionally considers two factors regarding the open innovation activities to access to external resources. The ratio of a firm’s external R&D investment to their total R&D investment implies the importance of cooperative and external innovations as the sources of the technological innovations. The number of technology transfers of a firm indicates the degree of the open innovation activities, especially the inbound or outbound flows of the technology innovations.

The **external capability** indicates the extramural environments of the firms. The environments are expected to influence the probability of the success of product introduction to the markets. This study considers three factors representing the external capability: technology uncertainty; R&D or commercialization funded; and tax reduction for R&D. The technology uncertainty represents the uncertainty or risk in the aspects of the technology characteristics. The factor is measured by the life span of a firm’s core product. The shorter life span of a firm’s products implies that the firm is being operated under more uncertain or risky environments. Furthermore, the government support systems for firms’ technology innovations includes various types with various objectives: tax exemption or reduction for R&D; R&D or commercialization funded; participating government R&D programs; government technology provided or guided; technology information provided; and technical professionals or training programs provided. This study considers the support systems only measurable in the monetary degree. Thus, the study considers the monetary values of funding or reducing tax for firms’ R&D or commercialization by the government support. The firms’ R&D or commercialization funded contributes to raising their returns, whereas the tax reduction for R&D does to reducing their costs related to their R&D investments.

This study considers two control variables to analyze precisely the effects of the factors on the commercialization. The performances of the technology commercialization are influenced not only by the activities and capability regarding the commercialization but also by the efforts for R&D, such as the R&D investment. Although the R&D investment is a significant determinant of the performances, this study focuses the technology commercialization. Hence, the R&D investment is considered as a control variable. In addition, the performance of technology commercialization would be various according to the size, and thus this study considers firms’ size as the other control variable.

### IV. RESULTS AND DISCUSSION

This study considers three logistic regression models for all firms, large sized firms, and small and medium sized firms, and the analysis results are shown in Table 2. Taken as a whole, the results of the logistic regressions represent most factors have significantly positive impacts on the success of the technology commercialization. The coefficients of the small and medium sized firms are more significant than those of the large sized firms. The difference of significance between the large sized firms and small and medium sized firms would come from two causes. First, the sample size of the model of the large sized firms is small in comparison with that of the small and medium sized firms. However, the results of the model of the small and medium sized firms are partly more significant than those of the total firms, and thus the difference cannot be explained only by the different sample size between the models. Second, the dependent variable and some independent variables are binary. The variables do not include the effects of the firm size. While the small and medium sized firms have relatively various values for the variables, almost large sized firms take value 1. The large sized firms would invest on their technology commercialization beyond a certain level, like a critical mass. However, the small and medium sized firms could focus on specific parts of the technology commercialization according to their strategies and characteristics in comparison with the large sized firms.

The major findings from the logistic regressions are five. First, while the appropriability does not influence the success of the technology commercialization in the model for the total firms, the appropriability of the small and medium sized firms has a significantly positive effect on the success. The firms have to protect their technological innovations from their competitors’ imitations, because a regime of appropriability is an innovator’s ability to capture the profits generated by their innovations [7][21]. In case of the technology-intensive, small and medium sized firms, the protection of their technological innovations through the appropriability regimes such as nature of technology and the efficacy of legal mechanisms of protection leads to the rise of the success probabilities of their innovations. This finding implies that the number of patents of the large sized firms, in
Third, while the rate of the external R&D investments has a significant and positive effect on the success in the model of the total firms, the number of technology transfers does not in the model. This result implies some activities of the open innovation would have no contributions to the performances of the technology commercialization. Nevertheless, the ratio in the model of the small and medium sized firms has a significantly positive effect on the performances. Open innovation processes involve a wide range of internal and external technology commercialization to acquire external technology source and complement assets [12]. This result indicates the effects of the open innovation activities are partly different according to the firm size. Moreover, it implies the small and medium sized firms importantly considering external sources for their technological innovations would take competitive edges from their open innovation activities. It means that the openness of the small and medium sized firms affects their performance of technology commercialization more than that of large sized firm, because the small and medium sized firm need relatively more complement assets for their commercialization.

Fourth, in the aspect of the external capability, any significant results related to the technology uncertainty are not found, and the government supports for the R&D and its commercialization, however, have positive effects on the success of the technology commercialization. Especially, the effects are more significant in the model of the small and medium sized firms. The results support the validity of the government supports for the technology commercialization, and moreover indicate that the government supports for the R&D, as well as its commercialization, contribute to the successful technology commercialization. In addition, the effects of the supports on the success probability in the model of the total firms are partly significant. More specifically, while the funding on the R&D or its commercialization has a significant effect in the model of the total firms, the tax reduction for R&D does not significantly correlate with the success due to their equally favorable appropriability regimes. However, the regimes of the many small and medium sized firms would be poor, and thus their efforts regarding the appropriation contribute to the rise of the success rate of commercialization. It means that the small and medium sized firms in commercialization environment – the microeconomic and strategic condition facing a firm need to maintain the competitive edge through appropriability regimes.

Second, the three types of the innovative capabilities, such as process, organizational, marketing innovation capabilities, have significantly positive impacts on the success of the technology commercialization. In this study, innovative capabilities mean the internal capabilities which can be applicable to profit from innovation through commercialization. The results show that the innovations in the facts of production processes, organization characteristics, and marketing powers support directly the commercialization processes specially, the impacts of the small and medium sized firms are more significant than those of the large sized firms. These results indicate that a firm with strong innovative capabilities can lead to successful technology commercialization, consistently with previous studies [23][25].

Fifth, the control variables mostly do not have significant effects on the success of technology commercialization. In the aspect of the firm size, the success possibility of the larger firms is higher than that of the small and medium sized firms. This is due to the tendency that the larger firms would invest...
on more technological innovations and attempt to conduct more technology commercialization activities. Thus, in the separate models of the large and the small and medium sized firms, the effects are not significant.

V. CONCLUSION AND POLITICAL IMPLICATIONS

This study investigated the commercialization of government-sponsored firms and analyzed the relationship between the performance and its determinants of the successful commercialization such as internal capability and external capability. In addition, this study analyzed which factors influence the performance of technology commercialization according to the firm size. This study investigated the determinants affecting a commercialization performance using the KIS data set of 1192 Korean manufacturing firms supported by the government programs during the period 2005-2007. The results showed that the innovative capabilities, the ratio of the external R&D to total R&D investments as the open innovation activities in the internal capability and the government funding for R&D and commercialization in external capability have significantly positive impacts on the technology commercialization. In addition, this study found that the determinants of successful commercialization performance in the large sized firm are different from that of the small and medium sized firm.

This study makes contributions to the following two areas: the measurement of the commercialization performance; and the determinants of the performance. First, this study attempted to measure the performance of technology commercialization and to analyze empirically the determinants of successful technology commercialization. Many previous studies did not have clear measurements of the performance of technology commercialization and their success. To measure the performance of technology commercialization, this study utilized the success or failure of the firms’ market introduction of their products. Second, this study demonstrated the difference of factors in the successful commercialization according to the firm size. The Korean government has strategically facilitated the technology transfer and commercialization to profit from the technological innovation and to reinforce competitive edges in the private sector, especially the small and medium sized firms. This study is expected to help the formulation of the policies related to the technology commercialization through the empirical analysis of the determinants of the successful commercialization in government-sponsored firms.

In the facet of the policy issues of promoting commercialization, this study provides three political recommendations to facilitate the commercialization of the small and medium sized firms as follows: First, the government needs to support strategically the protection of intellectual properties as appropriability regimes and to strengthen the innovative capability such as process, organization, and marketing innovation capabilities in the technology-based firms, because the appropriability and innovative capability of the firms has a significantly positive effect on the performance of technology commercialization. Second, the government needs to facilitate the openness of firms and their collaboration with universities, research institutes, and other firms. The result showed that the external R&D investments of the small and medium sized firms has a significantly positive effect on their performances unlike the large sized firms and the effects of the open innovation activities are partly different according to the firm size. In addition, the effects of the government supports for the R&D and its commercialization are more significant in the small and medium sized firms. The Korean government has financially supported the firms and emphasized recently the open innovation paradigm in the national innovation system. These results support the validity of the Korean government’s supports for the technology commercialization and indicate that the effects of the government supports are more remarkable in the small and medium sized firms than the large sized firms. Third, the government needs to develop various policy initiatives to improve the technology commercialization for the private sector. The technology policies to profit from the technological innovations are best implemented through legislation. Furthermore, more active participation of civil servants in government agencies and extensive collaboration with the private sector is needed.

Although providing the valuable implications above, this study examined the relationships between internal and external capabilities and their performance without considering other environments, such as the type of industry and market environments. Hence, the future studies need to consider these environments which the firms confront and various determinants of technology commercialization derived from this study. Moreover, the firm’s market introduction of their products as the performance of technology commercialization do not reflect the economic returns in this study, and thus the variables of performance such as sales from the commercialization representing economic returns need to be considered to measure the performance of technology commercialization. In addition, further studies could more specifically consider various factors, influencing the performance of technology commercialization, according to the types of the government support programs.

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