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Technological Capabilities, Entrepreneurship and Innovation of Technology-Based Start-Ups: The Resource-Based View

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Abstract: Despite large-scale financial support of the government, there is increasing criticism about the inefficiency of public R&D investment that fails to lead directly to technological innovation of technology-based start-ups. This paper analyzes the factors that influence technological innovation in Korean technology-based start-ups based on the resource-based view (RBV). The empirical analysis combines ordinary least squares and ordered probit analysis of data collected from 248 technology-based start-ups in Korea. The analysis results statistically confirm the effects of technological capabilities and entrepreneurship on technological innovation. First, a start-up's technological capabilities measured by patents and technological competitiveness have significant positive effects on technological innovation, while the effect of having an in-house R&D department for technological innovation is not significant. Second, entrepreneurship has a significant positive effect on the technological innovation of a start-up, and this positive effect has a moderating effect that further promotes the positive effect of technological competitiveness on technological innovation.

Keywords: technological capabilities; entrepreneurship; innovation; start-ups; RBV

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1. Introduction

A technology-based start-up is a company that achieves profitability through research and development (R&D), new knowledge, and new market development. Recently, technology-based start-ups have been expected to play a key role in expanding employment through the creation of new jobs by replacing or expanding existing markets [1]. In Korea, as jobless growth and stagnant job creation continue, the government, seeking to create jobs through technology-based start-ups, supports various R&D subsidies for driving technological innovation. As a result, R&D investments for start-ups in Korea have increased at an annual average of 10.9% over the last five years, more than the 6.2% growth rate of the national R&D investment [2]. The government continues to expand its R&D investments into technology-based start-ups, but questions remain as to whether its effectiveness is guaranteed. Moreover, despite large-scale financial support of the government, there is increasing criticism about the inefficiency of public R&D investment that fails to lead directly to technological innovation of technology-based start-ups.

This paper thus analyzes the factors that influence technological innovation in Korean technology-based start-ups. Previous empirical analyses have focused on technological capabilities and entrepreneurship, investigating the characteristics of human capital and knowledge capital as important determinants of technological innovation by technology-based start-ups [3–11]. Many studies report that corporate performance is likely to be influenced by various factors, such as the manager's competence, leadership, and especially entrepreneurship, which affects the way a company develops its ideas and formulates a business plan and has a significant impact on its performance [7,12–17].

Among related theories on firm performance, the theoretical usefulness of the resource-based view (RBV) has been widely recognized to provides a useful framework for analyzing such entrepreneurial firms as technology-based start-ups [11]. According to RBV, if technological capabilities and leadership resources meet the requirements for sustained competitive advantage, they can have a positive impact on the technological innovation of start-ups. To identify factors that influence the technological innovation of technology-based start-ups, we analyzed such factors based on the RBV. Specifically, technological capabilities and entrepreneurship are measured for technology-based start-ups and the effects of these factors on technological innovation are verified. The empirical analysis combines ordinary least squares (OLS) and ordered probit analysis of data collected from 248 technology-based start-ups in Korea.

The paper is organized as follows: first, we review previous research on start-ups and explore an outline of the RBV. Next, based on the existing literature, we establish our hypothesis about the effect of technological capability and entrepreneurship on the technological innovation of technology-based start-ups. After that, we describe the data, variables, research models, and analytical methods used and then present the results of this study. Concludingly, we derive managerial and policy implications from discussing the results of the study.

2. Literature Review

2.1. Start-Ups Research

Innovation allows businesses to meet market demand, manufacture products using appropriate technologies, and meet future demand. Innovation in technology-based start-ups can be a source of long-term profits through the successful introduction of new products in the market [18]. This is because innovation contributes greatly to a company's sales growth and competitive advantage [19].

As factors influencing technological innovation in technology-based start-ups, company and industry characteristics are considered important. Firm characteristics include size, cash flow, product diversification, firm-specific R&D-related capabilities, and division of innovative labor. Business characteristics include the industry's market concentration, demand, and technical opportunities.

Although previous studies are meaningful in that they provide empirical analyses of the factors affecting technological innovation, there are many forms of measurement and determinants of technological innovation. What is most important for analyzing the factors that influence technological innovation is to measure how new knowledge contributes to technological development; for example, based on innovation count, innovation calculations as an indicator of innovation [20] or patents [21].

However, the economic value of innovation output is not homogeneous and is difficult to adopt for purposes of comparing companies and industries. In the case of patents, most of them are not used commercially and only a few contribute to the development of major technologies. In recent years, different ways of measuring innovation have been applied. For example, ref. [22] used three measures of R&D concentration, training concentration, and product technology concentration to analyze innovation; ref. [23] used new product sales and product innovation indices to measure innovation performance; and ref. [24] used new product sales, exports, and new patents to measure innovation performance while analyzing the impact of government R&D grants on innovation performance. Measuring technological innovation and analyzing the factors that influence them is important to derive insights on successful technology-based start-ups.

The fundamental purpose of technology-based start-ups is to create wealth through the commercialization of technology. In this regard, it is necessary to identify the determinants of technology start-up performance and to promote such factors effectively to maximize performance. To date, the area of technology-based start-ups performance has been actively studied. Specifically, various performance indicators and influencing factors of technology-based start-ups have been considered. For instance, ref. [25] analyzed factors that influence the intention of self-employed and small business owners in Greece to start a new venture. Applying planned behavioral theories, the authors considered factors such as demographics, personal interests, subjective norms and values, and perceived control. They found that personal attention and perceived sense of control are strong influencers, and that subjective norms and values intervene directly or indirectly with personal interest, while demographic factors are insignificant but present. In addition, their findings regarding the founding intention had 61% explanatory power. Meanwhile, ref. [26], applying structural equations to a model of the planned behavioral theory, performed an empirical analysis on the founders of 133 new technology-based companies in Italy. They found that perception influences the intention to start a business, personal competence and psychological characteristics determine attitudes toward entrepreneurial behavior, and environmental support and perceived control are also considerations. Moreover, the authors considered technical, procedural, and managerial competences as factors of individual competence. They found that in relation to promoting the intention of start-ups, individual competence and the environment influence attitude and perceived control, respectively. In particular, they identified technological capabilities as a major determinant of individual competence and confirmed that empirical factors related to technology, such as the founder's patents and his/her technology development experience, influence the intention of technology-based start-ups.

After analyzing existing technology start-up performance studies, ref. [9] presented four dimensions to measure performance, as follows. First, performance can be quantified by objective indicators (as measured by the number excluding the subjectivity of evaluators), as well as subjective indicators (as evaluated based on the judgment of evaluators). Second, performance can be divided into dichotomous, multilayered performance, which measures two or more levels of performance, as well as continuous performance, which is measured by the continuous variable itself. Third, performance can be divided into financial performance such as sales, operating profit, and ROI (return on investment), as well as nonfinancial performance such as employee satisfaction, knowledge sharing system, and product improvement. Fourth, performance can also be considered as the achievement of a goal, in which case performance can be measured by checking the degree to which the actual result matches the originally set expectations and goals.

More recently, start-ups have been studied in open innovation scholarship [27–35]. Although these previous studies identified various factors that affect technology start-ups and technological innovation, they have limitations in that an analysis based on theory or a conceptual framework that can systematically explain the causal relationship between these factors was not performed. To make up for this research gap, this study performs an empirical analysis based on the RBV.

2.2. Resource-Based View

Among factors that influence corporate innovation, the theory that pays particular attention to the importance of resources held by organizations is the RBV [3,4,10,36–38]. In the RBV that was applied to start-up research [11,13,39–44], "resources" is a concept that encompasses various forms of assets, capabilities, procedures, and characteristics, as well as knowledge and information used to achieve an organization's goals. Resources enable the planning and implementation of strategies [3,4,45]. These resources are precious (valuable), currently rare and unavailable to competitors (rare), not easily imitated (inimitable), and cannot be traded or replaced by other resources that the competitors have (nontradable/nonsubstitutable), representing the so-called "VRIN" properties [3]. If a particular organization has a value-creating strategy that cannot be used by its competitors today and in the future, it is considered as having a "competitive advantage". An organization that enjoys a competitive advantage that has VRIN attributes is considered to possess a "sustained competitive advantage" [3]. With an effective combination and proper deployment of internally held resources, an organization can improve its performance and sustain its competitive advantage. Creating a sustainable competitive advantage leads to collective learning that is unique to a particular organization, thereby becoming part of a company's core competence, which facilitates the integration and coordination of various types of resources, production skills, and technologies (i.e., core competence) [46].

According to the RBV, organizational performance is based not on external factors that competitors can easily access, but on the ability to retain specific resources or create new ones internally [3]. Organizations can be thought of as bundles of disparate resources, with different distributions of resources, and such differences persist over time [47]. Organizations have different types of resources. Specifically, according to [48], an organization's resources include financial resources and physical assets, such as facilities and raw materials, fame, brand image, product quality, and human-based resources, such as technical know-how and knowledge resources (e.g., organizational culture, employee training, loyalty, and others). According to [3], physical capital resources include physical skills, plant, equipment, geography, and accessibility of raw materials, while human capital includes resources to train, experience, and make judgments, as well as intelligence, relationships, and insights. Meanwhile, organizational capital resources include formal reporting structures, formal and informal planning, control and coordination systems, and informal relations within and outside the organization [49]. Among these various types of resources, which one can improve organizational performance is a key theme that the RBV seeks to explore.

Meanwhile, the new growth theory [50–52], which emphasizes the importance of technological innovation in a production function (e.g., $f = a \cdot (L, K)$ model), assumes that a corporation is a series of transformations of input factors into outputs. In this sense, corporate R&D can be explained by the differences in technological efficiency. According to [53], in addition to labor and capital as inputs, endogenous factors, such as technological innovation and knowledge, play an important role in improving the growth and productivity of a company. In particular, human capital and knowledge capital are key drivers of technological progress and continuous productivity gains. Knowledge capital is accumulated through R&D as a source of new value added, and as the accumulation increases, the innovation cost decreases. Especially, human capital is the capital acquired and embodied in human beings through education or skill training. As the human capital of a company increases, the effects of technological progress, productivity improvement, experience accumulation, and learning-by-doing are disseminated, creating a spillover effect. Therefore, the accumulation of human capital by individual workers does not diminish marginal productivity from a firm's perspective, even if diminishing returns occur. In other words, an increasing return to scale can occur [51,52].

According to the RBV, human resources refer to the labor force that embodies technical capacity. In other words, human resources can be seen as knowledge capital embodied in human capital. In the past, traditional resources (i.e., natural resources and technical resources) were necessary for an organization's competitive advantage. However, these resources have limitations in that they can be easily imitated by firms and easily replaced by other resources [3,36,38]. Meanwhile, knowledge, experience, skills of technicians, managerial skills, and the culture of professional R&D personnel are considered important factors for successful innovation [54,55]. As such, start-ups with high-quality human resources have the ability to harmonize internal and external knowledge and demand and achieve better performance [43,56,57].

3. Methodology

3.1. Hypotheses Development

Technological Capabilities and Innovation

Intellectual capital factors that affect technological innovation are related to technological capabilities. Technological capabilities serve as the foundation for creating a sustainable competitive advantage that would enable a company to absorb and utilize external technical knowledge or create new knowledge by itself [7,58–60]. The ability of companies to acquire and use technology, solve technical problems, and procure and deploy technical personnel can directly contribute to success in technological innovation [7,61,62]. The ability to obtain patents and systematically manage them is important as well [63]. Clearly, technology start-ups particularly depend on technology for their success or failure [5,8]. Technological capabilities are difficult for competitors to imitate and replace as it exists in the form of patents, legal and institutional guarantees, or intangible assets that are tacitly inherent to an organization [46,64]. Thus, developing technological capabilities can provide a foundation for creating long-term competitive advantages for technology start-ups that lack financial resources.

In previous studies, various criteria were suggested to measure technological capabilities. In this study, in-house R&D department [65], patents [66–68], and technological competitiveness [69,70] were used.

First, in-house R&D department refers to the form and status of the company's R&D, which reflects how innovation activities are managed. In the beginning, many companies generally do not set up separate laboratories, operate R&D and management personnel in a systematic manner, or set up a research lab in a way that creates a growth path for more specialized research. In Korea, it is recommended to set up a dedicated R&D research institute to support the technological capabilities of small and medium enterprises (SMEs). The country endeavors to provide various government R&D supports by certification processes that give additional points to SMEs based on whether their in-house R&D department is founded and operated. Firms that have established structures with an R&D-only status reflect the top management's commitment to technological innovation and, in fact, these firms enjoy advantages in terms of sales and profits, as compared with those that do not [71].

Second, patents represent objective and measurable technical competencies, and they are the most commonly used variables. Despite the disadvantage of ignoring tacit knowledge, patents are often used as the most intuitive quantitative indicator of the accumulation of technical knowledge [7,63]. Recently, not only companies' patents but also the use and application of patents [72] and their influence and technology life cycles [67] have been considered as subvariables of the technology related to patents. Ref. [7], who considered both the number and quality of patents as representing technological capabilities, found that the technological capabilities and financial resources of early technology-based start-ups in the product development stage had a positive effect on performance. Ref. [73] also found that R&D investment and technological capabilities, as measured by patents, are positive factors for corporate performance.

Third, technological competitiveness means subjective judgment when assessing the competitiveness of a company's technological capabilities in comparison with other companies. Technological competitiveness can generally be measured in objective and subjective ways and can be classified into ownership-based and knowledge-based resources [74]. Ref. [69], who analyzed the effect of technological competitiveness on the performance of technology-based start-up companies, argued that the subjective evaluation of technological competitiveness has a greater impact than objective technological capabilities. Based on the above discussions and the previous studies [11,13,39–44], we propose the following hypotheses regarding the effect of a start-up company's technological capabilities on technological innovation.

H1. *Technological capabilities have a positive effect on technological innovation.*

H1a. *R&D organization has a positive effect on technological innovation.*

H1b. *Holding a patent has a positive effect on technological innovation.*

H1c. *Higher technological competitiveness has a positive impact on technological innovation.*

3.2. Entrepreneurship and Technological Innovation

As entrepreneurship is critical for new job growth and development of new industries, interest in entrepreneurship has increased since the global financial crisis as a means to enhance innovation and flexibility in the economy [75]. Entrepreneurship is an area that has been analyzed and developed by various researchers since [76]. Its positive effect on entrepreneurship has been confirmed [6,7,9]. An entrepreneur works with his/her partners to directly invest money, goods, and technology, attract outside investments, and share some of the responsibilities of a successful start-up. An entrepreneur hires and delegates work that he/she cannot perform directly. New start-ups particularly have a large number of employees and do not have an organizational decision-making system. In this respect, entrepreneurship and leadership skills have great influence on entrepreneurial performance [7,16,17]. Entrepreneurship is the driving force toward innovative and challenging technologies and, as such, is a key variable [7,77,78]. Moreover, the technological capabilities, background, and experience of entrepreneurs are directly related to a company's technical and managerial performance [5,77,79,80].

In particular, interest in technology (or technological) entrepreneurship, which is high-value-added entrepreneurship, has been increasing [69]. Research on technology entrepreneurship takes a somewhat different view. For instance, ref. [81] defined technology entrepreneurship as high levels of potential technology-intensive commercialization opportunities by aggregating resources (e.g., capacities, capital, and high-growth/high-risk management) based on structured decision-making skills. Ref. [82] also defined it as the process by which entrepreneurs seek opportunities and combine organizational resources, technical systems, and strategies. Nevertheless, the term "technology entrepreneurship" is still often recognized as applicable only to early technology-based start-ups or is often used to refer to the act of setting up a technology start-up itself. Ref. [83] explained that three prejudices exist when discussing technology entrepreneurship: first is focusing on start-ups, second is focusing on individual entrepreneurs, and third is the excessive obsession with opportunity exploration. According to [83], who analyzed 93 technical start-up studies and extracted six representative definitions, technology entrepreneurship is, first, organized and managed by technology-based companies [84]. Second, it provides a solution to a problem [85]. Third, it represents the establishment of new technology ventures [86]. Fourth, entrepreneurs use resources and structures to secure new technological opportunities [87]. Fifth, it is an effort to explain difficult data, an understanding to continue technical efforts, and a steady and cooperative commitment to achieving technological change [88]. Sixth, it is a project promoted by various actors related to technology, and in terms of process, it causes a change toward new technical paths [89]. Based on this analysis, ref. [83] proposed that technology entrepreneurship is a series of projects that aim to integrate and effectively use personal and collective assets that are intricately associated with advances in scientific and technical knowledge for the purpose of creating and maintaining corporate entrepreneurship. According to this definition, technology entrepreneurship focuses on the use of technology assets for the survival and competitive advantage of a company, a concept that can be applied equally to a start-up or a large company.

In general, entrepreneurship consists of innovation, risk taking, and enterprising. The influence of individual components varies somewhat depending on the researcher. The author of [90] revealed that progressiveness had a positive effect on the emotional commitment of employees, and refs. [78,91] found that innovation has a positive effect on product competitiveness, financial performance, and technology development. Meanwhile, leadership is considered an administrative and managerial resource for efficiently managing the skills of start-ups. Thus, technology entrepreneurship could have the effect of moderating the relationship between technological competitiveness and technological innovation. Based on the above discussion and prior research [12–15], we propose the following hypotheses regarding the effect of entrepreneurship on the technological innovation of a start-up company.

H2. *Entrepreneurship has a positive impact on the technological innovation of start-ups.*

H3. *Entrepreneurship, as a moderating variable, further promotes the positive relationship between the technological competitiveness and innovation of a start-up company.*

3.3. Empirical Model and Variables

The research model is expressed by the following linear equation, which we solve by a regression process:

$$Y(Innovation) = \beta_0 + \beta_1(InhouseR\&D) + \beta_2(Patents) + \beta_3(TechCompetitiveness) +$$
$$\beta_4(Entrepreneur) + \beta_5(TechCompetitiveness) * (Entrepreneur) + \beta_6 Controlvariables + \varepsilon$$

3.3.1. Technological Innovation

Using a five-point Likert scale, technological innovation is measured through the subjective perception of the level of innovation of products and services produced by start-ups. In quantifying subjective perception, one takes into account the limitations of the methodology for the objective performance measurement of start-ups [92,93] and accepts the argument of previous research about the necessity of a comprehensive consideration of various performance indicators [94–97]. Thus, technological innovation was measured by five questions concerning the status and performance of products and services in the market [62,78]. Specifically, the questions comprise market creation, functional diversity, market convergence, industry competitiveness, technology innovation of products and services.

3.3.2. Technological Capabilities

Based on the RBV research [11,13,39–44], R&D organization, technological competitiveness, and patents were examined to measure technological capabilities of start-ups:

First, a dummy variable, in-house R&D department, was set at 1 for companies with an in-house R&D department and 0 for those without an affiliated R&D institute, dedicated R&D organization, or R&D personnel. This was performed to identify the effect of the presence of an R&D department in a start-up on the firm's performance.

Second, the numbers of patents were measured depending on whether the company currently owns industrial property rights and patents. In addition to the patents registered by a start-up company, patents in the application process were also counted.

Third, technological competitiveness, defined as the subjective evaluation of a company's technology acquisition and alliance ability, technical problem-solving ability, and technology acquisition and utilization ability, was measured based on its level relative to its competitors by applying a five-point Likert scale.

3.3.3. Entrepreneurship

Entrepreneurship has been previously identified as a factor affecting performance. In previous studies, innovation, risk taking, and progressiveness were generally regarded as elements of entrepreneurship [6,7,9,76]. Embracing this view, eight items—four for innovation, one for risk-taking orientation, and three for forward thinking—were introduced and measured on a five-point Likert scale, and entrepreneurship was operationally defined as the average of these eight items, such as creativity and innovation, teamwork and competence, resource acquisition and driving force, overall view, risk-taking propensity, environmental response, systematic accessibility, and ability to gather resources.

3.3.4. Control Variables

First, R&D intensity [63,72,98–102] was used an indicator of how active an organization is in creating knowledge and the influx of external knowledge [103]. It indicates the extent to which an organization is engaged in technological innovation relative to its size. Specifically, R&D intensity can be measured in terms of labor inputs, based on the number of R&D

personnel compared with the total number of employees. In terms of capital inputs, it can be measured as the ratio of R&D investment to sales. Ref. [63] explained that the impact of R&D intensity is different for each industry, but it is the most positive factor in terms of sales and operating profit. The R&D intensity variables of this study were defined in operational terms. Specifically, R&D labor intensity is the average number of R&D workers divided by the total number of employees between 2013 and 2015, while R&D capital intensity is the average R&D investment divided by the average turnover between 2013 and 2015.

Second, a company's growth is a process that involves solving the problems faced by the organization [104]. In relation to the organization life cycle theory, efforts were made to discover and systematically develop the necessary competencies for each growth stage of a company [105,106]. From this viewpoint, entrepreneurship performance may vary depending on a company's growth stage [106–110]. As a control variable, the company's growth stage was based on the company's age (an objective indicator) and the company perception (a subjective indicator). Specifically, a firm's age was measured from its founding year to the year the survey was conducted. In addition, the growth stage that a company subjectively perceives was determined with reference to [111]. Each growth stage, including infant stage, initial growth stage, high growth stage, mature stage, decline stage, was coded as a dummy variable.

Third, the factors that influence a start-up's performance may vary by industry. Technology start-ups are sensitive to changes in their industrial environment and are particularly affected by market competition, industrial life cycles, market size, and barriers to entry [17,112,113]. In several previous studies [107,114–116], external environmental factors have been suggested as determinants of the performance of start-up companies. Moreover, discriminatory relationships in management activities were identified based on the type of business. Among technology-based start-ups, manufacturing companies and knowledge service companies were determined to have different value chains in the development, production, and delivery of products and services. As such, these sectors were included as dummy variables, with the manufacturing industry taking the value of 1 and the knowledge service industry taking the value of 0.

3.4. Data and Methods

The SMBA and the Entrepreneurship Promotion Agency classify companies with fewer than seven years of experience in the manufacturing and knowledge services sectors as technology-based start-ups [117]. A survey was conducted for these technology-based start-ups to secure relevant data for empirical analysis. The extensive survey was designed to identify entrepreneur characteristics and technological capabilities as factors influencing the performance of technological innovation. In this paper, the companies surveyed were limited to such companies (i.e., those defined as technology-based start-ups by the SMBA), and the detailed list was extracted from the Korean company yearbook of 2017 [118]. Among the total 441,528 companies in the database, companies defined as technology-based start-ups were extracted proportionately to the 71 industries, 7 levels of firm age, and 17 regions in the database. While a total of 9,134 companies were selected as target companies for the survey, 251 responses, with a recovery rate of 2.7%, were collected through a survey via facsimile, internet, mobile, and e-mail. Accordingly, 248 responses were used for analysis, excluding three suspicious answers from the recovered samples. This survey procedure was conducted for one month from 26 September to 26 October 2016. Appendix A (Tables A1 and A2) shows the results of reliability and validity of the scale as well as descriptive statistics of key variables.

Regarding analytical methods, OLS regression analysis was used for hypothesis testing. In addition, considering that the dependent variables were measured on a 5-point scale, we analyzed the data using the ordered probit model.

4. Results

According to the results of the multiple regression analysis (Table 1) for testing the hypotheses of this study, the sign and statistical significance of the regression coefficients from the OLS models (①, ②, and ③) and the ordered probit models (④, ⑤, and ⑥) are consistent. Multicollinearity was found to be high between the technological competitiveness and entrepreneurship variables. Thus, two variables were created using the z-score standardized interaction terms (technological capabilities × entrepreneurship). To verify the multicollinearity between explanatory variables, the mean variance inflation factor (mean VIF) between explanatory variables was checked.

Table 1. Analysis Results.

Model	OLS			Ordered Probit		
	H1	H2	H3	H1	H2	H3
	β (s.e)	β (s.e)	β (s.e)	β (s.e)	β (s.e)	β (s.e)
In-house R&D	0.08 (0.14)	0.06 (0.13)	0.06 (0.13)	0.27 (0.19)	0.22 (0.19)	0.20 (0.19)
Patents	0.13 * (0.12)	0.11 * (0.12)	0.12 * (0.12)	0.38 * (0.17)	0.33 * (0.17)	0.37 * (0.17)
Technological Competitiveness	0.44 *** (0.05)	0.29 *** (0.06)	0.28 *** (0.06)	0.58 *** (0.08)	0.41 *** (0.09)	0.40 *** (0.09)
Entrepreneurship		0.30 *** (0.06)	0.31 *** (0.06)		0.42 *** (0.09)	0.47 *** (0.09)
Technological Competitiveness × Entrepreneurship			0.18 *** (0.04)			0.27 *** (0.06)
R&D Labor Intensity	0.03 (0.00)	0.03 (0.00)	0.04 (0.00)	0.00 (0.00)	0.00 (0.00)	0.00 (0.00)
R&D Capital Intensity	0.07 (0.01)	0.05 (0.01)	0.04 (0.01)	0.01 (0.01)	0.01 (0.01)	0.01 (0.01)
Initial Growth Stage	0.05 (0.12)	0.06 (0.12)	0.07 (0.12)	0.11 (0.17)	0.14 (0.17)	0.20 (0.17)
High Growth Stage	0.04 (0.18)	0.01 (0.17)	0.00 (0.17)	0.13 (0.25)	0.02 (0.25)	−0.02 (0.25)
Mature Stage	0.03 (0.54)	0.05 (0.52)	0.04 (0.51)	0.36 (0.74)	0.60 (0.74)	0.59 (0.74)
Decline Stage	−0.14 * (0.20)	−0.08 (0.20)	−0.09 (0.19)	−0.57 * (0.28)	−0.31 (0.29)	−0.36 (0.29)
Firm Age	−0.04 (0.03)	−0.04 (0.03)	−0.04 (0.03)	−0.03 (0.04)	−0.03 (0.04)	−0.03 (0.04)
Manufacturing Industry	−0.03 (0.10)	−0.03 (0.09)	−0.02 (0.09)	−0.08 (0.14)	−0.08 (0.14)	−0.05 (0.14)
Constant	(0.17)	(0.16)	(0.16)			
Observations	248	248	248	248	248	248
F-value/LR chi^2	12.60 ***	14.29 ***	14.81 ***	115.55 ***	138.56 ***	156.50 ***
R^2(Adj. R^2)/Pseudo R^2	0.37(0.34)	0.42(0.39)	0.45(0.42)	0.08	0.10	0.11

Notes: Results in the OLS model are standardized. Standard errors are in parentheses and * $p < 0.05$, *** $p < 0.001$.

The results of the analysis are as follows. First, with regard to the technological capabilities of the start-up companies, patents and technological competitiveness have statistically significant positive effects on technological innovation. However, the effect of having an in-house R&D department for technological innovation is not statistically significant. Thus, Hypothesis 1a is rejected, and Hypotheses 1b and 1c are supported. This means that patents and technological competitiveness are important factors of technological capabilities, which has a positive effect on technological innovation [7,11,13,39–44,69,73]. On the contrary, the reason for rejecting Hypothesis 1a can be interpreted as follows. In Korea, the government has been heavily involved in encouraging R&D of technology-based start-ups by providing financial support to SMEs and venture companies. Most of the government's financial incentives are subject to the establishment of an in-house R&D organization. The government's way of supporting R&D is likely to lead to moral hazards in setting up a nominal R&D organization for technology-based start-ups in Korea. Second, entrepreneurship has a statistically significant positive effect on the technological innovation of a start-up company, and this positive effect has a moderating effect that further promotes the positive effect of technological competitiveness on technological innovation. Thus, Hypotheses 2 and 3 are supported. Meanwhile, comparing the size of the standardized regression coefficient (Beta), entrepreneurship (0.31), technological competitiveness (0.28), and patent (0.13) showed the greatest effect of entrepreneurship on technological innovation. These findings support previous studies that showed a positive impact of entrepreneurship on technological innovation [1,6,7,9,12–17,77,78,90,91,119–121].

5. Discussion

The empirical analysis of this paper confirmed the effects of technological capabilities and entrepreneurship on technological innovation. First, we confirmed the effect of technological capabilities on the technological innovation of a technology-based start-up [11,13,39–44]. According to the RBV, the resources of an organization that contributes to corporate innovation brings added value and are so unique or scarce that potential competitors now or in the future are unable to obtain them. Moreover, they are not easily imitated or secured by competitors and have attributes that cannot be traded or replaced (i.e., VRIN) [3]. The results of this study are based on both the technological competitiveness of knowledge-based resources as measured by subjective recognition [74] and on patents held by companies, which are objective measures of the company's technological capabilities [74]. However, the empirical analysis shows that it is difficult for a company to establish an in-house R&D organization for purposes of technological innovation.

Second, we confirmed the influence of entrepreneurship on the company's technological innovation. With creating new technologies, inducing product and process innovation, and opening up new markets, an entrepreneur is the source of creative destruction and the most important factor in promoting a corporate development in the process of creating change and determining the success or failure of entrepreneurship [1,12–15]. The results of this study show that entrepreneurship has a positive effect on a company's technological innovation and the extent of its influence can be greater than that of technological capability. Moreover, results show that with a high level of entrepreneurship, a firm's technological capabilities can promote positive effects on technological innovation.

6. Conclusions

This paper presented a linear regression analysis on the data of 248 Korean technology-based start-ups. The analysis was performed to accept or reject technological capabilities and entrepreneurship hypotheses regarding the technological innovation of these companies. A statistical connection between factors influencing technological innovation and their likely roots for start-up companies was sought. The results show a sharp direction in the way organizational resources should be managed to pursue technological innovation of technology-based start-ups. Specifically, technological capabilities and entrepreneurship are measured for technology-based start-ups and the effects of these factors on technological innovation are verified. From these results, we can derive theoretical implications to the current knowledge development on start-ups research, especially in terms of the relationship among the RBV, human capital, and entrepreneurship. In other words, causal linkages between innovation and resources of technology-based start-ups may be moderated by entrepreneurship, which raises the necessity of constructing a conceptual framework for integrating the factors affecting the innovation performance of the start-ups.

The results of the paper may also be useful if conditions are extrapolated to other countries or scenarios. Based on our empirical results, we can derive several managerial and policy implications as follows: First, managerial implications, especially for startups and entrepreneurs, include the necessity to reinforce the technological capabilities of a sustainable competitive start-up. Specifically, technological competitiveness and patents have a positive effect on the company's technological innovation performance; thus, it is important for startups and entrepreneurs to invest in these areas. Accordingly, realizing this potential for technological innovation will help technology-based start-ups to drive growth with competitive advantage in the long term. Moreover, as the urgency of promoting entrepreneurship has been universally recognized in the business sector, start-ups' need to introduce various educational programs for entrepreneurship has been expanded.

Second, as for the government policy implications of the paper, it is necessary to further develop ways to formulate and measure the knowledge service industry's innovation activities that are not physically identifiable. The existing government R&D evaluation system for measuring technological innovation activities, such as R&D personnel and organization, patents, and R&D intensity, is currently focused on the manufacturing industry. As such, limitations exist as to the ways of measuring the implicit, informal, and tacit knowledge-creation activities of the knowledge service industry. Thus, in the future, a more innovative government R&D evaluation system should be formed, with further promotion of the risk-taking culture associated with entrepreneurship. As entrepreneurs are at the core of company growth, and they promote the development of the business sector in the process of seeking and creating various changes, recently, various public and nonprofit private organizations have conduced numerous activities to enhance entrepreneurship in society. The entrepreneurship of individual managers is influenced by the values of both the business sector and society and is closely related to the socio-economic environment and legal and institutional conditions. Therefore, with regard to the spread and revitalization of entrepreneurship, the government should pursue more consistent policy directions such as the diversification of investment fund recovery methods and provision of re-challenge opportunities for failed attempts. Furthermore, efforts should be made to establish the relevant legal and institutional foundations so that managers can succeed by their entrepreneurial trials.

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Appendix A

Table A1. Validity and Reliability of Measures.

Variables	Items	Factor Loading	Eigenvalue	Percent of Variance	Cronbach's Alpha
Product Innovation	① Market creation of products and services ② Functional diversity of products and services ③ Market convergence of products and services ④ Industry competitiveness of products and services ⑤ Technology innovation of products and services	0.82 0.88 0.81 0.85 0.88	3.61	72.21	0.90
Technical Competitiveness	① Ability to acquire technology and cooperate with competitors ② Technical problem-solving ability ③ Ability to secure and utilize technicians compared with competitors	0.89 0.91 0.83	2.31	76.99	0.85
Entrepreneurship	① Creativity and innovation ② Teamwork and competence ③ Resource acquisition and driving force ④ Overall view ⑤ Risk-taking propensity ⑥ Environmental response ⑦ Systematic accessibility ⑧ Ability to gather resources	0.70 0.74 0.81 0.44 0.75 0.80 0.70 0.85	4.31	53.87	0.89

Notes: Factor loading cut-offs are over 0.4 [122–125].

Table A2. Descriptive Statistics of Key Variables.

Variable	No. of Obs.	Mean	Std. Dev.	Min	Max
Technological Innovation	248	3.15	0.91	1	5
In-house R&D department	248	0.15	0.36	0	1
Patents	248	0.77	0.42	0	1
Technological Competitiveness	248	3.74	0.84	1	5
Entrepreneurship	248	3.81	0.63	1.57	5
R&D Labor Intensity	248	0.42	0.34	0	1
R&D Capital Intensity	248	0.01	0.07	0	0.75
Infant Stage	248	0.22	0.41	0	1
Initial Growth Stage	248	0.56	0.50	0	1
High Growth Stage	248	0.12	0.33	0	1
Mature Stage	248	0.01	0.09	0	1
Decline Stage	248	0.09	0.28	0	1
Firm Age	248	4.01	1.70	0	8
Manufacturing Industry	248	0.52	0.50	0	1

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