University Start-Ups: The Relationship between Faculty Start-Ups and Student Start-Ups

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Abstract: University start-ups include faculty and student start-ups. Earlier research on universities’ roles in start-ups was focused on faculty. When student start-ups outperform faculty start-ups, the resources affecting these start-ups, and their relationship, should be analyzed. This study investigates the determinants of faculty and student start-ups, comparing key resources and exploring whether faculty start-ups affect student start-ups and vice versa, as well as whether the relevant resources interact, using panel data from 92 Korean universities from 2012 to 2018. Resource variables including labor costs, bonuses, research expenses, laboratory expenses, equipment costs, and technology transfer offices were used as explanatory variables. Additionally, for faculty start-ups, central and local government funds, science citation indices, patents, technology revenues, and student start-ups were used as explanatory variables. For student start-ups, university funding, government funding, start-up clubs, Capstone Design funding, and faculty start-ups were used as explanatory variables. Using these start-ups as endogenous variables in estimations, this study adapts a simultaneous equation model with panel data, analyzing it with three-stage least square regression method. Faculty labor costs and central and local government research funds significantly positively affect faculty start-ups. Support funding, start-up clubs, and technology transfer offices significantly positively affect student start-ups. Results show that faculty start-ups significantly affect student start-ups, but there is no influence from student start-ups on faculty start-ups.

Keywords: university resources; faculty start-ups; student start-ups; Korean universities; panel; simultaneous equation fixed model; three stage estimation

1. Introduction

The roles and functions of universities change over time [1]. Universities that had focused on knowledge, education, and research began to emphasize industry-university cooperation in the late 1970s [2]. Entrepreneurial colleges emerged that, while continuing to emphasize knowledge and skills [3], also focused on research and development through cooperation with companies, utilization of university research results, transfer of university patents and technologies, and start-ups at universities [4]. While university research results had been initially concentrated more on promoting patents and technology transfers, recent emphasis has been placed on start-ups at universities [5]. Universities are also offering education and support for start-ups in various forms, such as reforming the curriculum through industry-academic cooperation projects, encouraging capstone projects, developing idea-based start-up items through start-up clubs, and finding star start-ups through start-up competitions. Industry–academic cooperation in the curriculum is designed to improve the relevance of learning outcomes and to enhance the contents of courses to meet the needs of industry. A start-up club is an autonomous group of students who meet regularly to promote entrepreneurship.
A Capstone Design is a curriculum that allows students to design, produce, and evaluate products aiming to train technical personnel in on-site working skills and to promote creativity to train students who are qualified to work in industry. The start-up environment for university teaching staff and researchers is also changing. Systematic efforts have been undertaken to induce technology start-ups through laboratories and to commercialize university research achievements.

Given this context, assessing resources that affect start-ups is crucial. Studies on student start-up factors have specifically focused on personal and institutional resources [6]. Studies concerning personal factors have included students’ age [7], gender [8], and family income [9], while studies concerning institutional resources have included facilities such as university resources and incubators, and science parks [10], as well as educational activities in relation to start-ups [11]. As with the study of student start-up resources, those on faculty start-up resources can be divided into micro-level focused studies [4,12,13] and macro-level focused studies [14,15], which have identified various relevant resources.

While numerous studies have analyzed resources relating to start-ups at universities, these studies have tended to separately focus on resources concerning student start-ups [16,17] or faculty start-ups [18,19]. Whereas considerable research had been undertaken on faculty start-ups, student start-ups have received relatively little attention [20], due to a prioritization by decision-makers of faculty start-ups and a lack of data on student start-ups [21]. However, it is increasingly necessary to analyze the resources affecting student start-ups at a time when there are more student start-ups than faculty start-ups, and when student start-ups have also been shown to outperform faculty start-ups in terms of quality [6].

This study divides university start-ups into faculty start-ups and student start-ups and explores relevant influencing resources. In addition, this study investigates the relationship between the two types of start-ups, student start-up and faculty start-up. Even though university resources serve as key factors that affect faculty and student start-ups, previous studies have provided scant evidence as to whether and to what extent such resources influence these types of start-ups. Universities need to examine which resources they use to produce a wide range of products involving many input elements. Korean higher education has faced an unprecedented period of change due to a decline in the school-age population and a freeze in enrollment fees [22]. This has pressured universities to run efficient management systems in finance, generating income to offset reduced funding. An analysis of the start-up resources in universities can help universities establish their direction and efficiently utilize their resources [23].

Resources may be sourced internally or externally and may be composed of diverse items; these factors may generate different outcomes. The resources affecting university start-ups are diverse and complex. Internal resources such as labor costs, research costs, and laboratory costs can affect start-ups, as can external resources such as specific government and industry finance. Additionally, research and patents initiated by university faculty members can affect start-ups, as can education content and financial support affect student start-ups. Each of these resources can have varying effects, and it is worth analyzing how these resources affect university start-ups. This study considered various relevant input resources affecting both faculty and student start-ups, how these resources are related to each other, and which resources differed between the two types of start-ups. The study also explored whether faculty start-ups affect student start-ups and vice versa and whether the relevant resources interact. The guiding research question of this analysis are as follows: What are the resource determinants of faculty and student start-ups in Korean universities? What is the relationship between faculty and student start-ups?

The overall study aim was to broaden understanding of relevant start-up resources through examining the relationship between faculty and student start-ups, to shed light on what resources promote university start-ups. In analyzing the relationship between faculty and student start-ups, three-stage regression least squares analysis was used within a panel simultaneous equation fixed model.
Next, in Section 2, previous research related to start-ups is considered, after which, in Section 3, the theoretical framework is discussed, and a focus is placed on resources influencing faculty and student start-ups. Section 4, the materials and methods section, introduces the analysis models and variables that are used in this study, while Section 5, the results section, presents the analysis results and discussion. Section 6 concludes the study.

2. Literature Review

University start-ups can be divided into those concerning either faculty members or students, with most studies separately analyzing the resources that influence faculty and student start-ups. Studies on resources affecting student start-up can be divided into the following: studies that analyze the influencing resources of start-ups at a personal level involving the effects of students’ general characteristics as well as socio-psychological, demographic, and empirical resources [24,25]; studies that offer an analysis of a university’s education, for example, concerning entrepreneurship, in relation to start-up intentions [26–28]; and one study on the effects of regional and cultural organizational environments on the formation of start-up intentions [29]. This study engaged with certain resources including the effects of start-up education (for example, concerning entrepreneurship) on start-up intentions and the effects of the social environment and the role of specific organizations on start-up intentions.

First, Alves et al. [6] assessed 2230 students from 70 universities in Brazil on decision factors in start-ups. The analysis showed that a student’s intention to start a business seemed not to be readily explicable in terms of any specific factors. Morris et al. [30] analyzed the factors that affected engagement with the entrepreneurial process in students in 25 countries and found that, while curricular and co-curricular programs had a positive effect on engagement with the entrepreneurial process, university support had a negative effect. As with student start-ups, factors that influence faculty start-ups can be divided into those that focus on the personal characteristics of faculty members undertaking start-ups [31] and those that focus on university support and institutions [18]. The latter study identified the university’s reputation, the policy of a university’s technology transfer office regarding investment in the university, and the low share of inventors’ royalties as major resources affecting university start-ups. Shane and Stuart [14] analyzed the effects of early capital investment on university start-ups using evolutionary economics theory and entrepreneurial research. Based on a history of 134 start-ups established from 1980 to 1996, it was found that it was easier to receive venture capital if the founder of the venture had direct or indirect relations with the investor, but that otherwise the chances of failure were high. Jung and Kim [19] analyzed how regional characteristics such as research and development (R&D) zones affect university start-ups, using panel logit models and negative binomial analysis of 122 universities from 2013 to 2015. That study suggested that the number of papers and patents generated, and the nature of research funding provided, were important resources affecting university start-ups. Powers and McDougall [5] used resource dependence theory to analyze the factors affecting start-ups in universities and assessed those factors using negative binomial regression concerning their effects on start-ups and the number of start-ups initiated. The financial, human, and organizational resources of the university were shown to have significant explanatory power in relation to generating start-ups, whereas the university patent variable was found to have an insignificant effect on both start-ups and the number of start-ups initiated. Douglas et al. [32] analyzed the influence of university entrepreneurial push strategies on the entrepreneurial intention of its students. For Brazilian universities, this study compared the effect of entrepreneurial push strategies with traditional managerial education without a specific focus on entrepreneurial activities. Using partial least squares structural equation modeling, this study showed that entrepreneurial push strategies in universities does not account for differences in the students’ entrepreneurial intentions. Last, even though they did not discuss universities, Eulalia and Romuald [33] examined success factors of start-ups in the European Union. Emphasizing that it is imperative for start-up companies to boost innovation levels, the competitiveness of national economies also needs to be considered as a factor.
impacting sustainability [34], this study determined the key success factors of start-ups in the EU and classified the gap between developed and lagging member states. The results indicated that more developed countries offer an institutional competitive advantage to start-ups through such factors as institutions, human capital, and certain dimensions of social capital. Most of these studies have separated student start-ups from faculty start-ups. In contrast, Astebro et al. [21] investigated both faculty and student start-ups, claiming that an analysis of existing research showed a focus on faculty start-ups and that it was necessary to analyze the resources affecting student start-ups, and found that student start-ups were more active than faculty start-ups. In addition, they conducted a case study involving the Massachusetts Institute of Technology, Halmstad University, and Chalmers University of Technology concerning their start-up education, which suggested that student activities related to start-ups and positive norms among students and faculty members regarding start-ups were important in fostering student start-ups, and that an industry-oriented education program and entrepreneurship were also important.

Previous studies have been useful in undertaking empirical analyses at both the micro-level and macro-level concerning the resources affecting university start-ups. However, these studies have failed to consider comprehensively the specific characteristics of the university as an organization and the multiple resources affecting university start-ups. For example, Di Gregorio and Shane [18] considered only four resources influencing university start-ups in relation to variables related to university policy. Powers and McDougall [5] considered corporate R&D funding as an important explanatory variable. However, the finances that affect university start-ups consist of the university’s own research funding, government research funding, local government research funding, and research funding from private companies. That study, however, only analyzed private companies in terms of research funding. Jung and Kim [19] analyzed the number of papers and patents generated, and the research costs involved, as resources affecting start-ups at universities. However, other resources besides these variables are likely to be influential, such as financial investment within a university, the technology transfer office, and the degree to which university education or research is linked with industry. A university functions in various and complex forms, with multiple resources affecting university start-ups, but previous studies have not considered this wide range of variables. If there are various resources affecting start-ups and these variables are not considered, despite their importance, then selection bias is likely to arise. Even as objects of analysis, the factors affecting start-ups in universities have only been analyzed in a limited manner despite increasing numbers of both student and faculty start-ups, and with student start-ups emerging as an important phenomenon. As noted, few studies have examined resources affecting student start-ups, and policy makers have paid less attention to student start-ups, because of limitations in student start-up data provided by university technology transfer offices, because research related to student start-ups has been conducted mainly through questionnaires for graduates, and because generalization is impeded as only a small number of universities have been investigated [21]. To analyze start-ups systematically in universities, it is necessary to analyze the resources influencing start-ups for both students and faculty members and how the resources interrelate, as one type of start-up may affect the other and there may be different resources involved for each type of start-up, as well as specific kinds of relationships between student and faculty start-ups. Studies have not focused on these multiple and interlinked aspects. Therefore, this study sought to address a research gap in this regard.

3. Theoretical Background and Variables

A start-up can be defined as the establishment of a viable new organization with the aim of organization development, technology and product development, and market development [30]. In universities, faculty start-ups are used to commercialize the technology developed by universities, which is a direct use of such technology in contrast to patents and technology transfers [5]. Student start-ups occur as the fruit of entrepreneurship education and through exercising skills in relation to exploring and commercializing new opportunities. University start-ups are a preferred
model in terms of being able to take the lead in building cooperative networks with industries [35]. Not only can start-ups generate financial revenue for R&D investments, but they also play an important role in creating jobs and developing the local economy that communities need [36].

To investigate the key resources that foster entrepreneurial propensity, this study adopted a resource dependence perspective [37,38]. Resource dependence theory views an enterprise as a collection of resources and describes differences between organizations in terms of resources and capabilities, as well as the effects of these resources on the behavior and performance of the entity [38]. Resources held by an entity play a key role in determining the scope of its business [39] and companies focus on their core capabilities through efficient allocation of resources and generate outcomes accordingly [40]. This theory predicts that universities will show varying degrees of performance because of the resources and capabilities they have at certain points in time, and that, where resources available are adequate or sufficient, the likelihood of a spin-off will increase [41].

Many different types of resources have been considered in resource dependence theory. Similarly, resources that affect university start-ups exist in various forms. First, university resources can be divided into internal and external resources, and further into financial, human, and physical resources [42]. Previous studies have analyzed the function and role of these resources through distinguishing them and analyzing the utilization patterns of specific resources, as noted previously in studies by O’Shea et al. [43] and Power and McDougall [5]. In this study, the resources that may affect faculty and student start-ups have been divided into shared and distinctive resources.

3.1. Resources Affecting Faculty Start-ups

The resources that affect faculty start-ups include internal and external resources, intellectual prominence, and technology transfer offices. Internal resources comprise those resources in which universities have invested to operate and maintain university activities. Universities are organizations that produce education, research, services, and intellectual commercialization, and there are elements within universities that are commonly linked to produce these outcomes, including the cost of labor of faculty members, performance bonuses, research costs, laboratory costs, and machinery costs. Faculty members are essential to the operation of universities and carry out key activities to enable universities to perform. As the activities of faculty members, previously limited to education and research, have expanded to include start-ups, the role of faculty members in starting businesses has received greater emphasis, with their cost of labor and performance bonuses considered as resources likely to affect start-ups that require analysis. Research funding is a key resource affecting university performance [44–46]. Universities have considered research funding to be an influencing resource for start-ups, as it is possible to secure innovative technologies through research activities and enhance the likelihood of starting a business through such technologies. Along with labor costs, performance bonuses, and research costs, this study considered laboratory and equipment acquisition costs as elements of the resources used in universities. These internal resources and their elements have been considered as shared resources among faculty and student start-ups in this study.

Concerning external resources in relation to faculty start-ups, these resources involve resource support derived from outside the university to aid the university or to attract external businesses and could include government research and corporate research funding. Government research funding is a key source to assist with research in universities and is an important resource in generating university research results. Many studies have shown that government research funding has a positive effect on university performance. For example, Foltz [47] found that United States federal funding of research increased patent activities. Salter and Martin [48] found that government financial support had a significant effect on university research performance. However, there are conflicting studies on how government research funding affects the commercialization of universities, for example, in relation to start-ups. It has been contended that government funding is often focused on basic research, which could hamper commercial activities such as start-ups. Given this context, this study aimed to understand how government research funding affects faculty start-ups.
Corporate funding for research can have a significant effect on start-ups. There are various reasons why universities cooperate with industries. A commercial entity may wish to conduct a basic study that might be difficult to perform [49] and which linkage to a university could facilitate through allowing access to equipment not possessed by that commercial entity. In addition, companies can obtain support from faculties in determining strategies, and cooperation from universities is also essential in training the preliminary workforce of companies [50]. Corporate research funding is also essential for universities to foster effective research. Receiving research funding from industries enables collaborative research with companies and facilitates knowledge transfer, as such processes increase understanding of the market and increase the likelihood of using subsequent networks to start a business [51]. However, research results have shown conflicting outcomes concerning how corporate research funding affects start-ups. It has been claimed that, although cooperation with companies may activate commercially oriented research, it can also reduce start-up activities because industry-funded firms sometimes want to gain patent rights to inventions [5,18]. Given these varying views, it appears useful to determine more clearly how corporate funding affects faculty start-ups.

Intellectual prominence has been cited as an influencing resource in faculty start-ups, particularly in predicting start-ups [18]. One study has shown that intellectual prominence not only facilitates the establishment of innovative ventures in universities, but also enables high-quality start-ups [52]. It has been claimed that the greater the intellectual prominence of faculty members, the more likely they are to receive financial support from industries and from the government, as the probable knowledge asymmetry is likely to be attractive for venture investments [18]. This study used science citation index (SCI) papers, patents, and technology transfer indicators to determine how intellectual prominence affects faculty start-ups.

The functions and roles of technology transfer offices also affect university start-ups. Technology transfer offices play a key role in technology commercialization in situations where faculty members and students have comprehensive ownership of their inventions but are unable to initiate start-ups due to a lack of information on technology commercialization and start-ups [5]. Technology transfer offices have expertise in relevant institutional and policy changes concerning technology commercialization and can assist with initial investment, corporate management, and portfolio management. Given the importance of technology transfer offices, this study aimed to determine their effects on both faculty and student start-ups.

Finally, student start-ups have influenced faculty start-ups, as can be seen with major success stories in student start-ups such as Google and Facebook. In addition, if universities have a start-up environment, they are likely to operate in a mutually reinforcing and positive manner [30]. The importance of student start-ups has been increasingly emphasized and various education and support programs for student start-ups are being conducted, which are expected to further boost faculty start-ups. Therefore, this study considered student start-ups as a further resource affecting faculty start-ups.

3.2. Resources Affecting Student Start-ups

Concerning the resources affecting student start-ups, internal resources and technology transfer offices were also considered, along with the university support system for start-ups and education on entrepreneurship.

The support system for student start-ups in universities includes education that fosters potential entrepreneurship, simulation that helps students to carry out their start-ups, and incubation that helps them grow their start-ups to become independent companies [53]. Over a range of activities, education concerning entrepreneurship has been found to have a significant effect on start-ups [7]. To promote student start-ups, it is necessary to encourage student intentions to start a business, for which education is required concerning how to start a business at university, as well as special lectures on start-ups and practical education and experience in relation to relevant contextual resources. Through education on start-ups and actual cases, expectations can be raised and perceived self-efficiency can be enhanced.
through practical education and experience. A recent study on start-ups also found that knowledge of entrepreneurship and entrepreneurial opportunities were related [54].

Education on entrepreneurship is an educational process that seeks to improve entrepreneurial attitudes and skills [26] and ranges from the establishment of business plans to content creation [55]. Preparation of a business plan is an important part of the curriculum for educating students in entrepreneurship, as entrepreneurial intentions can be honed and relevant skills and knowledge developed. Venture creation is facilitated through programs that impart understanding of the process of establishing and operating a venture. Various methods are used in entrepreneurship education, but this study focused on start-ups in relation to a type of team project, Capstone Design, and start-up clubs.

Capstone Design is a curriculum that allows students to design, produce, and evaluate products that they are likely to use in business or in other areas based on knowledge acquired in each discipline. This program is designed to train technical personnel in on-site working skills and to promote creativity to meet the demands of industry. Capstone Design is a type of project-based teaching method that achieves learning objectives based on experience through practice based on projects [56]. Project-based learning is similar to real life and improves practical sense through linking abstract knowledge with concrete reality. Using project-based learning in education, such as Capstone Design, and developing entrepreneurship that requires varying degrees of knowledge and skills ranging from business planning to start-ups, have been identified as effective methods of education [57]. Through Capstone Design, students can experience cooperation with industry, and such experience is likely to have a positive effect on start-ups as it provides an opportunity to develop interest and knowledge concerning particular industries and markets.

A start-up club is a group in which students interested in starting a business can share ideas. This is a co-curricular activity outside the classroom and is a key element of entrepreneurship education programs [58]. Mentoring, counseling, guidance, and promotion of start-ups are carried out through start-up club activities, in which the ability to identify start-up opportunities, develop start-up items, improve management skills, and develop entrepreneurship can be improved. Education programs for entrepreneurship, such as start-up clubs and Capstone Design, are an important source of entrepreneurial attitudes and business intentions. Thus, this study analyzed how start-up club activities, Capstone Design activities, and financial support for these activities affect student start-ups.

Faculty start-ups also affect student start-ups. A university is an organization that shares common values and culture, and if more faculty members are starting their own businesses, then it is more likely that students will be active in starting a business. Also, students can identify opportunities for start-ups, learn methodologies for start-ups, and improve their business management skills through faculty start-ups. Therefore, this study investigated faculty start-ups as an important resource affecting student start-ups. In this vein, this study examines the following hypotheses.

**Hypothesis 1.** University resources will have positive effects on faculty and student start-ups.

**Hypothesis 1a.** Financial expenditure on labor costs will have positive effects on faculty and student start-ups.

**Hypothesis 1b.** Financial expenditure on bonuses will have positive effects on faculty and student start-ups.

**Hypothesis 1c.** Financial expenditure on research expenses will have positive effects on faculty and student start-ups.

**Hypothesis 1d.** Financial expenditure on laboratory expenses will have positive effects on faculty and student start-ups.

**Hypothesis 1e.** Financial expenditure on equipment costs will have positive effects on faculty and student start-ups.
Hypothesis 1f. The size of the technology transfer office will have positive effects on faculty and student start-ups.

Hypothesis 2. University resources for faculty will have a positive effect on faculty and student start-ups.

Hypothesis 2a. The number of science citation indices in a university will have positive effects on faculty start-ups.

Hypothesis 2b. The number of patents in a university will have positive effects on faculty start-ups.

Hypothesis 2c. The amount of technology revenue in a university will have positive effects on faculty start-ups.

Hypothesis 2d. Government research funding in a university will have positive effects on faculty start-ups.

Hypothesis 2e. Local government research funding in a university will have positive effects on faculty start-ups.

Hypothesis 2f. Enterprising research funding in a university will have positive effects on faculty start-ups.

Hypothesis 3. University resources for students will have a positive effect on student start-ups.

Hypothesis 3a. University start-up funds for student will have a positive effect on student start-ups.

Hypothesis 3b. Government start-up funds for student in university will have a positive effect on student start-ups.

Hypothesis 3c. The number of participants in start-up clubs will have a positive effect on student start-ups.

Hypothesis 3d. Capstone design funding for students will have a positive effect on student start-ups.

Hypothesis 3e. Capstone design support for students will have a positive effect on student start-ups.

Hypothesis 4. Faculty and student start-ups will positively affect each other.

Hypothesis 4a. Faculty start-ups will positively affect student start-ups.

Hypothesis 4b. Student start-ups will positively affect faculty start-ups.

The control variables that affect university start-ups were analyzed in terms of the size of universities and whether medical schools or engineering colleges were also involved. Regarding the size of a university, one study has shown that the larger a department is, the more likely the faculty members cooperate with each other and that the department benefits from intellectual synergy [59]. However, there is limited research analyzing the effect of the size of universities on faculty and student start-ups, and in relation to whether medical schools or engineering colleges are operating in universities. This study took these factors into account, especially given, concerning patents or licensing inventions, that studies have shown that bio-medical colleges are more productive [36,45], and that start-ups are more active in bio-medical and engineering fields [13,43,60], but it remains unknown whether this is the case in Korea. Finally, this study set the university’s founding year as a control variable to analyze the characteristics of recently established universities compared to long-established universities.

The dependent variables were divided into faculty start-ups and student start-ups to identify the number of faculty and student start-ups per university and what resources affect the start-ups. Precise analysis of the relationship between faculty and student start-ups is challenging, as the numbers of faculty members and students varies across universities. Thus, this study focused on the number of
start-ups per full-time faculty member and the number of start-ups per graduate student in any given year. Considering these variables, the study used the items shown in Table 1 below:

**Table 1.** Explanatory and dependent variables in relation to faculty and student university start-ups in Korea.

| Variable                      | Resources                                      | Formula                                                                 | Hypothesis |
|-------------------------------|------------------------------------------------|-------------------------------------------------------------------------|------------|
| Labor costs                   | Full-time faculty remuneration/No. of full-time faculty members | Hypothesis 1a                                                          |            |
| Bonuses                       | Full-time faculty performance-based payment/No. of full-time faculty members | Hypothesis 1b                                                          |            |
| Research expenses             | Spending on research and research management/No. of full-time faculty members | Hypothesis 1c                                                          |            |
| Laboratory expenses           | Spending on experiments/No. of full-time faculty members | Hypothesis 1d                                                          |            |
| Equipment costs               | Spending on machines and apparatus/No. of full-time faculty members | Hypothesis 1e                                                          |            |
| Technology transfer offices   | No. of staff in the university technology transfer office | Hypothesis 1f                                                          |            |
| Science Citation Index (SCI)  | SCI equivalent (+ other journals published internationally)/No. of full-time faculty members | Hypothesis 2a                                                          |            |
| Patents                       | No. of domestic patents/No. of full-time faculty members | Hypothesis 2b                                                          |            |
| Technology revenues           | Sum of licensing revenue/No. of full-time faculty members | Hypothesis 2c                                                          |            |
| Government research funding   | Government research fund/No. of full-time faculty | Hypothesis 2d                                                          |            |
| Local government research funding | Local government research fund/No. of full-time faculty | Hypothesis 2e                                                          |            |
| Enterprise research funding   | Enterprise research fund/No. of full-time faculty | Hypothesis 2f                                                          |            |
| University student fund       | University start-up fund/No. of graduates       | Hypothesis 3a                                                          |            |
| Government student fund       | Government start-up fund to universities/No. of graduates | Hypothesis 3b                                                          |            |
Table 1. Cont.

| Variable          | Resources                          | Formula                                                  | Hypothesis |
|-------------------|-----------------------------------|----------------------------------------------------------|------------|
| Start-up clubs    | No. of participants in a          | Hypothesis 3c                                            |            |
|                   | start-up club/No. of graduates    |                                                          |            |
| Capstone Design   | No. of students receiving         | Hypothesis 3d                                            |            |
| funding           | Capstone Design funding/No. of    |                                                          |            |
|                   | graduates                         |                                                          |            |
| Capstone Design   | Capstone Design support/No. of    | Hypothesis 3e                                            |            |
| support           | graduates                         |                                                          |            |
| Faculty start-ups | No. of faculty start-ups/No. of   | Hypothesis 4a                                            |            |
|                   | full-time faculty members         |                                                          |            |
| Student start-ups | No. of student start-ups/No. of   | Hypothesis 4b                                            |            |
|                   | graduates                         |                                                          |            |
| Region in Korea   | Seoul, metropolitan area/province |                                                          |            |
| No. of students   | Less than 5000, 5000–10,000, more |                                                          |            |
|                   | than 10,000                       |                                                          |            |
| Presence of an    | Presence/absence of an            |                                                          |            |
| engineering school| engineering college               |                                                          |            |
| Presence of a     | Presence/absence of a             |                                                          |            |
| medical school    | medical school                    |                                                          |            |
| Year of university| establishment                     |                                                          |            |

Control variables

Dependent variables

4. Materials and Methods

4.1. The Model

The target data involved panel data on which panel data regression was applied. Panel data regression is a combination of cross-sectional data and time series data that can be analyzed through explicitly considering the heterogeneity of the panel objects, as follows:

\[ y_{itf} = \alpha + \beta x_{it} + u_i + \varepsilon_{it}, i(university) = 1, 2, 3, \ldots, n \text{ and } t(year) = 1, 2, 3, \ldots, t \]

\[ y_{its} = \alpha + \beta x_{it} + u_i + \varepsilon_{it}, i(university) = 1, 2, 3, \ldots, n \text{ and } t(year) = 1, 2, 3, \ldots, t \]

where \( y_{itf} \) is the faculty start-up, \( y_{its} \) is the student start-up, and \( x \) is the determinant vector.

Hypothesis testing can be performed, taking into account the time-invariant object characteristics of the error term \( u_i \) in using panel data regression, through applying the Breush and Pagan Lagrangian multiplier test, which tests \( u_i = 0 \) for all panel objects. If the hypothesis is shown to be correct, then the characteristics of the panel objects need not be taken into account as they can be estimated with pooled ordinary least squares. However, if the hypothesis is rejected, the characteristics of the panel objects are estimated using a fixed effect model. When selecting panel data regression through the Breush and
Pagan Lagrangian multiplier test, a decision is required on whether to use fixed effects or random effects models. After testing, a panel fixed regression model was found to be suitable.

For this study, a panel simultaneous equation model was applied in relation to whether faculty start-ups affect student start-ups, whether student start-ups affect faculty start-ups, and whether these resources interact with each other, using the following equations:

$$\text{faculty start up}_{itf} = \beta_0 + \beta_1 \text{student start up}_{it2} + \beta_2 x_{it1} + u_{it1} + \epsilon_{it1}$$  \hspace{1cm} (1)

$$\text{student start up}_{its} = \beta_0 + \beta_1 \text{faculty start up}_{it1} + \beta_2 x_{it2} + u_{it2} + \epsilon_{it2}$$  \hspace{1cm} (2)

where $y_{itf}$ is the faculty start-up, $y_{its}$ is the student start-up, and $x$ is the start-up determinant vector, $i(\text{university}) = 1, 2, 3, \ldots, n$ and $t(\text{year}) = 1, 2, 3, \ldots, t$.

Among the independent variables, financial variables were utilized through conversion to natural log. Financial variables differ greatly based on a university’s size, and the distribution of variables is highly skewed. Logged conversion of financial variables not only minimizes the effect of extreme values in estimating the regression coefficients, but also enables efficient estimates [61].

In these models, faculty start up $_{it1}$ and student start up $_{it2}$ are endogenous variables that were determined at the same time, and $x_{it}$ are exogenous variables. In addition, an error component was assumed to control for the heterogeneity of unobserved panel groups. An instrumental variable method can be used to obtain a consistent estimator from this model. When estimating Equation (1), $x_{it2}$, which is the exogenous variable of the second formula, was used as the instrumental variable. When estimating formula (2), $x_{it1}$, which is the exogenous variable of the first formula, was used. Each of the above models can be estimated using a two-stage least squares method or a generalized method of moments, this study used the three-stage least squares method to estimate both formulas simultaneously. The three-step least squares method works as follows. Instrumental variables are used to obtain estimations of endogenous explanatory variables (step 1), and the residual obtained in step 1’s model estimation is used to obtain the covariance matrices for each equation error term (step 2). Finally, a generalized least squares estimation can be performed through stacking the two equations using the estimations and covariance matrices obtained in steps 1 and 2. The reason for considering such a model is that the panel simultaneous equation model estimates both equations at the same time instead of each separately, which not only provides more efficient estimates but also provides a consistent estimate. Such a model is appropriate for analyzing the relationship between faculty and student start-ups.

4.2. Data

Data on universities for this study were gathered from the Korean university information disclosure system (the URL for this site is: http://www.academyinfo.go.kr/index.do?lang=en). This site provides data for only the three most recent years. Further data are available upon request from the Korean Council for University Education. From these sources, we obtained information concerning 237 universities. Among these data, we extracted data in relation to 92 universities that held start-up data. A total of 17 universities had less than 5000 students, 28 universities had 5000–10,000 students, and 47 universities had more than 10,000 students. Concerning medical schools, 59 universities had medical schools and 33 universities did not. Technological start-ups can be active depending on whether an engineering college is set up. Twelve universities did not have one while 80 universities did, indicating that most sample universities run an engineering school.

Among the common resources that could affect start-ups, labor costs averaged 63,972 KRW (1 U.S. dollar = 1180 Korean won). Each full-time faculty member spent 9,011,000 KRW on campus research, with a minimum expenditure of 161,000 KRW and a maximum expenditure of 69,456 KRW, indicating a wide gap. Regarding resources related to student start-ups, each student received an average of 35,000 KRW in funding for initiating a start-up, while each student received an average of 218,000 KRW from the government, indicating that the government provided considerably more
financial support than the universities. The rate at which students participated in start-up clubs was 0.107, and the number of students who received support from Capstone Design was 0.481, indicating that more students participated in Capstone Design than in start-ups. In terms of research funding per full-time faculty member, central government funding was the highest, followed by privately funded research. The number of SCI-class papers, indicative of intellectual prominence, was found to be 0.25 per full-time faculty member, and patent registration was 0.117 (Table 2).

Table 2. Descriptive statistics for variables.

| Resources                          | Mean   | Standard Deviation | Minimum | Maximum |
|------------------------------------|--------|--------------------|---------|---------|
| Labor costs                        | 63,972 | 31,417             | 19,214  | 250,884 |
| Bonuses                            | 11,829 | 13,814             | 0       | 68,106  |
| Research expenses                  | 9011   | 8990               | 161     | 69,456  |
| Laboratory expenses                | 4442   | 2906               | 594     | 19,750  |
| Equipment costs                    | 7101   | 6377               | 635     | 57,807  |
| Technology transfer offices         | 2.295  | 2.453              | 0       | 22.2    |
| Science Citation Index             | 0.250  | 0.231              | 0.002   | 1.387   |
| Patents                            | 0.117  | 0.142              | 0       | 1.116   |
| Technology revenues                | 814    | 1373               | 0       | 18,237  |
| Government research funding        | 37,054 | 48,429             | 3861    | 436,126 |
| Local government research funding  | 2210   | 2500               | 0       | 15,861  |
| Enterprise research funding        | 7544   | 16,490             | 0       | 169,377 |
| University student fund            | 35     | 73                 | 0       | 971     |
| Government student fund            | 218    | 548                | 0       | 7957    |
| Start-up clubs                     | 0.107  | 0.764              | 0       | 19.25   |
| Capstone Design funding            | 0.481  | 0.671              | 0       | 8.718   |
| Capstone Design support            | 52     | 161                | 0       | 3380    |
| Faculty start-ups                  | 0.0021 | 0.004              | 0       | 0.049   |
| Student start-ups                  | 0.0030 | 0.004              | 0       | 0.062   |

Note: Unit: KRW (Korean won), no. of faculty members, no. of students, no. of articles, no. of patents, no. of start-ups.
When comparing the frequency of start-ups, students were found to have more start-ups than faculty members. Furthermore, when assessing the current status of start-ups through controlling for the number of faculty members and students, the number of start-ups per faculty member was 0.0021, whereas the number of start-ups per student remained more frequent at 0.003.

Data stationary tests were performed prior to the panel data analysis. In the case of the Levin, Lin and Chu (LLC) test, all variables were required to be balanced panel data, and the Im, Pesaran, and Shin (IPS) test can be utilized for panel data of more than 10 years. Inverse chi-squared results showed that there was no unit root in any variable apart from the government funding for start-ups per student variable, which was found to have significant values at the level of 0.0001 after performing a unit root test using log transformation.

5. Results and Discussion

5.1. Results

The results obtained in relation to model fitness indicated that the faculty start-up model’s R-squared value was 0.258 and chi-square value was 97.17. The student start-up model showed more explanatory power, with an R-squared value of 0.38 and a chi-square value of 179.44 (Table 3).

| Equation         | Root-Mean-Square Error | R-Squared | Chi-Squared | p Value |
|------------------|------------------------|-----------|-------------|---------|
| Faculty start-up | 0.003996               | 0.2589    | 97.17       | 0.0000  |
| Student start-up | 0.002573               | 0.3829    | 179.44      | 0.0000  |

The results of the analysis of the influencing resources on faculty and student start-ups and the relationship between the two are shown in Table 4. The results showed that there was no difference in the number of faculty start-ups from year to year. On the other hand, the number of student start-ups has been on the rise since 2016 as compared to 2012. In terms of university size, faculty members were more likely to initiate start-ups at larger universities, whereas there was no difference noted for students. There were more faculty start-ups at universities with a medical school than at universities that did not have one, and also a high transfer of patents and technology at universities with a medical school. However, there was no difference in the number of start-ups depending on whether there was a medical school or an engineering college.

| Variables        | Coefficient (Standard Error) | Variables        | Coefficient (Standard Error) |
|------------------|------------------------------|------------------|------------------------------|
| Faculty start-up |                              | Student start-up |                              |
| 2013             | −0.000 (0.001)               | 2013             | −0.000 (0.001)               |
| 2014             | 0.000 (0.001)                | 2014             | −0.000 (0.001)               |
| 2015             | 0.001 (0.001)                | 2015             | 0.001 (0.001)                |
| 2016             | 0.001 (0.001)                | 2016             | 0.002 ** (0.001)             |
| 2017             | 0.001 (0.001)                | 2017             | 0.002 ** (0.001)             |
| 2018             | 0.001 (0.002)                | 2018             | 0.003 *** (0.001)            |
In terms of internal resources, the labor costs per full-time faculty member had a significant effect on faculty start-ups but not on student start-ups. Interestingly, the research costs per full-time faculty member negatively affected faculty start-ups but had a positive effect on student start-ups, which can be interpreted as faculty members being more active in producing papers and fulfilling other requirements than in start-ups when using university research funding. As resources affecting faculty start-ups, external resources showed positive effects when there was financial support from central or local governments, whereas private research funding showed negative effects. Intellectual prominence did not have a significant effect on faculty start-ups. Finally, it was found that student start-ups did not have a significant effect on faculty start-ups.

University funding for student start-ups had a significant effect on student start-ups whereas government funding did not, indicating that performance varied depending on the source of funds. The number of people participating in start-up clubs was significant, indicating that start-up club activity positively affected student start-ups. However, Capstone-related personnel assistance and support funding were found to have a negative effect or to be insignificant. Technology transfer office was not significant for faculty members but was significant for students. An analysis of the effect of faculty start-ups on student start-ups showed that faculty start-ups had a significant effect on student start-ups, with a higher regression coefficient value than other variables (Table 5).
Table 5. Results of analysis.

| Hypothesis     | Variables                        | Faculty Start-Up | Student Start-Up |
|----------------|----------------------------------|------------------|------------------|
| Hypothesis 1a  | Labor costs                      | Accepted         |                  |
| Hypothesis 1b  | Bonuses                          |                  |                  |
| Hypothesis 1c  | Research expenses                | Negative         | Accepted         |
| Hypothesis 1d  | Laboratory expenses              | Accepted         |                  |
| Hypothesis 1e  | Equipment costs                  | Accepted         |                  |
| Hypothesis 1f  | Technology transfer offices       |                  | Accepted         |
| Hypothesis 2a  | Science Citation Index (SCI)      |                  |                  |
| Hypothesis 2b  | Patents                          |                  |                  |
| Hypothesis 2c  | Technology revenues              |                  | Accepted         |
| Hypothesis 2d  | Government research funding       | Accepted         |                  |
| Hypothesis 2e  | Local government research funding | Accepted         |                  |
| Hypothesis 2f  | Enterprise research funding       | Negative         |                  |
| Hypothesis 3a  | University student fund          | Negative         | Accepted         |
| Hypothesis 3b  | Government student fund          |                  |                  |
| Hypothesis 3c  | Start-up clubs                   | Accepted         |                  |
| Hypothesis 3d  | Capstone Design funding          | Negative         |                  |
| Hypothesis 3e  | Capstone Design support          |                  |                  |
| Hypothesis 4a  | Faculty start-ups                |                  | Accepted         |
| Hypothesis 4b  | Student start-ups                |                  |                  |

Note: Accepted: Significant and positive, Negative: Significant but negative.

5.2. Discussion

This study analyzed the resources affecting faculty and student start-ups and the relationship between them, through a simultaneous equation model. First, there were no differences in the trend of faculty start-ups from 2012 onwards, whereas student start-ups increased from 2016. Faculty start-ups have been initiated steadily from 2012, whereas student start-ups began later. Student start-ups are likely to have become more active since 2016 in response to employment challenges faced by students. Universities with medical schools were found to have lower numbers of faculty start-ups, a result different from that found in previous research [13,43,60]. For example, O’Shea et al. [43] suggested that the more research funding universities received in relation to specialist areas such as life science, chemistry, and computer science, the more spin-offs those universities would set up. Those findings indicated that the fields of biomedical research and engineering were start-up-friendly. However, this study found that universities with a medical school had fewer faculty start-ups. One possible explanation is that faculty members may be more passive toward start-ups. Entrepreneurship requires an innovative and creative spirit [62]. In Korea, universities with medical schools are recognized as highly reputable and, with their reputations already intact, faculty members at such universities may be less likely to engage in the higher risks and uncertainty that come with start-ups. No significant differences for student start-ups were found in terms of university characteristics, such as the location of the university, its size, or whether there was a medical school or an engineering college. However, financial investment and education were important resources for student start-ups. Overall, there were specific differences between the dependent variables of faculty
and student start-ups in terms of resources and university characteristics influencing the number of start-ups.

Labor costs were shown to be significant variables in faculty start-ups, but not in student start-ups. What was noteworthy was that university research funding had a significant negative effect on faculty start-ups, but had a significant positive effect on student start-ups, indicating that greater university research funding leads to fewer faculty start-ups but more student start-ups. The general view is that research funding is an important resource affecting research productivity, such as patents, and that the productivity of faculty members increases only when sufficient funding is provided [44]. The results here showing that more university research funding invested led to fewer faculty start-ups gives rise to two possible interpretations. First, it is possible that because university research funding is intended to promote graduate student research or educational purposes, it has a negative effect on faculty start-ups but positively affects student start-ups. Second, the use of research funding may have more effect on the production of papers and patents rather than on start-up activities. Given that the independent variables considered in this study were shown not to have multicollinearity, the interpretation that expenditure on research affects more the production of papers or patents appears less plausible. Laboratory costs and machinery purchase costs, which belong to another category of internal resources, were found to affect faculty and student start-ups in different ways. Other differences between student and faculty start-ups were found. Previous studies have suggested that faculty members with high intellectual prominence are more likely to start a business [19]. However, in this study, intellectual prominence, expressed through SCI papers, patents and technology transfer revenue, did not have a significant effect on faculty start-ups. One possible explanation for this result is that faculty members may be less interested in start-ups that involve relatively high risk and uncertainty, and prefer to focus on publishing papers, which is an essential element in securing tenure. This finding suggests that, to fully understand the resources affecting faculty start-ups, it is necessary to consider specific characteristics or the extent of entrepreneurial willingness among faculty members alongside institutional aspects.

Many studies have shown that government research funding has a positive effect on performance, such as the number of university patents and papers [47,48] but research analyzing its effect on start-ups is limited. Some previous studies have reported that government research funding negatively affected start-ups, but this study found that government research funding had a significantly positive effect on start-ups, as did local government research funding. On the other hand, research funding from private companies did not show the same pattern. Generally, it has been considered that the closer the link between universities and private companies, the more likely issues faced by private companies will be solved, with a greater likelihood of new technologies becoming available. Such a scenario has been claimed to increase the likelihood of start-ups [43], specifically that because research funding from private companies involves fewer issues in relation to information asymmetry than government research funding, it increases the chances that researchers will initiate start-ups [18]. However, this study found that corporate research funding had a significantly negative effect on start-ups. This result supports a view that commercially oriented research through industry funding can reduce start-up activities because company funding may entail obtaining the rights to inventions or technologies that are the result of research [5]. Technology transfer offices did not have a significant effect on faculty start-ups but did on student start-ups. A possible explanation for this finding is that even if a faculty member secures a patent or technology, there is no necessary link in doing that with initiating start-ups, especially if a culture of start-ups is not widespread.

As a resource influencing student start-ups, university funding for start-ups was positive and significant, whereas government funding was not significant. It has previously been shown that providing start-up funding has a positive and significant effect on start-ups [6], most likely because such funding enables the creation of business plans, facilitates market research, and allows for the production of prototypes [63]. In addition, financial support from universities can play a critical role in the early stages of start-ups, as it can be difficult to secure external venture capital or attract an angel investor [64]. However, this study showed differing results depending on the source
of the funds. As seen in the descriptive statistics, government funding for student start-ups was approximately six times higher than university funding. A possible explanation for the negative effect of government funding is that university funding has been more effectively targeted, while there has been inefficiency in the utilization of government funding, with education programs or activities to promote start-ups not being conducted effectively. Start-up clubs were found to have a positive and significant effect on student start-ups, with a higher regression coefficient than that of other variables. A start-up club is a community of students who are interested in starting a business in the same field, where entrepreneurship, mentoring, and coaching on start-ups take place and learning by doing occurs, and these aspects are likely to play an important role in the positive effects of start-up activities on student start-ups. The results in this regard were also consistent with a previous study [65]. Capstone Design had no significant effect on student start-ups. Capstone Design, involving practice-based learning, is considered to improve creative problem-solving skills and to facilitate knowledge acquisition concerning specific industry technology, and many universities use Capstone Design to foster start-ups. Our results showing that Capstone Design was not significant in this regard differed from previous studies [30,66]. It is possible that Capstone Design has not been suitably applied in universities because, in Korea, Capstone Design is an important indicator of government financial support assessment, and therefore, the number of students may have been exaggerated or perfunctory programs run, or even goals displaced or outcomes manipulated, to receive financial support [22,67].

While faculty start-ups had a significant effect on student start-ups, student start-ups did not have a significant effect on faculty start-ups. The number of faculty start-ups was lower than that of student start-ups, but active start-up activities by faculty members led to active start-up activities by students. Several interpretations are possible concerning these results. One interpretation is that, as shown with faculty start-ups being initiated at a steady rate since 2012 whereas student start-ups were beginning to increase from 2016, faculty start-ups have increasingly begun to positively affect student start-ups. Another interpretation is that student start-ups have not affected faculty start-ups (at least as of yet) because star start-ups such as Google and Facebook have yet to emerge in student start-ups. A further interpretation, drawn from resource dependence theory, is that faculty start-ups influence student start-ups in terms of being a resource, whereas student start-ups do not play that role as yet for faculty start-ups. While an ideal start-up university environment would involve positive and reinforcing interaction in a virtuous cycle [23], it would appear that the start-up environment in Korean universities currently demonstrates a predominant one-way influencing pattern from faculty start-ups to student start-ups.

These findings provide implications that may be used to guide university resource management in the design of an entrepreneurship program. Regarding student start-ups, a university student fund has a positive and significant effect on them, while there is no such significant effect from a government student fund. We can assume that there may be an agency problem in government student funds. It will be necessary to adapt methods to increase the effectiveness of government financial support such as performance-based systems or performance monitoring systems. In addition, this study shows that a start-up club has a significant effect on start-ups and its explanation power is strong. A start-up club is a key element of entrepreneurship for developing an item and improving management skills through mentoring and counseling. Formal and non-formal learning in start-up clubs is an important foundation for entrepreneurial competence development [68]. In this vein, universities need to develop a measure to activate start-up clubs and introduce substantial operation programs for facilitating start-ups. Regarding faculty, this study suggests that the mechanism to link intellectual prominence and start-ups be taken into account. This includes leaves of absence for start-ups and the expansion of start-up–related indicators in evaluation or promotion.

Even though this study provides empirical evidence and implications for start-ups in universities, it has some limitations, and further studies are needed. First, this study did not consider individual attributes because of a lack of relevant data. Personal attributes such as
age, gender, discipline, and family income play a fundamental role in the recognition of start-ups and numerous studies have explained the determinants of individual attributes in start-ups [6–8]. However, in this study, individual determinants were not considered and these limitations may lead to bias in the research results. If personal information related to start-ups such as age, gender, subject area, position, and history of entrepreneurship of faculty members, for example, had been provided along with university resources, the factors influencing start-ups could be assessed more systematically.

Second, it is necessary to analyze the quality of a start-up such as through the creation of employment, sales, operation profit, net income in relation to start-ups, and other determinants of quality. Launching a start-up is becoming attractive for students and faculty and it is gaining prevalence in universities, but substantive literature has focused on the number of start-ups and their determinants in universities [21,26–28,30]. Similar to previous studies, this study fails to analyze the determinants of start-up quality in universities. The factors affecting start-ups and their quality may differ and some resources or attributes can have varying effects on the quality of start-ups. However, we have scant empirical evidence whether and to what extent different factors affect start-up quality. Further study is needed to analyze the determinants of start-up quality.

Third, alongside university resources, an understanding of the influence of environmental factors in start-ups should be examined. Many previous studies have explored the effects of environmental factors such as venture capital [14], science parks [10], and incubation facilities [53] on start-ups. However, there is little empirical evidence that analyze the effects of environmental factors in relation to university resources. An understanding of the effects of resources and environmental factors in start-ups should be fully examined. Fourth, analysis is needed with regard to how much time it takes to initiate a start-up and whether there is a difference in the time required for students and faculty members and, if so, what the relevant resources are. These types of analyses are necessary to help predict the appropriate investment period and ensure that the allocation of resources can be appropriately undertaken.

6. Conclusions

Starting a business in a university has become an aspect of the role and function of a university, with varying types of support provided to boost university start-ups involving the development and operation of various education programs at the university level. To effectively promote university start-ups, it is important to analyze the relevant resources affecting university start-ups. However, most studies have analyzed the resources influencing faculty start-ups separately from the resources influencing student start-ups. This study divided university start-ups into faculty start-ups and student start-ups to assess the respective influencing resources involved and the interrelationships. Using resource dependence theory, variables including internal resources, external resources, intellectual prominence, the number of technology transfer offices, and the number of student start-ups were assessed concerning faculty start-ups. For student start-ups, internal resources, internal and external start-up support funding, Capstone Design, start-up clubs, and the number of faculty start-ups were used as variables. These variables were systematically analyzed through distinguishing between shared and distinctive resources. The analysis, using a panel simultaneous equation fixed effect model, showed that the resources affecting faculty start-ups differed from those affecting student start-ups, and that the characteristics of the universities also differed in terms of start-up differences. Faculty start-ups had a significant effect on student start-ups but not vice versa. Faculty labor costs and central and local government research funding had a significant positive effect on faculty start-ups. Start-up support funding on campus and the number of start-up clubs, technology transfer offices, and faculty start-ups had a significant positive effect on student start-ups.

This study sheds new light on how resources influence start-ups in universities. Moreover, by focusing on the role of resources in the relationship between student start-ups and faculty start-ups, it contributes to entrepreneurship literature, which has devoted little attention to the influence of resources on these start-ups. This study adds new knowledge about how allocated
resources promote start-ups. Finally, this study provides the foundation for more research to better understand those start-ups in universities such as by examining the effects of individual attributes, determinants of start-up quality, the significance of environmental factors, and the time lag between resources and start-up.

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