Effects of firm size and geographical proximity on different models of interaction between university and firm: A case study

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Abstract
This paper analyzes a total of 1930 collaboration projects, including contract research, joint research, technology transfer, and incubation models, between National Cheng Kung University (NCKU) and firms during the period between 2001 and 2009. Effects of both firm size and geographical proximity on the frequency of different models of collaboration are addressed. Results show that large-sized enterprises prefer adopting the contract research model and implementing it in a more comprehensive cooperation mechanism or with long-term cooperation relationships. By contrast, small and medium-sized enterprises prefer to give equal prominence to both contract research for research subject dominance and joint research due to low investment requirements. Results also show that geographical proximity is an important factor during the interaction between enterprises and NCKU. However, the influence is quite different when the cooperation models are compared individually.

1. Introduction
1.1. Models of industry–university collaboration

Since the late 1970s, university missions have been widely discussed and have moved progressively from teaching and research to teaching, research, and public service. This means that besides sharing existing knowledge and advancing new knowledge, universities have the new mission of transferring academic knowledge and resources to the public, and generating technological spillover through university–industry interaction (Etzkowitz & Leydesdorff, 2000; Leydesdorff & Meyer, 2003; Lin, Chang, & Chung, 2012a, 2012b; Mansfield, 1995). The interaction includes recruitment of university graduates, personnel exchanges, joint research, contract research, consulting, patents and publications, licensing, spin-off companies, industry-funded laboratories and other facilities, and also through informal contacts such as meetings and conferences.

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from efficiency-driven to innovation-driven according to the report), the Taiwanese government is aware of the importance of innovation creation and knowledge spillover, and has placed great emphasis on the promotion of a national innovation system, especially from the universities end. For example, R&D expenditures of high educational institutions (HEIs) have increased rapidly during the past 10 years, as illustrated in Fig. 1. Among which, R&D expenditures appropriated from government, business enterprises, and other sectors have all been increasing upward annually between 2000 and 2009. However, the annual percentage of R&D expenditure contributed by business enterprises has just kept pace. Such a tendency can be demonstrated by the ever-increasing prevalence of industry—university projects over the past 10 years; however, this situation is far from the need of industry to create innovation and knowledge spillover from university.

According to the analysis of Shi (2009), there are two major shortcomings in the allocation of Taiwan’s R&D resources: a shortfall in allocation of university—industry R&D resources, and a gap in the innovative connection of R&D activities between enterprises and educational institutes. The shortfall of university—industry resource allocation is caused by the majority of personnel with doctorate qualifications (72.1% of all PhDs) being in the academic realm, whereas the gap in the innovative connection of R&D activities between enterprises and educational institutes is caused by a division of focus in technology development and academic research, respectively.

From the results of Shi’s analysis, it is particularly important for Taiwan’s government to enhance industry—university collaboration to bridge the gap in the innovative connection of R&D activities between enterprises and educational institutes, and thus, release the capability of personnel with doctorate qualifications from university to industry. Therefore, the objective of this research is to understand the different models that different firms appear to use in order to access knowledge and innovation from universities, especially the firm size and geographical proximity between the university and the firm. Consequently, using the statistical results of the industry—university cooperation models over the past decade, an understanding of what concerns will be factored into the decision making of industry—university models and more provisions of references will be made available for the policymakers.

The remainder of this paper is organized as follows. The “Data and Methods” section sets out the definition of interaction channels between the university and the firms, as well as the data and interactions (Agrawal & Henderson, 2002; Cohen, Nelson, & Walsh, 2002; D’Este & Patel, 2007; Mansfield & Lee, 1996; Mowery & Sampat, 2005; Schartinger, Schibany, & Gassler, 2001). For example, Agrawal and Henderson (2002) used data from the departments of mechanical and electrical engineering at MIT to demonstrate that patents are a relatively small source of knowledge transfer (less than 10%) out of the university. Cohen et al. (2002) used data from the Carnegie Mellon Survey on R&D performing firms in the United States and concluded that most patents and licenses were less important models compared with publications, conferences, informal interactions, and consulting. Consequently, more emphasis should be placed on investigations of knowledge flow through contract research, joint research, publications, conferences, and informal consulting.

It can be understood that different firms appear to use quite different models to access knowledge from universities (Agrawal & Henderson, 2002). However, the major barrier for a researcher who measures the interaction between universities and firms is the lack of information from both university and firm (Schartinger et al., 2001). Traditionally, the main indicator that measures the R&D cooperation between university and industry can only be obtained from the annual reports of the university and by surveying university faculties and firms (OECD, 1999). However, it has been generally difficult to obtain details of all individual industry—university cooperation projects because they are mostly classified “confidential” by individual universities. Thus, existing impediments for getting access to the information concerning the enterprises experiencing such industry—university cooperation and the rare availability of such information had also contributed to the relevant reference documents. In this research, size of firms and geographical proximity were investigated because in the literature, they are important determinants related to industry—university collaboration (Brostrom, 2010; Elyse, 2006; Monjon & Waelbroeck, 2003; Schartinger et al., 2001). Data collected from National Cheng Kung University (NCKU; the most active university that collaborated with enterprises) are used, which includes 1930 collaboration cases of contract research, joint research, technology transfer, and incubation between NCKU and enterprises during the period from 2001 to 2009. Such a large number of cases allows for a wide grasp of the factors involved in the decision making that concerns enterprises in selecting an industry—university cooperation model and the influential significance levels of geographical proximity.

1.2. Industry and university environment in Taiwan

Taiwan has a land surface of approximately 36,000 km² and a population of roughly 23 million people. Businesses are mainly composed of small and medium-sized enterprises (SMEs), which make up 97.9% of the total enterprises (Small and Medium Enterprise Administration, Ministry of Economic Affairs, 2010). In terms of technology trade, the expenditures of Taiwanese enterprises in recent years have always been much greater than their incomes. In 2008, for example, the national technology trade income and expenditure ratio was 0.26 (National Science Council, 2010); this shows that Taiwan’s technology trade is still in a deficit situation, and enterprises’ innovative operations still lack sufficient power for R&D. Furthermore, according to the Global Competitiveness Report, the economic development can be classified into factor-driven, efficiency-driven, and innovation-driven stages (World Economic Forum, 2008). For several decades, Taiwan has been characterized by an efficiency-driven economy. This image was symbolized by many original equipment manufacturers in the electrical and electronics industry with high production efficiency, but with low returns.

In attempting to transform the economy to the innovation-driven stage (Taiwan has been characterized as being in transition from efficiency-driven to innovation-driven according to the report), the Taiwanese government is aware of the importance of innovation creation and knowledge spillover, and has placed great emphasis on the promotion of a national innovation system, especially from the universities end. For example, R&D expenditures of high educational institutions (HEIs) have increased rapidly during the past 10 years, as illustrated in Fig. 1. Among which, R&D expenditures appropriated from government, business enterprises, and other sectors have all been increasing upward annually between 2000 and 2009. However, the annual percentage of R&D expenditure contributed by business enterprises has just kept pace. Such a tendency can be demonstrated by the ever-increasing prevalence of industry—university projects over the past 10 years; however, this situation is far from the need of industry to create innovation and knowledge spillover from university.

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The remainder of this paper is organized as follows. The “Data and Methods” section sets out the definition of interaction channels between the university and the firms, as well as the data and
method used in the analysis. The “Results and Discussion” section describes the main empirical results regarding the impact of firm size and geographical proximity. Finally, the “Conclusion” section concludes the article.

2. Data and methods

Because NCKU\(^1\) is one of the premier research institutions and the most active university interacting with industries in Taiwan, this paper analyses NCKU to understand the intensity of the university–industry relationship. According to statistics of the Higher Education Evaluation and Accreditation Council of Taiwan regarding the performance of university–industry collaboration from 2006 to 2009, among public Taiwanese HEIs, NCKU won first prize in “the broadness of participating in university–industry collaborative activities” for 4 consecutive years (2006–2009), and in “actively striving for university–industry collaborative funding and efficacy” for 3 consecutive years (2006–2008). This indicates that the university–industry collaborative model of NCKU can serve as a worthy reference for other Taiwanese universities (Lin et al. 2012a, 2012b).

Take the top four Taiwanese universities as examples: National Taiwan University (NTU), NCKU, National Chiao Tung University (NCTU), and National Tsing Hua University (NTHU; Fig. 2) were granted annual R&D funding of less than US$200 million, of which, R&D funds from enterprises totaled less than US$13 million. These two amounts of funding were far less than those granted to internationally renowned universities. A comparison of the proportion of corporate funding in the total R&D funding granted to these four Taiwanese universities indicates that the proportion for NCKU was 10.8% in 2009, which is roughly equal to that of other universities that are well-known globally, followed by NTHU (6.8%), NCTU (3.4%), and NTU (2.0%).

The statistics presented in this research was based on data collected for a period of 9 years, from 2001 to 2009. The data collected included all industry–university collaboration projects (1930 projects in total) between NCKU and the enterprises involved in terms of four models, namely, “contract research,” “joint research,” “technology transfer,” and “incubation.” The definition of the four models of industry–university collaboration in this research is as follows:

Joint research refers to collaboration agreements between NCKU and industry that involve research work undertaken by both parties. Contract research refers to work commissioned by industry and undertaken only by NCKU researchers. Technology transfer refers to patent licensing or technology transfer from NCKU to industry. Incubation refers to collaboration projects by enterprises incubated in NCKU or counseling projects offered by managers in the NCKU incubation center.

All the corporate paid-in capital and duly organized addresses cited in this research are adopted from publicized statistics in the “Commerce Industrial Services Portal,” Dept. of Commerce, Ministry of Economic Affairs and the “eTax Portal, Ministry of Finance.” For the purpose of calculating the linear geographic distance between each individual collaborating enterprise and NCKU, the “Coordinative Reference System” (developed by the Center for Geographic Information Science, Research Center for Humanities and Social Sciences, Academia Sinica) was used in this research for creating a corresponding point layer (longitude/latitude) in the X and Y coordinates of each individual enterprise. Second, the “two-degree transverse Mercator” methodology for converting WGS84 (World Geodetic System) into TWS67 (Taiwan Datum) was applied, and was followed by the application of Pythagorean theorem to obtain the linear geographic distance. Another in-depth analysis included in this research is the adoption of a “location quotient” (LQ) for evaluating the enterprise concentration rate for each individual industry–university collaboration model. Being an indicator commonly used in regional economics and economic geography, the LQ has also been frequently employed for understanding the space distribution of all collaborated enterprises. LQ is calculated as follows:

$$\text{LQ} = \frac{C_i / S_i}{C_{\text{tot}} / S_{\text{tot}}}$$

where C indicates the amount of the enterprises sharing collaboration projects with NCKU; S refers to the amount of enterprises; the subscript i refers to district classification, and tot refers to the total amount in Taiwan. The geographical distribution statistics of all the enterprises sharing collaboration projects with NCKU had been further used for evaluating the corresponding ratio of total enterprises in every district by means of the LQ, in case the urban scale and economic compositions are not factored in.

3. Results and discussion

3.1. Demographics and descriptive statistics

The statistics adopted by this research included data collected over a 9-year period in total (i.e., from 2001 to 2009). With respect to all the collaboration projects of NCKU (Table 1), which constituted four models inclusive of contract research, joint research, technology transfer, and incubation, the total number of samples amounted to 1930. Of this total number, 1254 are contract research projects, representing a ratio of 65.0% of the total number of projects, followed by 358 joint research projects, 155 technology transfer contracts, and 163 incubation projects. Enterprises sharing collaboration projects with NCKU amounted to 1049 (including branches), in which the registered corporation information was

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\(^1\) NCKU was established in 1931. Through 80 years of cultivation, NCKU gradually developed nine colleges, which include Liberal Arts, Science, Engineering, Electrical Engineering and Computer Science, Planning and Design, Management, Medicine, Social Sciences, and Bioscience and Biotechnology. Currently, NCKU is the most essential academic research institution in Southern Taiwan.
mainly based on the initial records from the administrator of NCKU, and the corporate capital was subject to the paid-in capital.

With regard to the industry–university collaboration models of NCKU in the past 9 years, the enterprises demonstrated a preference for the “contract research” model with NCKU (65.0%), followed by “joint research” (18.6%); by contrast, the “technology transfer” (8.0%) and “incubation” (8.4%) models had limited popularity. These results nearly coincide with those of Schartinger et al. (2001), whose study involved a questionnaire survey of firms in Austria. The results of their study indicated that the innovative firms mainly adopted the “contract research” and “joint research” models, accounting for 32% and 23%, respectively, whereas the “technology transfer” model constituted the rather poor ratio of 7%. Several studies have noted that patenting and licensing account for just a small proportion of industry–university interactions (Agrawal & Henderson, 2002; Cohen et al., 2002; D’Este & Patel, 2007; Mansfield & Lee, 1996; Mowery & Sampat, 2005; Schartinger et al., 2001).

Among the aforementioned four models, a significant variance is demonstrated with respect to the average project scale (Table 1). The average project scale for the case of “contract research” had the highest value, as much as NT$1.35 million, whereas “technology transfer” received NT$1.22 million, ranked second; by contrast, “joint research” and “incubation” received as little as NT$0.53 million and NT$0.42 million, respectively, further supporting its poor favorability among enterprises. The “joint research” model adopted by enterprises generally varies with the subsidy application offered by the government, but stipulates that most of the intellectual property rights derived from such a model belong to the counterparty university, which contrasts with partial ownership or the pre-emptive technology rights for the enterprises involved. Thus, most enterprises would not invest heavily in this model because most of their motivations would stem from the adoption of a mutually cooperated mechanism for the purpose of establishing a preliminary–phase industry–university cooperation relationship, and obtaining access to the relevant expertise in the fields concerned and creating awareness of academic research development. In addition to the ownership ratio of the subsequent R&D outputs available to the enterprises, exerts influence on professors’ research subjects for promoting accessibility to the enterprises involved is one of the major purposes contributing to the fact that the “contract research” model is much more preferred by enterprises involved than “joint research.”

3.2. Firm-size impact analysis

Firm size is important and has a clear relation with innovation (Hsu & Liu, 2008; Imnyxai & Takahashi, 2012). According to surveys (Schartinger et al. 2001) of Austrian innovative firms, there is a clear relationship between firm size and the valuation of highly skilled, university-educated personnel. Through empirical analysis of a survey questionnaire, Caceres, Guzman, and Rekowski (2011) also concluded that firm size is highly related with training, R&D, and collaboration.

According to the research of Tien, Chiu, and Chen (2011), firm size can significantly moderate momentum only on the dimension of plant and equipment newness, whereas firm age can moderate momentum on the dimensions of nonproduction overhead and advertising intensity. Furthermore, previous research on innovation adoption identifies many factors, which influence organizations to adopt new ideas, products, technologies, or services. Some of these factors are support from top management and innovation champions, attitude toward innovation, competitive advantages, and innovation characteristics. These previous studies demonstrate that innovation adoption is influenced by a complex dynamic of multiple factors. For example, Choi (2000) found that environmental factors, such as environmental uncertainty, competition, and IT intensity, are important for improving innovation capabilities among SMEs in Korea. Copus, Skuras, and Tsegenidi (2008) examined innovation capabilities among SMEs in six European Union members and found that social and institutional capital were important factors for innovation performance. Kim and An (2004) found that innovation adoption in large Korean companies was affected by attributes of usefulness only, whereas in small Korean companies it was affected by the strategy and the industry environment, as well as usefulness. However, the study did not look at innovation adoption at the organization level. Chen and Fu (2001) found that SMEs in China were heavily influenced by the market, whereas large firms in China were influenced by firm size.

Regarding collaborative models with which firms access knowledge and innovation from universities, D’Este and Patel (2007) found that joint research agreements will enable researchers to access industry skill and facilities. This implies that researchers motivated to interact with industry are likely to do so through a variety of forms rather than via a single mechanism. Such variety enables them to reap both larger pecuniary and non-pecuniary benefits. Schartinger et al. (2001) studied collaboration models adopted by different firms (size based) through a questionnaire survey of firms in Austria. The results showed that firms adopted the “contract research”, “joint research,” “technology transfer,” methods for the collaboration models. Their study also found that innovative firms mainly adopted the “contract research” and “joint research” models than “technology transfer.” The authors also found that large firms value the benefit of universities higher than small ones by making use of highly skilled personnel, directly supporting the development process, and utilizing the university’s consulting services. However, the reciprocal relationship between firm size and collaboration models are not understood clearly from literatures, and therefore, a deeper study to understand this relationship is needed.

In the following section, an in-depth analysis of the relevancy between the individual firm size and its willingness to adopt different models of collaboration projects is presented by examining the participation frequency. The analysis procedure begins by separating the enterprises involved into two categories, namely, “large-sized enterprises (LEs)” and “SMEs,” according to the paid-in capital of an enterprise. As stipulated by the “Small and Medium Enterprise Development Promotion Guidelines,” “whichever an enterprise dealing in manufacture, construction, mining, or earthworks industry with a paid-in capital of no more than NT$80 million,” or “a paid-capital of no more than NT$100 million in the event of dealing in any industry other than the previously prescribed” shall be legitimate for being classified into the category of SMEs. Based on this stipulation, the classification standards for this research have been further simplified as follows: whichever enterprise with paid-in capital of no more than NT$ 80 million shall be classified under SMEs; and if the paid-in capital is more than NT$80 million, the enterprise shall be classified under LEs.
The simplified classification standards have been applied in calculating the total collaboration projects, projects/firms, and the average project scale (Table 2) in the two categories of enterprises, LEs and SMEs, that have established a partnership with NCKU from 2001 to 2009. As shown in the Table 2, the projects involving SMEs amount to 835, constituting 43.3% of the total, whereas those concerned with the LEs amount to 1095, accounting for 56.7% of the total. With regard to the overall Taiwan business ecosystem structure, SMEs constitute an overwhelming 97.91% of the total businesses, whereas the ratio of LEs is confined to only 2.09% (Small and Medium Enterprise Administration, Ministry of Economic Affairs, 2010). Thus, it can be said that LEs are considerably more interested in collaboration with NCKU than SMEs.

In consideration to other evaluation results, such as the projects-to-firms ratio (projects/firms) and the average project scale with NCKU, the average value of total projects/firms contributed by the category of LEs is 2.83, which is significantly better than the value of 1.67 attributed to SMEs (in which the former is 1.69 times the latter). The average project scale resulting from the LEs is NT$1.46 million, which is again much more than the average amount of only NT$0.64 million achieved by SMEs. It thus can be evidenced precisely that LEs will perform better if evaluated in terms of both cooperation sustainability tendency and investment values. The overall investment potentiality of the LEs is also much greater than that of the SMEs. The aforementioned statistics can validate a distinctive feature that innovation demands among Taiwanese corporate and the industry-university cooperation environments have a significantly distorted orientation, whereas SMEs, constituting 97.91% of the total, performed worse than LEs when compared in either the ratio of total cooperation projects with NCKU or the cooperation sustainability and potentiality, or even the average investment value. Such analysis results simply support the fact that SMEs suffer from shortage of R&D talent, funds, facilities, and innovation models for supporting their business operations. As such, SMEs have difficulty in improving their R&D due to limited financial resources available for participation in such industry-university cooperation. Therefore, it is hereby advised that policy-makers devise more affirmative and effective policies that offer SMEs greater access to business innovation opportunities.

Possessing certain in-house R&D resources, LEs support rapid industry development advancement, prefer to succeed in conceptualizing more innovative business ideas, and shorten the durations of completing the targeted R&D by adopting industry-university collaboration models. The systematic R&D activities carried out by LEs within structured laboratories are more effective than the occasional R&D activities undertaken by SMEs (Santarelli & Sterlacchini, 1990). Because SMEs often conduct their innovative activities without specific financial and managerial resources and, in particular, without formalized procedures, they tend to undertake a significant amount of innovative activities in their design, production, and even in sales departments rather than in their R&D departments. Thus, they more frequently develop incremental innovations rather than product innovations, which are mostly achieved by LEs. Another perspective regarding the R&D of SMEs from a survey of 3000 Dutch firms (Kleinknecht, 1989) should be noted: if informal R&D is taken into account, the R&D commitment of SMEs is considerably higher than that reported by official sources; however, due to a lack of information in the literature, the influence level surrounding this issue is not clear and worthy of future research.

The statistics in Table 2 can be further utilized for analyzing the decision-making tendency of industry-university cooperation involving LEs and SMEs. With respect to the adopted model between the LEs and NCKU, the “contract research” model was the most prevalent (75.9%), creating 3.18 projects on average per enterprise, which is much more than the value resulting from other cooperation models (such as the average of 1.48 projects for “incubation,” 1.29 projects for the “joint research,” and 1.24 projects for “technology transfer”). Therefore, a reasonable estimation can be assumed that in addition to achieving relevant R&D successes, LEs commonly choose the “contract research” cooperation model to mainly motivate professors to focus on relevant research subjects and also to cultivate long-term human resources suitable for their own enterprises. This situation is consistent with Schartinger et al. (2001) that LEs value the benefit of employing educated and highly skilled personnel more than SMEs.

Thus, it can be concluded that LEs commonly prefer to adopt the “contract research” model for achieving more comprehensive or long-term cooperation relations. This implies the lack of R&D personnel (generally with doctorate qualifications) in firms, and usually adopting research achievements from universities to meet their requirements. This also verified the result of Shi (2009). The policy-makers should also make a note of the limited project scale (0.94 million) and lower ratios of projects per firm (1.29) in cases of joint research model involving LEs and NCKU. It implies the lack of deep reciprocal relationship between LEs and universities to build long-term and large-scale cooperated projects by focusing on topics that benefit both entities. It thus has limited functions such as enhancing research performance and publications of university professors, and shifting university curriculums from basic toward applied research toward recent collaboration projects between LEs and universities. Proper mechanisms such as “matching fund,” which implies focusing on topics that benefit both entities and establishing long-term collaboration projects, are needed. Thus, the deep reciprocal relationship between LEs and universities can fulfill and overcome the two major shortcomings in the allocation of Taiwan’s R&D resources analyzed by Shi (2009).

Furthermore, in the category of LEs, among all cooperation models, the “technology transfer” model had the highest average investment value of NT$1.59 million, instead of the “contract research” model, which had an average investment value of NT$1.59 million. This indicates that although LEs prefer to conduct assignments or transfers by spending higher amounts relative to obtaining the relevant intellectual property in case of any available critical technology or patent, the total investment values resulting from the “technology transfer” model constitute only a limited ratio in proportion to the overall investment.

Therefore, a reasonable estimation can be assumed that in addition to obtaining relevant R&D achievements, LEs commonly choose the “contract research” cooperation model to mainly motivate professors to focus on relevant research subjects and also to cultivate long-term human resources suitable for their own enterprises. This situation is consistent with Schartinger et al. (2001)

### Table 2

<table>
<thead>
<tr>
<th></th>
<th>Project number</th>
<th>Projects/firm</th>
<th>Average project scale (million NT$)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>With LEs</td>
<td>With SMEs</td>
<td>With LEs</td>
</tr>
<tr>
<td>Contract research</td>
<td>831</td>
<td>423</td>
<td>3.18</td>
</tr>
<tr>
<td>Joint research</td>
<td>101</td>
<td>257</td>
<td>1.29</td>
</tr>
<tr>
<td>Technology transfer</td>
<td>67</td>
<td>88</td>
<td>1.24</td>
</tr>
<tr>
<td>Incubation</td>
<td>96</td>
<td>67</td>
<td>1.48</td>
</tr>
<tr>
<td>All projects</td>
<td>1095</td>
<td>835</td>
<td>2.83</td>
</tr>
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</table>

LEs – large-sized enterprises; SMEs – small and medium-sized enterprises.
that LEs value the benefit of employing educated and highly skilled personnel more than SMEs. However, in the category of LEs, among all cooperation models, the “technology transfer” model resulted in the highest average investment value of NT$1.95 million, instead of the “contract research” model, which had an average investment value of NT$1.59 million. This indicates that although LEs prefer to conduct assignments or transfers by spending higher amounts relative to obtaining the relevant intellectual property in case of any available critical technology or patent, the total investment values resulting from the “technology transfer” model constitute only a limited ratio in proportion to the overall investment.

Factors such as shortages of R&D personnel, funds, and facilities are the reasons why SMEs prefer the “contract research” model for achieving dominance in the decision-making of research subjects (50.7%) and the “joint research” model (30.8%) featuring a low-investment benchmark. These two models have also achieved success in carrying out more cooperation projects with individual SMEs, with the former model having 1.54 projects on average and the latter having 1.44. When compared with LEs, SMEs demonstrate less interest in establishing a comprehensive or long-term cooperation relation. In terms of the average project investment value in the category of SMEs, the “contract research” model has the highest value (NT$0.86 million), instead of the “technology transfer” model (NT$0.65 million), which again suggests that SMEs demonstrate substantive business strategies or goals in adopting the “technology transfer” model; in addition, SMEs also tend to be less interested in obtaining costly intellectual property rights.

To completely understand the industry—university models and average corporate project scale with respect to “firm size,” the “firm size” was adopted as the X coordinate and the “research grant/royalty” was adopted as the Y coordinate for constructing the industry—university cooperation pattern structure of NCKU (Fig. 3). The research data considered in this analysis are inclusive of all the contracts in terms of “contract research,” “joint research,” “technology transfer,” and “incubation” models established with NCKU between 2001 and 2009. As shown in Fig. 3, enterprises that have established industry—university cooperation with NCKU show extensive variation in terms of the paid-in capital, which varies from less than NT$1 million to more than NT$10 billion. As such, the investment values of industry—university cooperation projects range between NT$7250 and NT$43,200,000. It can be found in Fig. 3 that the “joint research” model is distributed in the lower left-hand corner, whereas the “contract research” model has a broad distribution range in the X direction.

Firm sizes were further separated into seven categories, as illustrated in Fig. 4, including those with paid-in capital of less than NT$1 million, between NT$1 million and no more than NT$10 million, between NT$10 million and no more than NT$100 million, between NT$100 million and less than NT$1 billion, from NT$1 billion to less than NT$10 billion, from NT$10 billion to less than NT$100 billion, and more than NT$100 billion. When calculating the weight ratio of technology transfer, incubation, contract research, and joint research projects as adopted by regional enterprises and NCKU, the tendency of various enterprises (SMEs vs. LEs) to adopt different models of industry—university collaboration is rather significant. The percentage of contract research increased along with the increase in firm size. For enterprises whose capital exceeded NT$1 billion, 80% of the projects in collaboration with NCKU belonged to contract research, whereas for firms whose capital exceed hundreds of billions have 100% adoption of contract research. However, the percentage of joint research and technology transfer tends to decrease with the increase of firm size, and incubation does not reveal significant variance with regard to firm size.

In summary, these research results imply that LEs generally adopt the “contract research” model when cooperating with NCKU, and also establish more diversified cooperation effects or longer cooperation relationships with this cooperation model. Moreover, the tendency to adopt the “contract research” model varies increasing with the ever-increasing paid-in capitals of LEs. When any critical technologies or patents are required, LEs would rather procure intellectual property rights at values that are commonly regarded more costly. SMEs are equally interested in “contract research” for achieving dominance in determining research subjects and “joint research,” which features lower investment funds, but they are not interested in achieving more comprehensive cooperation dimensions or maintaining long-term mutual cooperation.

One of the conclusions from this research analysis is that there still exists a significant distorted orientation in Taiwan between the motivation and demands of enterprises seeking innovation within the industry—university collaboration ecosystem. Even though SMEs constitute an overwhelming 97.91% of the total corporations in Taiwan, the cooperation projects with NCKU and all investment values contributed by SMEs are both much less than those of LEs. This is because SMEs generally suffer a shortage of R&D personnel, investment funds, facilities, and innovative business operation modes for supporting their business operations, as well as
availability of limited channels for SMEs to improve their R&D activities. Policy-makers should thus create valid and effective policies, such as modifying existing resource and tax policies, or create cut-to-fit collaboration models for enabling SMEs to gain greater access to more business innovation opportunities.

It thus can be concluded that LEs commonly prefer to adopt the "contract research" model for achieving more comprehensive or long-term cooperation relations. It implies the lack of R&D personnel (generally with doctorate qualifications) in firms, and usually adopting achievements from universities to meet their requirements. This also verified the result reported previously by Shi (2009). The policy-makers should also make a note of the limited project scale (0.94 million) and lower ratios of projects per firm (1.29) in cases of joint research model involving LEs and NCKU. It implies the lack of deep reciprocal relationship between LEs and universities to build long-term and large-scale cooperated projects by focusing on topics that benefit both entities. It thus has limited functions such as enhancing research performance and publications of university professors, and shifting university curriculums from basic toward applied research toward recent collaboration projects between LEs and universities. Proper mechanisms such as "matching fund," which implies focusing on topics that benefit both entities and establishing long-term collaboration projects, are needed.

3.3. Geographical proximity impact analysis

Start-up companies, as well as new technology-based firms working with universities, are more likely to be in close proximity to the licensing institution in order to capture the benefits of subsequent innovations (Elyse, 2006). Proximity between firms and universities promotes the natural exchange of ideas through both formal and informal networks (Deeds, Decarolis, & Coombs, 2000; Lindelof & Lofsten, 2004). Formal methods include licensing and cooperative alliances (Lane & Lubatkin, 1998), whereas informal methods include mobility of scientists and engineers, social meetings, and discussions (Pouder & St. John, 1996).

Various studies have indicated that geographical proximity has positive effects on the willingness of enterprises to adopt industry–university cooperation and also on the subsequent performance of the cooperation projects (Anselin, Varga, & Acs, 1997; Fischer & Varga, 2003; Fritsch & Slavtchev, 2007; Jaffe, 1989; Mansfield, 1995; Moreno, Paci, & Usai, 2005; Oerlemans & Meeus, 2005). For example, Jaffe (1989) conducted an empirical analysis using the "knowledge production function" developed by Griliches (1988), and verified that the more innovative the R&D activities are carried out by universities, the better performance of innovation a state will achieve afterward. This therefore supports that university-involved R&D projects can stimulate more enterprises to participate in R&D activities and thus achieve better performance in terms of the amount of patent applications filed. Moreover, based on a survey (Mansfield, 1995) of 200 academic researchers and 66 enterprises belonging to major manufacturing industries, the mutual distances between the enterprises and the corresponding cooperative universities are on average within 100–1000 mi (approximately within 161–1609 km), making face-to-face contact more convenient between the two cooperating parties, which could lead to increased cooperation and better project performances.

Yun and Lee (2012) compared the regional knowledge creation, utilization, and transfer between South Korea and Taiwan's science parks. They found that the Hsinchu Science Park in Taiwan is more active toward cooperative relations than the Daedeok Innopolis in Korea, making the innovation institutions in different regions as different micro units of Triple Helix. Thus, it is important for innovation participants from university, industry, and government to play the role of creating knowledge space, consensus space, and innovation space, as it is important for innovation participants to develop co-evolving relationships. Yeh, Lin, and Kung (2011) investigated the effect of geographical proximity on the characteristic of industry–university collaboration by analyzing secondary data. Results revealed that urbanization, population, resource partitioning, industrial structure, and the social economy indeed have a positive effect on geographical distribution of enterprises that cooperated with universities.

This research has thus been initiated by statistically analyzing all the cooperation projects carried out between the years 2001 and 2009 to calculate the average distances between NCKU and the enterprises involved according to the model adopted. Results show (Fig. 5) that the average distance of all enterprises involved in technology transfers with NCKU is 167 km, which was the longest; the average distances of all enterprises involved in contract research and joint research were 143 and 117 km, respectively; and, the average distance for the incubation model was 66 km, which was the shortest. It turns out that the shortest average distance results from enterprises migrating into NCKU or the enterprises receiving consultancy support from the incubation manager of NCKU. The "technology transfer" model demonstrated the longest geographic distance, and thus, it is completely free of geographic distance restraint.

The conversion outputs of the aforesaid “TWS67” coordinates were then mapped out, as shown in Fig. 6, indicating that most enterprises concerned with cooperation projects are located within the top five biggest metros (including Taipei City, Hsinchu City, Taichung City, Tainan City, and Kaohsiung City). Such location distributions are in complete conformity with the natural geography of Taiwan. As the Central Mountains extend from the north of the island to the south, all populous cities are distributed along the west island seashore. This geographic obstacle has also resulted in most enterprises being located within those populous cities along the west island seashore. Scholars have adopted various measurement methodologies for evaluating how the geographical proximity might influence knowledge spillover in a specific region; however, as yet, there is not a set of measurement standards among those scholars. For example, both Mansfield (1995) and Gittelman (2007) claimed that enterprises conducting industry–university cooperation projects are all located within an average distance between 1000 and 1500 mi (equal to 1609–2414 km.

![Fig. 5. Avera...](image-url)
approximately). Because the longest linear distance of Taiwan is no more than 400 km, which is much less than the aforesaid longest distance of 2414 km, all cases of cooperation in this research are within this region. Anselin et al. (1997) estimated the spatial spillover between university research and high-technology innovations based on the well-known Griliches–Jaffe knowledge production function (Jaffe, 1989), and confirmed that a positive and significant relationship exists. They also found that a range of 50 mi for the research spillover from metropolitan statistical areas and result can be extended up to 75 miles in electronic industries (Anselin, Varga, & Acs, 2000).

With logical derivation, it can thus be deduced that the ranges of geographical proximity of these enterprises in Taiwan shall be confined within acceptable ranges of knowledge spillover in conjunction with the geographic obstacles of the island. As most scholars have asserted that the spatial spillover is confined within 50 mi (about 80.5 km) (Anselin et al., 2000; Gittelman, 2007), which is accordance with the current national administration zoning of Taiwan, seven counties and cities2 in southern Taiwan are defined as being in geographical proximity districts with NCKU, including Pingtung County, Kaohsiung County, Kaohsiung City, Tainan City, Tainan county, Chiayi County and Chiayi City, as detailed in Fig. 6.

With respect to the distribution analysis of enterprises that have established cooperation with NCKU, as illustrated in the Fig. 6, the total projects between NCKU and the enterprises located in the geographical proximity districts are 916, constituting 47.5% of the overall number of collaboration projects, whereas the projects between NCKU and the enterprises outside of the geographical proximity districts amount to 1014, representing 52.5% of the overall number. Therefore, nearly half of the projects are within the effective knowledge spillover district as defined by Gittelman (2007) and Anselin et al. (2000), but the other half of the total projects is still outside of the knowledge spillover district. Taiwan’s territory is pretty limited and differs greatly with that of the European countries and the US. Most projects involve enterprise clusters, with only two effective knowledge spillover districts (Tainan City and Kaohsiung City), but three cities outside these districts are defined by this research (Taichung City, Hsinchu City and Taipei City). Such a unique mixture phenomenon is justifiable for further research in the future.

After the aforesaid districts of effective knowledge spillover have been applied for examining all the enterprises that have established cooperation projects with NCKU, the survey results for this research, as illustrated in Fig. 7, indicate that only 35% of the total enterprises that adopted the “technology transfer” model are located within the aforesaid zonal range. The values for the enterprises that adopted the “contract research,” “joint research,” and “incubation” models are 38%, 55%, and 77%, respectively. The significant differences among the aforesaid comparison ratios can seemingly explain that the “preference ratios” for the enterprises located within the aforementioned effective districts for participation in the “incubation” and “joint research” models are much more than that of the enterprises located outside of these effective districts; in addition, it can be seen that the ratio attributable to the “incubation” model shows the greatest difference. However, as the overall Taiwan business ecosystem is composed of atypical nonuniform distributions (in that only 20.7% of the total enterprises in Taiwan are located within the aforesaid geographical proximity districts), the “normalization” effect can be used for individually examining the participation ratios of all enterprises involved with all the individual models.

This research was conducted by applying the LQ for analyzing the enterprise concentration levels for all individual industry—university cooperation models. Being an indicator commonly used in the fields of economics and economic geography, LQ has frequently been applied for the measurement of specific industries in the corresponding area for fully characterizing the enterprise distributions geographically. The subsequent calculation results of

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2 According to the Taiwan Administration Territory Planning, Kaohsiung County has been merged into Kaohsiung City; Tainan County has been merged into Tainan City; Taichung County has been merged into Taichung City; as well as Taipei County was upgraded to New Taipei City on December 25, 2010. These four cities along with Capital Taipei are the five Municipalities in Taiwan currently.
this research are illustrated in Fig. 7, whereby the LQ of firms with geographical proximity in the technology transfer model is 2.6, compared with 3.0 for contract research, 10.1 for joint research, and 16.0 for incubation (5.0 of all 4 models).

The phenomenon can validate that the enterprises executing the industry–university cooperation projects with NCKU demonstrate the tendency in conformity with the geographical proximity. For example, the participating rate of the enterprises in the geographical proximity districts is five times the average value of all enterprises in Taiwan. Moreover, the LQs for the enterprises within the geographical proximity districts participating in “technology transfer” and “contract research,” are only 2.6 and 3.0. These two values can indicate the limited relevancy between geographical distances and the participating rate of the enterprises with the two models. By contrast, the LQ for the enterprises within the geographical proximity districts participating in the “incubation” model is overwhelmingly 16 times of that in Taiwan overall. It demonstrates that enterprises incubated in NCKU do feature stronger geographical proximity compared with other models, which is compliance with the empirical research results among all individual types of questionnaires conducted by Elyse (2006).

The results of this research thus indicate that the industry–university collaboration administrator of a university should pay more attention to the relevancy between the promotion strategy of all individual cooperation models and the geographical proximity of the enterprises involved, so as to strengthen regional enterprise networks and interactions for the promotion of “incubation” and “joint research” models. They should also broadening marketing scope to all Taiwan and even launch international enterprise cooperation in the case of “technology transfer” and “contract research” models, which feature limited relevancies with geography restraints.

4. Conclusions

In this research, effects of the size of enterprises and geographic proximity were investigated through the comparison of 1930 collaboration projects, including contract research, joint research, technology transfer, and incubation, between enterprises and NCKU, which is a representative university of Taiwan, during period between 2001 and 2009. The collaboration projects were evaluated to explore the counteracting relevancies in order to understand the factors involved while making decisions for selecting an appropriate industry–university cooperation model and the influential significance levels.

Results show that LEs prefer to adopt the “contract research” model for industry–university cooperation and implement the model more comprehensively. Such a tendency varies positively with the paid-in capital of firms. LEs would rather procure intellectual property rights at values that are commonly regarded more costly if they find the patents or critical technologies useful. However, the ratio of this cooperation model is limited in proportion to the overall cases. Conversely, SMEs are equally interested in “contract research” to dominate research subjects, whereas “joint research” attracts lower investment funds. SMEs are interested in neither achieving more comprehensive cooperation dimensions nor maintaining long-term mutual cooperation.

Based on the results derived from this research, it can also be affirmed that the demand for seeking innovation and the ecosystem of industry–university cooperation in Taiwan are characterized by extremely distorted orientations. Even though SMEs constitute 97.91% of the total corporations, the cooperation projects with NCKU and all investment values contributed by SMEs are both much less than those for LEs. This is because SMEs generally suffer from shortages of R&D personnel, investment funds, facilities, and innovative business operation modes for supporting their business operations, in addition to the limited collaboration activities available for improving their R&D activities.

Policy-makers are recommended to create valid and effective policies, such as adjusting the existing resource and tax policies, or create cut-to-fit collaboration models for enabling SMEs to gain greater access to more business innovation opportunities. The policy-makers should also make a note of the limited project scale (0.94 million) and lower ratios of projects per firm (1.29) in cases of joint research model involving LEs and NCKU. It implies the lack of deep reciprocal relationship between LEs and universities to build long-term and large-scale cooperated projects by focusing on topics that benefit both entities. It thus has limited functions such as enhancing research performance and publications of university professors, and shifting university curriculums from basic toward applied research toward recent collaboration projects between LEs and universities. Proper mechanisms such as “matching fund,” which implies focusing on topics that benefit both entities and establishing long-term collaboration projects, are needed. Thus, the deep reciprocal relationship between LEs and universities can fulfill and overcome the two major shortcomings in the allocation of Taiwan’s R&D resources.

With regard to the geographical proximity, results show that it is increasingly influential for enterprises that have established industry–university cooperation with NCKU—the participation ratio of enterprises within the geographical proximity is fivefold to that of all other aspects. Moreover, the participation ratios of enterprises within the geographical proximity vary significantly with each of the individual cooperation models, among which the “incubation” and “joint research” can be defined as being in geographical proximity, while the “technology transfer” and “contract research” models demonstrate limited orientation. It is therefore advised that policy makers should be more devoted to the significance of geographical proximity. In the cases of the “incubation” and “joint research” models, they should strengthen regional enterprise networks and interactions. Otherwise, for the cases of “technology transfer” and “contract research” models, they should clarify the attributes of all individual industry sectors and interactive effects among industry chains, and then extend the industry–university cooperation scope to the whole of Taiwan and even globally.

Conflicts of interest

All contributing authors declare no conflicts of interest.

References


