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University-Industry Collaboration in Thailand: Firm Characteristics, Collaboration Modes and Outcomes

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Abstract: *University-industry collaboration has become a popular topic for Science, Technology and Innovation (STI) policy research. Nonetheless, we do not have adequate understanding on several concerning issues. This paper aims to investigate the following issues: the influence of firm characteristics on decision to collaborate with universities and collaboration modes and the influence of firm characteristics on collaboration outcomes and outcomes of R&D/Innovation activities. Salient findings are observed. First, firm characteristics influence decision to collaborate with universities and collaboration modes. Second, human resource (HR) is the most frequent mode whereas technology licensing is the least frequent mode. Nonetheless, HR mode does not relate to outcomes. Third, types of modes affect outcomes. Interestingly, informal mode influences intellectual property (IP), prototype and innovation. Perhaps informal collaboration may be a stepping stone and a trust-building mechanism for 'formal' and 'longer-term' modes of collaboration. The aforementioned findings have crucial implications for stimulating university-industry collaboration.*

Keywords: Firm characteristic, collaboration mode, collaboration outcome, outcome of R&D and innovation activities, university and industry collaboration
JEL classification: O32, O38

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1. Introduction

Universities play crucial societal roles as a source of fundamental knowledge (Wissema, 2009) because they are capital agents of technical advance, not only as scientists and trainers but as source of research findings and techniques (Costa & Teixeira, 2005). In this light, universities

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have become important sources of new knowledge for industry (Agrawal, 2001; Danell & Persson, 2003) that has attracted research attention and influenced policy makers' practices. Two schools of thoughts, namely Innovation System (IS) and Triple Helix (TH), have extensively studied the university and industry collaboration. However, two issues - the influence of collaboration modes on outcomes and the influence of firm characteristics on collaboration modes - have been under-researched. This paper therefore aims to investigate these issues. First, the issue of the influence of nature of firm is worth investigating because diversity among firms stems from factors such as historical development, the size of the firm, its structure of ownership, technological capabilities, culture, and values. Firms, therefore, embed their own specific nature, which affects their behaviour, practices, and decision making. Second, despite having their own comprehensive frameworks, IS and TH scholars have not specifically paid attention to the influence of collaboration modes on outcomes. This paper will partially fill the gaps by explicitly investigating how characteristics of firms influence the decision to collaborate with university, and whether and to what extent modes influence outcomes of collaboration and outcomes of R&D/Innovation activities. Data obtained from the National Survey of R&D and Innovation conducted in 2011 was used to analyse these issues. In conclusion, this paper provides a better understanding of the relationship between the factors of firm characteristics, collaboration modes and collaboration outcomes which may influence policy makers' practices.

2. University and Industry Collaboration Policy in Thailand

The University and industry collaboration in Thailand initially paid most attention to engineering activities (problem solving) and cooperative education. By setting up the Industrial Technology Assistance Program (iTAP) in 1992, the Thai government, through the Ministry of Science and Technology (MOST), provided technical guidance to industry through consultation and R&D. This programme was intended to strengthen the technological capabilities of Thai SMEs. It acts as an intermediary that locates and partially subsidises university professors, allowing them to work for Thai SMEs as consultants to solve their technical problems (S. Chatratana, personal communication, October 21, 2014; T. Smitinont and N. Singhavilai, personal communication, February 18, 2015). In the meantime, Suranaree University of Technology (SUT) initiated the concept of cooperative education in 1993. Ten years later, the Office of Higher Education Commission (OHEC), under the Ministry of Education (MOE), explicitly embraced the cooperative education concept and encouraged its application to all universities (Ruksasuk, 2011). In the same year (1993), Thailand Research Fund (TRF) was established to provide R&D grants for basic research, scholarships for students and researchers, and community-based research. Some R&D schemes focus on collaboration with universities, industry and communities (TRF). During the enactment of the National Education Act and the bureaucratic reforms between 1999 and 2000, the government encouraged public universities to become autonomous in order to increase management efficiency. This indirectly affected the effectiveness of collaboration between the two parties. In 2004, OHEC also encouraged universities to set up Technology Licensing Offices (TLOs) and university business incubators (UBIs) to stimulate technology transfer to industry and provide intellectual property services for university researchers (MOE, 2014). Furthermore, between 2004 and 2007, MOST set up science parks in three regions outside of Bangkok. The purpose of these measures is to transfer knowledge and technology, provide technical assistance to local businesses and incubate technology start-ups (K. Promwong, personal communication, February 17, 2015). Additionally, MOST established a clinical technology programme to provide consultancy services to universities and vocational educational institutes located mostly outside of Bangkok (MOST)[1]. In 2012, TRF initiated Research and Researchers for Industry (RRI) to provide research funding to students pursuing their Master's or Doctoral degree. The research topics are based on industrial demand (TRF). In 2014, the Thai government launched a talent mobility programme with the intention of encouraging university researchers to work with industry as full-time or part-time staff. Researchers who receive scholarships from government are able to join this programme. Time sharing or working with industry is considered to be compensation for these scholarships (K. Promwong, personal communication, February 17, 2015).

Even though the Thai government has made efforts to strengthen university and industry collaboration by establishing TLOs, university business incubators (UBIs) and science parks, the collaboration seems to rely on education. According to Office of Higher Education's report, the number of universities participating in cooperative education programme has increased from 56 in 2008 (17,399 students and 553 courses) to 117 universities in 2013 (36,735 students and 1,282 courses). In terms of intellectual property, between 2008 and 2011, Thai universities generated US$6.7 million (109 items) from licensing several types of intellectual properties such as patents, copyright, trademarks, geographical indications, plant varieties, and animal varieties (Office of Higher Education Commission, 2014).

3. Review of literature on University and Industry Collaboration

This section summarises existing literature on two issues: the influence of firm characteristic on university and industry collaboration and the influence of collaboration mode on outcome, to provide background of this study. First, the specific nature of firms (e.g. firm size and industrial sector) tends to affect the university and industry collaboration. Large firms appear to engage in collaborative R&D activities because they have a plenty of resources and tend to maintain their competitiveness. Second, to achieve the collaboration outcomes, it is necessary to understand the relationship between collaboration mode and collaboration outcome.

3.1 Concept of University and industry collaboration

The ideas and concepts associated with university and industry collaborations are not new. Triple Helix concept specifically focuses on the collaboration between the two. This concept was originated by Jorge Sábato in the 1960s through a concept called Sabato's Triangle (Mello, 2011). It stressed the active role of government in stimulating and facilitating creation of innovation (Mello, 2011). In contrast to Sabato's Triangle, the triple helix model posits multiple sources of initiative arising from each sphere individually and in collaboration with one or two others (Ranga & Etzkowitz, 2013).

3.2 Firm characteristics

It is believed that behaviours and practices of firms are affected by characteristics of firms such as type of ownership, industrial sector and size of firm. First, on ownership, World Intellectual Property (WIPO) (2007) explained that one of the reasons for weak university and industry relation in Philippines is the strong presence of foreign businesses among potential partners for university collaboration which tend to rely on R&D and intellectual property (IP) transferred from their parent companies. This is different from the European case. Kramer, Diez, Marinelli, and Iammarino (2009) conducted forty in-depth interviews among senior managerial and technical staff of flagship MNEs of the automotive, life science and ICT sector from both Germany and the United Kingdom. They found that multinational enterprises (MNEs) contribute to the regional human capital by participating in local skills transfer programmes and by engaging in educational partnership with universities. On the other hand, MNEs benefit from inter-firm mobility in highly innovative regions and from the spatial and relational proximity to local universities from which they can access both graduates and more senior personnel as well as know-hows (e.g.

through contract research). Chang et al. (2015) concluded that in the case of University of Michigan--Shanghai Jiao Tong University Joint Institute (JI), the advantage of collaborating with MNEs is to directly engage in multidisciplinary real-world problems, dynamically integrate the industry issues into course curricula, and vigorously build industrial-strength research and educational activities within the institution.

Second, intensity of R&D collaboration differs across industrial sectors. Rasiah and Chandran (2009) attempted to identify the important drivers of university-industry R&D collaboration by using a sample of automotive, biotechnology and electronics firms from Malaysia. They found that industry-type matters as the relationship between R&D intensity and the likelihood of R&D collaboration with universities and research institutes is the strongest in automotive firms followed by biotechnology firms. Industry type also mattered in the influence of perceived significance of universities and research institutes as sources of knowledge, partner diversity, range of information channels and firm strategies on establishing R&D links with universities and research institutes. This is because technological capability varies across different industry types and it may affect the approach of collaboration. According to Freitas, Marques, and e Silva (2013), firms in low-medium technology industries usually engage in frequent collaboration with universities to expand their general knowledge base and facilitate higher levels of technology integration with embodied knowledge whereas in high technology industries, cooperation with universities is more often aimed at enhancing new knowledge development.

Third, several scholars have indicated that firm size is important (Arundel & Geuna 2004; Mohnen & Hoareau 2003; Cohen, Nelson, & Walsh, 2002; Laursen & Salter, 2003). Some of them agree that larger firms tend to collaborate because they have more resources to help them in establishing their relationships with partners (Abbasnejad, Baerz, Rostamy, and Azar, 2011). Nonetheless, other scholars (e.g. Best, 2001; Motohashi, 2004) argue that small and young firms especially high-tech ones in US and Taiwan intensively collaborate with universities. As a result, relationship between size of firms and intensity of collaboration with universities is inconclusive. In addition, firm size influences the collaboration approach. For large firms, collaboration with a university may be a strategy designed to strengthen their skills and knowledge and to gain access to non-core technologies. In contrast, for small firms, universities tendsto focus on problem solving in non-core technological areas (Santoro & Chakrabrati, 2002 as cited in Freitas, Geuna, & Rossi, 2011).

3.3 Mode of collaboration and outcome of collaboration

University-Industry collaboration channels include, but not limited to, conference, publication/report, student thesis, technical assistance, consultancy, personnel exchange, patent, license, joint R&D project, contracting R&D, Science Park, equipment and facilities and spin-offs. The interaction can take place between individual researchers in both university and company or between company and university as institutions (Eun, 2009; Joseph & Abraham, 2009, Iqbal, Khan, & Senin, 2011; Agrawal & Henderson, 2002; Landry, Amara, & Ouimet, 2005; Bekkers & Freitas, 2008; D'Este, Nesta, & Patel, 2005; Meyer-Krahmer & Schmoch, 1998). However, the literature review found little consensus among scholars regarding the most effective channel of university-industry collaboration (Bekkers & Freitas 2008; Eun, 2009) which may be evaluated by examining outcomes of collaboration, for example, intellectual property (patent, petty patent, industrial design), and prototype and product and process innovation. In the case of University of Navarra in Spain, main outcomes of R&D contracts in SMEs are new product and process. At this university, research projects involving academic researchers were aimed at improving innovation performance of SMEs in terms of technical and commercial outputs, that is, applied results (Bayona-Sáez & González-Eransus, 2011). However, the study focused on one specific mode (R&D collaboration) only. The relationship between collaboration mode and collaboration outcome has not been well researched.

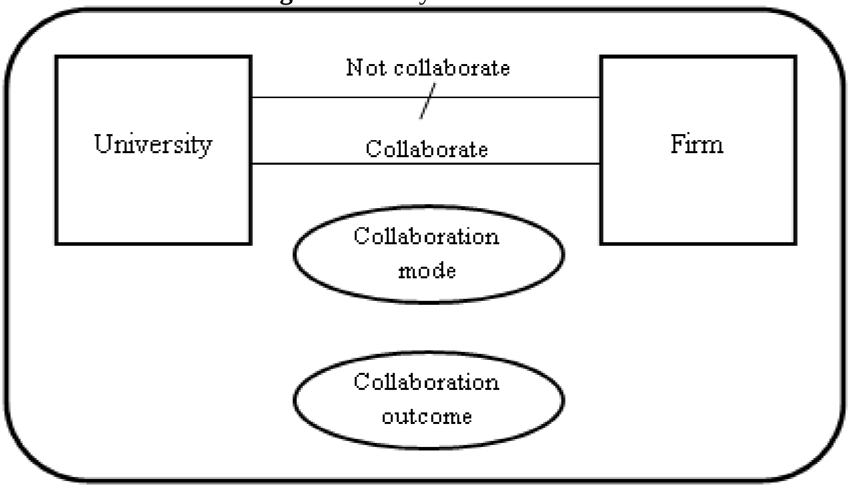
This paper attempts to partially fill the gaps by explicitly investigating the: 1) relationship between firm characteristics (age[2], ownership, size[3] and industrial sector) and decisions to collaborate with university 2) relationship between firm characteristics and modes of collaboration and 3) relationship between modes and outcomes (both outcomes of collaboration and outcomes of R&D/Innovation activities are examined).

4. Framework and Methodology

4.1 Research framework

Four groups of variables are investigated: 1) four characteristics of firms (age, ownership, size and industrial sector) 2) the decision to collaborate with university 3) twelve modes of collaboration[4] and 4) nine outcomes of R&D/Innovation[5]. The analytical framework addressing the three research questions is illustrated in Figure 1.

Figure 1: Analytical framework



4.2 Research methodology

4.2.1 Data Source

Thailand's R&D/Innovation Survey was commissioned by the Ministry of Science and Technology since 1999[6] to gain a better understanding of the nature of R&D/Innovation activities in Thai industries and find ways to enhance them. Response rate for the latest survey in 2011 (data as of April 24, 2014) is approximately 43.5% (4,246 firms). The questions about R&D activities and innovation activities were put together in the same questionnaire. The R&D/innovation survey questionnaire was in line with the OECD manual and European Community Innovation Survey (CIS) whose definitions of R&D and innovation are based on Frascati and Oslo manual respectively. The results of the 2011 survey indicated that 744 firms (out of 4,246 returned questionnaires) were engaged in R&D and innovation activities. Nonetheless, both R&D and non-R&D firms were allowed to answer questions about collaboration with universities. The survey results showed that 1,389 firms have been collaborating with universities (see Appendix 1).

The sampling frame of this survey was divided into three sets: (a) top 100 listed companies on Stock of Thailand, (b) data gathered from previous surveys and R&D organisation[7] and (c) data sampling from Business On-Line database which has a comprehensive information on approximately 300,000 establishments registered with the Commercial Registration Department, Ministry of Commerce[8] (see Table 1).

Table 1: Summary of national R&D and innovation survey

Items	**Thailand**
Survey Name and year	National Survey of Innovation 2011
Survey Method	1. SET100 (top 100 listed companies on Stock of Thailand) 2. Repetitive Group (Panel) 3. Non-Repetitive Group (Stratified Sampling and Systematic Random Sampling)
Coverage	25 industries in manufacturing sector, 17 industries in service sector and 5 industries in wholesale/retail sector
Industrial classification	International Standard Industrial Classification (ISIC) Revision 3.1
Guidelines	Frascati Manual and Oslo Manual
Response rate (for year covered)	4,246 firms (43.5%)

Source: National Science Technology and Innovation Policy Office (2014).

4.2.2 Variable measurement

The study adopts mainly quantitative research approach. The variables for all research questions are summarised in Table 2.

To examine the first research question, four independent variables: age, ownership, number of employee (size) and industrial sector (manufacturing sector) were investigated. Respondents (both engaged and not engaged in R&D) were asked whether they collaborate with universities; 0 if respondents did not collaborate with universities and 1 if respondents collaborated with universities. Probit regression was applied to analyse the influence of firm characteristics (independent variables) on the collaboration with universities (dependent variables).

To examine the second research question, four independent variables as mentioned earlier were included. Unlike the first research question, seven sub-industrial sectors: food, chemical, petroleum, metal, machinery, electrical apparatus and automotive were included as independent variables to see the influence on modes. Respondents (both engaged and not engaged in R&D) were asked whether they engage in the following modes with universities/higher education institutes (dependent variable). Choices were defined as 0 and 1 - 0 if respondents had no engagement and 1 if respondents had engagement. Multiple answers were allowed. The dependent variables (12 modes) were classified into five groups (see Appendix 2). Probit regression was applied to analyse the influence of firm characteristics (independent variables) on different modes of collaboration (dependent variables).

The third research question was related to outcomes of collaboration (two dependent variables) and outcomes (seven dependent variables) associated with collaborating firms were examined. Nine outcomes were categorised into two groups.

1) Outcomes of collaboration: Innovations were classified by new/significantly improved goods, new/significantly improved services, new/significantly improved processes. These variables are counting number.
2) Outcomes of R&D/Innovation activities are used as a proxy for outcomes of collaboration
    - Prototype. Choices were defined as 0 and 1 (0 if respondents had no output, 1 if respondents had output), and
    - Intellectual property (IP) illustrated by patent application, petty patent application, granted patent, granted petty patent, industrial design. Number of outputs or outcomes was replaced with dummy variable (0 if respondents did not use IPRs and 1 if respondents used IPRs.

Poisson regression and probit regression were used to estimate marginal effects of modes on both outcomes of collaboration and outcomes of R&D/innovation activities. In this equation, firm characteristics were also included as independent variables.

Table 2: Variable measurement

Variable name	Proxy variables
Age[9]	>15 years (1), ≤15 years (0)
Ownership	wholly locally owned (1), foreign firm and joint venture (0)
Number of employee (size)[10]	>200 employees (1), ≤200 employees (0)
Manufacturing sector	manufacturing (1), non-manufacturing (0)
Collaborate or not do collaborate with university	collaborate (1), do not collaborate (0)
Food	food (1), non-food (0)
Chemical	chemical (1), non-chemical (0)
Petroleum	petroleum (1), non-petroleum (0)
Metal	metal (1), non-metal (0)
Machinery	machinery (1), non-machinery (0)
Electrical apparatus	electrical apparatus (1), non-electrical apparatus
Automotive	automotive (1), non-automotive (0)
Mode of collaboration	collaborate (1), do not collaborate (0)

Table 2: (Continued)

Outcome of collaboration	
• product innovation	counting number
• process innovation	counting number
Outcome of R&D/ Innovation activities	
• intellectual property (IP)	have IP (1), have no IP (0)
• prototype	have prototype (1), have no prototype (0)

5. Findings and Discussion

5.1 Influence of firm characteristics on decisions to collaborate with Universities

Table 3 shows the tendency of larger firms and manufacturing firms to collaborate with universities while age and type of ownership do not significantly affect the decision to collaborate with universities.

Table 3: Relationship between firm characteristics and decision to collaborate with Universities

Independent Variable (Firm Characteristic)	Decision to Collaborate with University
Age	0.015
	(0.015)
Employee (size)	0.206***
	(0.017)
Owner	0.003
	(0.017)
Manufacturing	0.042***
	(0.016)
No. of observation	4,246
Log likelihood	-2,595.27
LR chi2	177.50
Prob>chi2	0.000

Notes: 1. ***1% level of significance, **5% level of significance, *10% level of significance. 2. Standard errors are in bracket.

In general, large firms form a higher proportion of collaborating firms. The implication of this result may be that most small firms lack the capability to access knowledge and technology from universities. Our finding is similar to some existing studies which indicate that large firms tend to collaborate with universities (e.g. Arundel & Geuna 2004; Cohen et al., 2002; Laursen & Salter, 2003; Mohnen & Hoareau, 2003 as cited in Rasiah & Chandran, 2009). Sector-wise, the manufacturing sector accounts for the highest proportion of collaborating firms and significantly relates to decision to collaborate with universities. Type of ownership does not present a significant relationship with collaboration. This result is different from previous studies; for example, Kramer et al (2009) mentioned that MNEs contribute to university and industry collaboration through participating in local skills transfer programmes and engaging in educational partnership with universities.

5.2 Influence of firm characteristics on collaboration mode

Table 4 shows the collaboration modes. The HR mode is the most frequent mode of collaboration in Thailand, followed by the informal mode, and service and infrastructure mode. The least frequent mode is technology licensing. These results are interesting and significant. Unlike universities in developed countries where patent-based collaboration and technology licensing from universities can be expected, Thai universities contribute to the local economy through providing education and training.

Industrial sector and size have statistically significant influence on modes of collaboration. Firms in food, chemical, petroleum and automotive sectors tend to collaborate with universities through various modes whereas firms in machinery sector (R&D mode) and electrical apparatus (service and infrastructure mode) are likely to use only one mode. The petroleum sector has the highest marginal effects on R&D mode, infrastructure mode, and informal mode. Food sector significantly relates to technology licensing. Interestingly, the collaborating firms in these three sectors - food, chemical and petroleum - have registered the highest amount of R&D spending in 2011 but do not have the highest marginal effects on R&D mode. Instead, firms in the automotive sector have higher marginal effects although these firms only moderately invest in R&D activities. These results are in contrast to the findings of Rasiah and Chandran (2009) who observed a relationship between R&D intensity and the likelihood of R&D collaboration with universities and research institutes. Our findings could have further implications. The R&D intensity is not a main factor in identifying level of R&D collaboration with universities. Those firms may conduct in-house R&D or collaborate with public research institutes. Interestingly, the informal mode may be one factor affecting other modes. Industrial sectors collaborating through informal mode also use other modes (see Table 5).

Firm size statistically relates to service and infrastructure mode, and HR mode (see Table 5). Large firms tend to use service and infrastructure mode as well as the HR mode. This implies that even large firms may not invest in technical infrastructure. They still need to use the technical service and infrastructure provided by universities.

Table 4: Number of firms collaborating with Universities (classified by modes of collaboration)

	Mode of Collaboration	Number of Collaborating Firm (firm)
1.	R&D mode *(joint R&D project, contracting out R&D project, co-publication)*	231
2.	Service and infrastructure mode *(academic consultant, analytical and testing service, technical infrastructure)*	304
3.	HR mode *(temporary personal exchange, student internship, training for employees)*	1,235
4.	Informal mode *(meeting or conference, personal contact)*	412
5.	Technology licensing	63
	Total Collaborating firms	**1,389**

Table 5: Relationship between characteristics of firm and modes of collaboration

Independent Variable (Firm Characteristic)	**Dependent Variable (Mode of Collaboration)**				
	R&D Mode (joint R&D project, contracting out R&D project, co-publication)	**Service and Infrastructure Mode (academic consultant, testing service, technical infrastructure)**	**HR Mode (temporary personnel exchange, student internship, training for employee)**	**Informal Mode (meeting or conference, personal contact)**	**Technology Licensing Mode**
Age	-0.027 (0.021)	-0.012 (0.023)	0.003 (0.017)	-0.005 (0.026)	-0.007 (0.012)
Ownership	-0.015 (0.023)	-0.038 (0.026)	-0.012 (0.019)	0.001 (0.029)	-0.005 (0.014)

Table 5: (Continued)

Size	0.021	0.057**	0.066***	0.031	0.003
	(0.022)	(0.025)	(0.017)	(0.027)	(0.013)
Food	0.127***	0.146***	-0.070***	0.185***	0.038**
	(0.033)	(0.035)	(0.027)	(0.037)	(0.020)
Chemical	0.098***	0.188***	-0.094***	0.150***	0.025
	(0.161)	(0.044)	(0.035)	(0.044)	(0.023)
Petroleum	0.457***	0.421***	-0.024	0.326**	0.087
	(0.161)	(0.159)	(0.118)	(0.161)	(0.119)
Metal	-0.018	0.087	-0.050	0.087	0.001
	(0.053)	(0.067)	(0.054)	(0.071)	(0.032)
Machinery	0.112**	0.046	0.035	-0.63	dropped
	(0.059)	(0.059)	(0.034)	(0.057)	
Electrical apparatus	-0.086	0.171**	0.030	0.036	-0.011
	(0.051)	(0.088)	(0.051)	(0.086)	(0.035)
Automotive	0.156**	0.159**	-0.014	0.256***	0.060
	(0.073)	(0.076)	(0.053)	(0.076)	(0.049)
No. of observations	1,389	1,389	1,389	1,389	1,389
Log likelihood	-604.85	-702.59	-465.60	-819.47	-249.25
LR chi2	40.36	54.56	36.46	49.99	8.08
Prob>chi2	0.000	0.000	0.000	0.000	0.527

Notes: 1. ***1% level of significance, **5% level of significance, *10% level of significance. 2. Standard errors are in bracket

5.3 Influence of Collaboration mode on outcome

We used probit regression to analyse the relationship between modes and outcomes. Then, we categorised them into two groups (Table 6 and 7).

First, the collaboration modes relate to collaboration outcomes. Three collaboration modes, namely R&D mode, service and infrastructure mode and informal mode significantly relate to product innovation but only two modes, R&D mode and informal mode, generate high marginal effects on product innovation. Firm characteristics do not significantly relate to product innovation. Similarly, the collaboration modes, namely R&D mode, service and infrastructure mode, and informal mode significantly relate to process innovation. However, the highest marginal effect values belong to service and infrastructure mode. Technology licensing has a negative relationship with process innovation. In the case of process innovation, the firm characteristics (older, smaller, manufacturing firms and foreign firm or joint venture) significantly relate to process innovation. To sum up, first, collaboration modes influence collaboration outcomes. The R&D mode and informal mode highly influence product innovation whereas service and infrastructure mode highly affects process innovation.

In contrast, the HR mode has no relationship with innovation-related outcomes. Surprisingly, technology licensing has no significant relationship with product innovation and has a negative relationship with process innovation. All firm characteristics relate to process innovation (smaller, older, foreign or joint venture and manufacturing firms).

Second, the collaboration modes relate to the outcomes of R&D/Innovation activities. The marginal effect value on intellectual property (patent, petty patent, industrial design) is relatively small. The R&D mode and informal mode significantly relate to intellectual property. Firm size and industrial sector relate to intellectual property. With regard to prototype, the collaboration modes have a significant relationship with prototype (except for HR mode). Technology licensing has the highest marginal effect values on prototype. Firm size significantly relates to prototype. Interestingly, most R&D/Innovation outcomes of surveyed firms are generated by firms collaborating with universities based on survey data. It is probable that the level of technological capabilities of collaborating firms are higher than non-collaborating firms.

When comparing marginal effects on all outcomes, modes of collaboration have a higher degree of marginal effect on innovation than IP-related outcomes. Perhaps collaborating firms may not yet be at the stage where they are interested to create new knowledge leading to IP. In addition, only larger firms and manufacturing firms tend to apply for IP. However, Thai SMEs accounts for 99%[11] of total enterprises applying for IP. In the case of Thailand, in order to generate more IP, it is necessary to use at least two modes: R&D mode and informal mode. Surprisingly, instead of product commercialisation, technology licensing relates to only prototypes. In contrast, an informal mode seems to be a trivial mode but it significantly affects all outcomes (product innovation, process innovation, IP and prototype).

Table 6: Relationship between collaboration modes and collaboration outcomes

Independent Variable (Mode of Collaboration/ Firm Characteristic)	**Outcome of Collaboration**	
	Product Innovation	**Process Innovation**
R&D mode	2.018*** (0.488)	1.320*** (0.305)
Service and infrastructure mode	0.859* (0.451)	3.225*** (0.620)
HR mode	0.235 (0.549)	-0.340 (0.384)
Informal mode	2.519*** (0.766)	1.049*** (0.365)

Table 6: (Continued)

Technology licensing	0.532 (0.339)	-0.856** (0.392)
Age	0.028 (0.327)	0.821*** (0.314)
Employee (size)	-0.234 (0.349)	-0.546* (0.281)
Owner	0.007 (0.359)	-1.290*** (0.282)
Manufacturing	-0.370 (0.345)	1.093** (0.521)
No. of observation	1,389	1,389
Log likelihood	-140.950	-183.60
LR chi2	144.84	226.56
Prob>chi2	0.000	0.000

Notes: 1. ***1% level of significance, **5% level of significance, *10% level of significance. 2. Standard errors are in bracket.

Table 7: Relationship between collaboration modes and outcomes of R&D/Innovation activities

Independent Variable (Mode of Collaboration/ Firm Characteristic)	**Outcome of R&D/Innovation Activities**	
	Intellectual Property	**Prototype**
R&D mode	0.074*** (0.025)	0.098*** (0.031)
Service and infrastructure mode	0.019 (0.017)	0.076*** (0.027)
HR mode	0.010 (0.016)	-0.000 (0.026)
Informal mode	0.037** (0.016)	0.035* (0.021)
Technology licensing	0.002 (0.023)	0.151*** (0.059)
Age	-0.005 (0.012)	-0.004 (0.018)
Employee (size)	0.025* (0.013)	0.038** (0.019)
Owner	0.019 (0.012)	-0.017 (0.020)
Manufacturing	0.023* (0.012)	0.031 (0.019)
No. of observation	1,389	1,389
Log likelihood	-296.20	-474.35
LR chi2	58.09	114.87
Prob>chi2	0.000	0.000

Notes: 1. ***1% level of significance, **5% level of significance, *10% level of significance. 2. Standard errors are in bracket.

6. Conclusion and Policy Implications

In relation to the research questions, key findings of the paper can be summarised as follows. This study partially fills in the gaps in the existing literature on university and industry collaboration.

First, large firms and manufacturing firms seem to collaborate with universities whereas age and type of ownership do not significantly influence the decision to collaborate with universities. The implication may be that large firms who cooperate, to a greater extent benefit more from cooperation and innovate more openly than SMEs (De Backer, 2008 as cited in Badillo, Llorente, & Moreno, 2014). The manufacturing sector significantly relates to decision to collaborate with universities perhaps because this sector often involves in R&D or engineering activities that require technical assistance.

Second, types of industrial sectors influence collaboration modes. Food, chemical, petroleum and automotive sectors relate to various collaboration modes whereas machinery sector (R&D mode) and electrical apparatus (service and infrastructure mode) seem to engage in one mode. Interestingly, this paper found that R&D intensity is not a main factor in identifying level of R&D collaboration with universities. Based on our findings, firms in food, chemical and petroleum sectors that have registered the highest amount of R&D spending do not have the highest marginal effects on R&D mode. Instead, firms in the automotive sector produce higher marginal effects although these firms only moderately invest in R&D activities. Perhaps those firms may conduct in-house R&D or collaborate with public research institutes. Similarly, firm size influences collaboration modes. Large firms tend to use service and infrastructure mode and HR mode. This implies that technical service and infrastructure provided by universities is an important mode for Thai manufacturing industries.

Third, in general, the collaboration modes have higher degree of marginal effect on innovation than IP-related outcomes. This implies that collaborating firms may not yet be at the stage where they are interested to create new knowledge leading to IP. The collaboration modes relate to collaboration outcomes and outcomes of R&D/Innovation activities. The R&D mode and informal mode generate high marginal effects on product innovation. In terms of process innovation, service and infrastructure mode provide the highest marginal effect. Surprisingly, technology licensing has no significant relationship with product innovation and has negative relationship with process innovation. With regard to outcomes of R&D/Innovation activities, R&D mode and informal mode significantly relate to intellectual property whereas the collaboration modes (except for HR mode) have significant relationships with the prototype.

Last but not least, policy implications for the government can be drawn from our study. Since 1990s, the Thai government has put efforts to foster university and industry collaboration through several policies and measures such as establishment of technology licensing offices, university business incubators, science parks and cooperative education. Nonetheless, the efforts of Thai government during the last two decades could be classified as ‘one-sized fit all’ policy.

In fact, firm characteristic is also a crucial factor affecting the decision to collaborate with university. Even modes of collaboration, firm size and industrial sector also have an influence. Firms in machinery sector (R&D mode) may have different demands from firms in electrical appliance industry (service and infrastructure mode) as seen from the different modes used. It is therefore necessary to determine a specific policy or a measure regarding firm characteristics. For example, the government may reconfirm that (1) electrical apparatus laboratories in Thailand have or do not have sufficient services for firms (2) facilities and equipment in laboratories are already outdated or still being upgraded and (3) government’s R&D incentives are or are not appropriate for firms in machinery sector.

In addition, the R&D mode has influence on all outcomes (intellectual property, prototype, product innovation and process innovation). This implies that in order to accelerate outcomes, policy on promoting R&D collaboration may be appropriate. However, the government needs to consider the factors enhancing R&D collaboration across industrial sectors. In contrast, technology licensing programme must be revisited to improve its operations because it could generate only prototypes and not IP or innovation-related outcomes. Interestingly, the informal mode is likely to be a trivial mode but similar to R&D mode, it significantly affects all outcomes as mentioned earlier. The government should not only promote formal collaboration but also help facilitate informal collaboration between university and industry. Informal collaboration may be a stepping stone and a trust-building mechanism for ‘formal’ and ‘longer-term’ modes of collaboration.

Notes

1. Clinic technology project, Ministry of Science and Technology, Thailand.
2. It is based on year of establishment.
3. It is based on number of employees.
4. They are joint research project, contract research project, academic consultant, technology licensing, analytical and testing service, technical infrastructure, temporary personal exchange, student internship, training for employees, co-publication, meeting or conference and personal contact.

5. They are patent application, petty patent application, granted patent, granted petty patent, industrial design, prototype, new/significantly improved goods, new/significantly improved services, new/significantly improved processes.
6. The surveys for 1999 and 2003 were conducted out by the National Science and Technology Development Agency while surveys from 2008 to present were carried out by the National Science Technology and Innovation Policy Office.
7. National Science and Technology Development Agency (NSTDA), National Innovation Agency (NIA), National Research Council of Thailand (NRCT), Thailand Research Fund (TRF).
8. Two techniques (stratified and systematic random sampling) were applied to this survey. All firms in this set were divided into three groups; Group 1: firms with highest revenue (1% of total firms) (all firms are samples), Group 2: Excluding group 1, firms with highest revenue (10% of total firms) (all firms are samples) and Group 3: the remainders (systematic random sampling technique based on revenue).
9. Average age of collaborating firms is about 18.5 years.
10. It is based on classification of Office of Small and Medium Enterprises Promotion, Thailand (small and medium: ≤200 employees, large: > 200 employees).
11. Bank of Thailand.

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Appendices

Appendix 1: Descriptive statistics

Variable	Observation	Mean	Standard Deviation	Min.	Max.
1. Mode					
R&D mode	1,389	0.1663067	0.3724898	0	1
Service and Infrastructure mode	1,389	0.2188625	0.4136241	0	1
HR mode	1,389	0.8891289	0.3140856	0	1
Informal mode	1,389	0.2966163	0.4569304	0	1
Technology licensing mode	1,389	0.0453564	0.2081595	0	1
2. Firm characteristic					
Age	1,389	0.5730742	0.4948095	0	1
Size	1,389	0.4067675	0.4914077	0	1
Ownership	1,389	0.712023	0.4529834	0	1
Manufacturing	1,389	0.7480202	0.4343061	0	1
Food	1,389	0.1720662	0.3775739	0	1
Petroleum	1,389	0.0064795	0.0802629	0	1
Chemical	1,389	0.1101512	0.3131909	0	1
Metal	1,389	0.0381569	0.191644	0	1
Machinery	1,389	0.0475162	0.2128169	0	1
Electrical apparatus	1,389	0.0237581	0.1523495	0	1
Automotive	1,389	0.0323974	0.1771169	0	1
3. Outcome					
Prototype	1,389	0.1281497	0.3343769	0	1
Intellectual property	1,389	0.062635	0.2423925	0	1
Product innovation	1,389	0.0309575	0.3103276	0	8
Process innovation	1,389	0.0439165	0.4380342	0	9

Appendix 2: Coverage of sub-modes

Mode	Sub-mode	Explanation
Research and development (R&D) *	• Joint R&D • Contract out R&D • Co-publication	• Joint or Collaborative R&D: Both or all of parties make a substantial contribution to the resource requirements. • Contract out or Commission: Research commissioned by a private firm to pursue a problem of interest. • Co-publication: Both or all of parties jointly publish publication which is an output of R&D activity. • Fund for university research: Research paid for by an external party. • Exchange of research sample: It is defined as the transfer of tangible research sample between two organisations.
Service and Infrastructure	• Academic consultant • Use of testing service • Share of technical infrastructure	• Consultancy is a service provided by expert staff. • Testing service and use of infrastructure: development, analysis and testing for industrial products and processes in university department.
Human resource transfer	• Temporary personnel exchange • Student internship • Training for employees	• Multi-context learning mechanisms such as training of industry employees, postgraduate training in industry, graduate trainees and secondments to industry, adjunct faculty.
Informal interaction	• Meeting or conference • Personnel contact	• Formation of social relationships and networks at conferences, etc.
Intellectual property (IP) licensing	• Technology licensing	• Transfer of university-generated IP (such as patents) to firms, e.g. via licensing.

Source: Adapted from Schartinger, Schibany, and Gassler, 2002; Perkmann and Walsh 2007; Eom and Lee 2009; Ponomariov and Boardman 2012; Vea 2013.

Note: * R&D mode consists of joint R&D project, contracting out R&D project and co-publication. Firms which answered at least one type or all types of R&D modes are defined as 1. One firm can be classified into different groups of modes because multiple answers were allowed.