DEVELOPING PUBLIC UNIVERSITY-INDUSTRY COLLABORATION AND INDIVIDUAL-LEVEL APPROACH TO THE MACHINERY INDUSTRY

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ABSTRACT

The objective of this study aims to explore the faculty's motivation and engagement of university-industry collaboration (UIC) at the individual level in Taiwan's public universities. Many researchers contributed to quantitative studies, while this study alternatively enriched the contextual and deep understanding by using the case study method. When SMEs in the machinery industry in Taiwan turned into the spotlight due to promotion of Industry 4.0, the firms look for the cost-effective alliances, which is external R&D in terms of collaboration with professors. Four professors teaching at the mechanical engineering department at the top ranking research-intensive public universities volunteered to tell their stories in the study. It was found that the individual-level approach to UIC discovered the gaps in social proximity and cognitive proximity. It is suggested that research-focus universities may do more marketing for senior professors to attract the industrial partners, whereas the junior professors must be supported to deal with teamwork and time management. This study indicated the need of the external R&D for Taiwan's SMEs in the machinery industry in order to facilitate productions of smart machines in the global marketplace.

Keywords: university-industry collaboration, SME, R&D alliance, Industry 4.0

INTRODUCTION

The higher educational institutes (HEIs) increasingly play a role to influence the network of business and industries. HEIs are regarded as the main sources of knowledge bases in the forms of strategic alliances for innovative firms and industrial clusters [15]. In the recent years, researchers indicated the great contribution of University–Industry Collaboration (UIC) to the performances of the technology transfer, university spin-off, and commercialized IP. Furthermore, the competitiveness of a nation relies on the overall economy with invention and innovation at the international marketplace. Thus, any national innovation systems must include the participation of HEIs and industries that altogether create knowledge flows and new inventions [37]. As following this trend occurred to the Western countries, Asian countries and HEIs have been catching up the development of UIC at different speed levels.

The research in this line of UIC favored the quantitative measures of R&D output in reference to the definition of innovation stated by OECD [46], such as the number of the IP granted, spin-offs, licensing, and amount of the contracted research projects. In the qualitative perspective, several forms of

interactions were uncovered in the literatures, for example, consultancy, teaching, continuing professional development and so on, were observed [9] [16] [31] [47] [49]. Nevertheless, there are significant inter-industrial and inter-disciplinary differences affecting the natures and channels of the output and interactions of UIC [8] [16] [50]. In fact, alliances with universities enable companies to engage in the academic networks on a basis of openness and knowledge sharing [9]. The universities consider the industrial partners as their most important external ally for getting the additional incomes and a better understanding of how new knowledge could be applied to commercialized products [20]. Both rely on mutual complementary roles in this economy-focused society [44].

One of the research models about UIC called for the inspection of three levels of academic engagement at the individual, organizational and institutional levels [49]. Following this blueprint, this study focuses on the most frontline level and its antecedents, in terms of the individual-level factors, which are neglected over years. This study presented a case study that outlining four faculty at the top ranking research-focused public universities who engaged in the process of collaboration with the machinery industry in Taiwan. Prior research related to Taiwan's development in UIC emphasized the significant influences of the top-down driving factors embedded in the organizational culture [40]. This case study attempted to provide a bottom-up approach in terms of individual accounts. This article is structured as follows: the next section aimed at outlining the context of Taiwan's governmental policy of promoting Industry 4.0. Industrial sectors and HEIs were involved as participants in the innovation system of "Smart Machines". In the third section of literature review, three types of proximity and partner/alliance selection were addressed. In the fourth section, the summary of interviews was discussed and used to highlight the dynamics of individual researcher's motivation and capabilities which are linked with a variety of SMEs that they collaborated with. Finally some concluding remarks are presented.

RESEARCH QUESTIONS AND CASE STUDY METHODS

R&D partnerships were the essential elements of competitive advantages so as to meet challenges of rapid changes in the society. It is noteworthy of reminding that the research focusing on individual university faculty makes contributions to the SME firms as the external R&D. A number of the research questions of interest are raised in this study, such as: Why collaborate? Who to collaborate with? How to relate individual research interest to the industrial partners' application? What elements are attributed to the satisfied outcomes? Four university faculties teaching at the mechanical engineering department in Taiwan were invited and accepted interviews to tell their stories.

OUTLINES OF RECENT INDUSTRIAL DEVELOPMENT IN TAIWAN

Strategic industrial sectors and Government's Policy

The technological development in Taiwan relies on technology diffusion and knowledge exchanges across the industries and universities. The government has decisive influences at the microeconomic and macroeconomic level so that the government would deliberately selected the strategic industrial sector to show the direction of the future industrial development. It is a hope that the industrial firms and HEIs would be attracted by the governmental budgets and public funds that were used to support strategic industrial sectors together to form a national/regional innovation system [40]. When the government leveraged their investment for industrial development, the industry would surely decrease the running cost using public funds or grants, to develop the vertical and horizontal applications and relationships in the strategic industrial sectors.

Taiwan's SMEs in the manufacturing sectors, used to focus on adding value to the core techniques imported and developed in the other countries. With legally add-on software and hardware, SMEs then sell or export the integrated products to domestic or international customers, in particular providing with after-sales services. It is reasonable that the Taiwan's SMEs might eliminate the efforts and costs on engaging internal R&D activities to offset the expenses of getting technology licenses in terms of patents, models, and know-how. According to WIPO, the technology licensing is mostly adopted in the SMEs' B2B business models. Thus, SMEs' business plays an indispensable role in creating domestically inter-firms access to new foreign knowledge or techniques. On the other hands, SMEs are confronted by long-lasting problems of resource limitation, such as limited investment capital, R&D expenditure and manpower.

Following Germany government's leading role to promote the concept of "Industry 4.0", Taiwan's government tried to implement new-generation products in the competitive global market. So the machinery industry has a new good name as "Smart Machines Industry" and is turned into "a strategic industrial sector". Smart machines involves machine automation, censoring devices, big data, and the core functions of context-sensitive analysis, which can greatly improve the reliability and accuracy of the machines. The machinery industry in Taiwan comprised of numerous SMEs had lay down a solid base of tool-making techniques. However, SMEs are limited in their knowledge bases and rely more on external sources of new knowledge [1]. In order to reduce the cost of personal mobility, small firms usually were tied into the regional innovation networks to a greater extent than the large firms [2] and the learning effects of SMEs are somehow stronger in domestic and exclusive alliances **[59].**

The concept of industrial district suggested earlier in Marshall' book [39] resulted in the implementation of the first science park built by Taiwan's government in 1979. Hsin-chu Science Park(SP) was located in Northern Taiwan. Most of firms located in Hsin-chu SP has been associated with semiconductor, information technology and telecommunication industries, so called "hi-tech large firms". In contrast, numerous SME firms in the machinery industry, running the small factories operated by few employees who were trained by local technical colleges were settled down over the area of the Central Taiwan. It was not until recently Central Taiwan SP is developed and receives a lot of government's attention and resources. Approximately twenty universities geographically located nearby Central Taiwan SP, joined the focal alliance sponsored by the MOST funds in order to develop partnerships among participants and maximize the effect of spillovers.

Booming of universities and their survival strategies in Taiwan

In the 21st century, HEIs in many Western countries has been fast growing, in order to accommodate more foreign students to study. Interestingly, the number of the universities in Taiwan was increasing in past 15 years, due to a political decision made kindly concerning domestic students in 1996. New universities were established and many colleges were extended to technological universities, recruiting more high school students to enroll as undergraduates. It is good news that the growth of higher education has made contribution to Taiwan by providing well-educated manpower. But it is bad news for the public universities, which always receives significant governmental funds that nowadays distributed the limited educational funds to many more universities in Taiwan. Up to the year of 2017, there are 33 public universities out of 173 colleges and universities in Taiwan, where Taiwanese population reached approximately 21 millions. The number of the private universities and students was twice as many as

that of the public universities and their students. After the global financial crisis was occurred in 2009, any activities was important to compete the public grants or funds, turned to be critical for the future survival of any universities. Among the universities, the top-ranking public universities realized that, in this highly resource-competitive environment, it is not only depending on the income of the tuitions, but it also the outstanding research capabilities for gaining extra incomes via spin-off, collaborated contract, or technology transfer with industrial partners [60]. UIC for public universities at Taiwan most likely become a channel of bringing monetary support for the operation of universities as tangible benefits [27].

In 2016, UCI was further reinforced by the amendment of Taiwan's Science-Technology Basic Law, which allowed the patents, Intellectual property (IP), shares of ownership, generated by the joint projects sponsored with the public grants or funds, to be shared by all participants. This is considered to be a big step to effectively provide an incentive to the HEIs and individual researchers. Furthermore, the latest policies of Taiwan's Ministry of Science and Technology (MOST) re-emphasizes on more resources, opportunies, and grants will be allocated to the research in line with the strategic industrial sectors in order to foster the development of the regional/national innovation systems.

LITERATURE REVIEW

Geographical proximity

Industrial clusters stand for of a group of companies, universities, governmental agencies, trade associations, and associated service providers in related industries, which are spatially located proximately[51],. This can serve a striking force of the economy, either in the advanced or in developing countries. By this point of view, studies show that firms prefer to cooperate with local university researchers within a distance of a hundred miles [38]. The importance of proximity for firms to outsource knowledge is increasing with the higher quality and output of public research [3]. However, some British researchers indicated that no empirical difference in research links between the academic institution and on-park firms was found, when compared with the off-park firms [43]. In the case of Taiwan, as one of the top-ranking public universities nearby Hsin-chu SP, NTHU takes the advantages over others to collaborate more with the firms in Hsin-chu SP [40]. The important contribution of the knowledge creation and diffusion between Hsin-chu SP and NTHU has been well-recognized internationally [28]. In fact, the firms in SP intend to collaborate with universities, not only for the reason of the source of knowledge and research capacity [43] but also for the supply of R&D employees (i.e., well-trained graduate students) [9] [28]. The UIC was highly driven by top-down leadership of the NTHU based on the faculty's survey [28]. In order to pursue tenure tracks, overall UIC output at Taiwan's public universities, in terms of academic publications was increasing [29] and most of the UIC activities are more contract-based R&D , instead of patents and technology transfer activities [28] [40].

Social proximity

Geographical proximity is not a primary factor that can stop the firms from accessing external knowledge. Proximity is not exclusively related to physical closeness so it might be addressed as multi-dimensional concepts, in views of alliance partner research [32]. Firms should adopt a proactive behavior to access to knowledge in need, even out of the spatial clustered contexts [45]. Social proximity refers to the degree of interpersonal closeness embedded in the social network in which people know each other and thereby interacting at the individual level or in private or professional occasions [30] [10]. Social proximity facilitates face-to-face interactions and communication between partners so as to exchange the high quality information and tacit knowledge rather than codified knowledge [10]. In particular, highly complex technologies and extraordinary scientific discoveries may

somewhat rely on inter-personal forms of knowledge sharing [56]. The firms are more likely to think spatial distance less important, when informal contacts are important for acquiring public research results and share useful knowledge [3]. Personal contact and interactions with partners are adopted more by small companies [21]. Relationships are ranked as the most important factor of UIC by Swedish universities [19] [57]. More experienced researchers are more likely to have larger networks, and hence more social capital that help them to select the right partners in the private sectors [24].

Cognitive proximity

Another one of the important dimensions of proximity is related to the concept of cognitive proximity. Cognitive proximity represents the similarity in the way of perceiving, interpreting, and understanding each other and to communicate with others effectively [30]. Cognitive proximity has closely associated with the issue of knowledge structures of alliance partners. Each firm may hold distinctive views in its knowledge bases and the interpretations of the systems between knowledge elements. Four features can account for the cognitive proximity [30] , such as (1) the use of the same technical language, (2) the similar way of making technological products, (3) the same degrees of being knowledgeable, and (4) the similar approach to the problem-solving. "Technological distance" between two partner firms due to divergences in their technological focus or profiles [5] seems to be the opposite form of cognitive proximity. For instance, larger companies with differentiated functional departments have less need for problem-solving capability, while the smaller companies relies on external sources due to lack of special expertise and equipment [50]. When the technological distance becomes too large, SMEs may not have the absorptive capacity to make organizational learning take place [14] [59]. Furthermore, time is likely to affect the interactions between alliances, that is, routine-based dissimilarities might be more troublesome at the earlier stage. In the mature stages, oriented-based dissimilarities are more likely to complicate the collaboration [20]. However, it is argued that increased technological distance between alliance partners is good for reaching the novel knowledge [12].

Different goals between UIC partners

The mission for the research-intensive universities is on achieving academic excellence in their core activities. The prestige and quality of top ranking universities will be most likely to attract industrial partners [3]. The large firms that want to reduce the risk and cost involved in the process of collaborating with universities may carefully consider the conditions, such as the public recognition of an university specialized expertise, the good performance of its graduates in society, and professors' reputation and awards in scientific fields [54] Academic researchers tend to pursue long-term, curiosity-driven research, while industrial firms are interested in short-to-medium-term outcomes in marketplace, such as patenting and technology transfer [48]. The industrial firms are more interested in problem-solved solutions and working on ready-to-market products, whereas the university faculty seeks the paper publication and peer recognition in the academia [21]. Collaboration with industry can allow the professors and researchers that access to relevant problems in the field to produce a positive impact on academic excellence [25]. Interestingly, research-intensive public universities at Taiwan may position themselves to work with the hi-tech industry (mostly large firms), while the technology-intensive public university would like to assist the SMEs, who are often referred to as 'medium-low tech industries' [40]. While collaborating with larger firms on R&D, the university may be engaged in aggressive projects [44]. Those companies expected the universities' contribution to project completion' more important than suggestion of new projects [13]. Therefore, it is indispensable to understand each party's priorities and capabilities, before becoming UIC partners [62].

Institutional incentives and individual motivation

There are five driving forces in the process of promoting UIC activities, including leadership, incentive/reward systems, resource and capability, external network, and reputation [40]. Universities with clear visions and missions to promote UIC will guide the faculty to experience a higher number of collaboration activities [9]. As a result of the positive culture, the male, engineering-disciplined professors generated more patenting activities [27]. While the faculty merely plays a passive role to get involved collaboration, they regard the work to be mediated or depended on the university specialized agent [31]. It seems to institutions very important to develop the top-down leadership and organizational culture in order to boost the growth of UCI by way of generating commercialized output and industrial application [55]. On the other hand, the reason why individual faculty or researcher collaborated with industry may be curious about new knowledge, supplement his or her own research, and secure funds [33]. In addition, by hosting a high monetary budget of UIC projects, one is able to conduct exceptional academic research [27]. Researchers who have diversified external linkages to the industry can utilize all types of UIC cooperation to strengthen their performance in academic research work [27]. A person's characteristics may significantly serve as the key predictor for engagement in UIC [48] [49]. Some outstanding scientists would like to devote to working with industrial partners, with the purpose of extending their academic research rather than commercializing their knowledge [17]. Like entrepreneurial spirit, a sense of accomplishment motivates an individual researcher to satisfy industrial demand as well as his/her academic pursuit [27] [42].

Selection of the alliance partners

Partner selection is one of the critical decisions when a firm looks for a strategic alliance [34].The resource-based view may account for the matching in partnerships. [44]. Any firm cooperating with others through strategic alliances is intended to obtain the complementary resources [26]. The technology or knowledge access, rather than market access may serve as a determinant of R&D collaboration [7]. SMEs tend to suffer from the financial and resource gaps that are difficult to fill up in terms of developing in-house R&D capability [11], so selection of R&D alliance partners presents a bigger challenge for small companies [59]. For example, small firms would less benefit from alliances with partners of similar technological profiles. The large firms with strong research and R&D capabilities have ability to transfer and absorb external knowledge, obtaining high benefits more from alliance participation [41] [61]. It is argued that when firms are seeking business advice, they are more likely to collaborate with regional universities while firms seeking R&D support and testing and analysis services are more likely to collaborate with both regional and non-regional universities [22]. The partner university's location internally depends on the level of investment in the budge plan of the firms [21]. Nevertheless, the firm becomes vulnerable in the situations that they have to protect their know-how and unique assets from partners' opportunistic behaviors in future [34] [36]. Co-operation with public partners does not involve commercial risk [44]. Three types of alliances were proposed as friends, acquaintances, and strangers [34]. When the firm faces new trend or new market, the strangers who can bring new information and techniques is more advantageous than friends [18]. More interaction over time is positively related to turn strangers into friends and develop a larger monetary budget of projects [18].

RESEARCH RESULTS AND DISCUSSIONS

The research subjects' profiles

The research subjects are full-time faculty who teach at the department of Mechanical Engineering (ME) in the top-ranking public universities located at the Taipei city, the capital of Taiwan. Their academic backgrounds and prior experiences associated with UIC are summarized in Table 1. The names of the research subjects were anonymized as David, Brian, Eric, and Frank. The age differences and seniority in teaching indicated that the research subjects represent two generations. Both David and Brain had been teaching at the same university, which is classified as research-intensive No. 1 university. Eric and Frank teach at the different technological universities for less than seven years. Both technological universities recruited the national champions out of the student contests where the occupational high school students competed for competency in industrial operational skills. As the high reputation in ranking, the technological universities' faculty must possess outstanding research capability to offer the doctoral programs.

David is the only one, out of four, who had ever worked in the industry. His research interests are diversified in the field of computer-aided coding, design and analysis. As the industry got more and more computer applications involved, this trend led David to develop a long history in UIC and maintained good relationships with quite a lot industrial partners. Conversely, Brian has exclusively focused on mechanics research and enjoyed publishing a substantial volume of paper in the past twenty years. Recently, Brian turned to conduct more experimental research and spent his grants purchasing the appliances in order to broaden his research scopes. As for the two young men' educational backgrounds, Eric and Frank are inter-disciplinary. Eric had taken courses in EE when he was a graduate student, where Frank was an excellent software coder. Both inter-disciplinary capabilities are quiet exceptional as compared to the traditional ME majors.

Table 1: The research subjects' background and experiences in UIC

Professor's Name	Position	Age	UIC experi-ences (yr)	Academic seniority (yr)	# of firms collaborated with	Research Interest	Amount of contracted R&D per year (in USD)
David	Associate Professor	65	30	35	15	CAD / Expert system /3D printing	$2500K
Brian	Distinguish Professor	62	6	32	6	Solid Mechanics	$600K
Eric	Associate Professor	37	4	7	2	Optic signal process / Piezoelectric	$100K
Frank	Assistant Professor	34	2	3	3	Digital image correlation / MATLAB coding	$500K

Finding partners in industry

It is assumed that to make the industrial collaboration happen depends on the firms that make the first move. Lack of geographic proximity is the first problem explicit to solve for professors in this study. Central Taiwan science park and the clusters of the machinery industry are two-hour driving distance

away from the Taipei city. It would be assumed that university professors might become passive in the initiatives of collaboration. However, it may be incorrect assumption. There are a variety of ways for the professors to actively attract the industrial partners' attention if they would like to do so. There are four proactive approaches found in the interviews, which includes: (1) winning the contests, (2) providing specific information in web pages, (3) contacting the employers of the graduate students, and (4) participating in the senior faculty's projects. The first two may reflect the concept of cognitive proximity and the last two approaches may link to the social proximity discussed in the section of literature review.

(1) Winning the contest

Based on the interview, Brian encouraged his graduate students to participate in the student contests held by mechanic firms since six years ago. His students won the top prizes for the consecutive years so as to attract the host company's attention. A couple of Taiwan's well-established and profitable firms annually hold the student contests with monetary prizes in competition of thesis, on-site demo, and orally defenses. The host firm invited Brian to test out his research experiments at the mechanic plant. Every time, Brian led a student team, spending two days working at the plant. By chance, Brian had a contact with one of the host firm's suppliers, which is a SME, established at Southern Taiwan for 50 years and possessing technology license agreement with Japanese company. Thereafter, the supplier invited Brian to visit his plant for working out the solutions to the existing problems of machines. As it can be expected, there will be a whole bunch of to-be partners in this supply chain for Brian to collaborate with. Nevertheless, Brian evaluated that his research capability in measuring experiments can solve much more complicated practical problems for those firms. This makes him feel a sense of achievement and a desire to continue the collaboration. The facilitative factors of cognitive proximity and physical proximity were not found in Brian's story, but they did not affect his motivation engaging in UIC.

Providing Information on web pages

David started his first collaborative project with his first employer, who had hired him as an engineer, as David being awarded the master degree. When David became the university faulty, his ex-employer came to the university to ask for his consultancy. How firms reached David is simply by browsing the introductory web pages about the university faculty. But, David's personal web pages look no different from other professors' pages. Since David learned to use computer application in the very early days, his excellent capability in CAD and coding could help the industrial partners applying to the field practices and products. Fortunately, those cooperative firms were located around the Northern Taiwan, within one-hour driving distance. Thus, David has the greatest number of collaborated firms and the highest amount of the project budgets among all. After the cooperation for many years, David's partners, majorly SMEs, have been engaging in incremental innovation, rather than inventing new products. David feels pathetic for SMEs, which have to cope with downsizing plants in order to survive during the slow-down economy. The fact that David has good and long relationships with industrial partners represents that the social proximity surpassed the cognitive proximity at the final stage of UIC.

Meeting graduate student's employers

Eric is an expert at adopting the interdisciplinary approach to comprehensively testing the quality of the mechanic products. He complained that the university mediation office fail to match or guide the firms to establish the partnership with him. Eric initially joined a senior faculty's project collaborated with a very large-sized state-owned enterprise located at Southern Taiwan, about four-hour driving distance from the Taipei city. It is until his graduate student had introduced his employer, this perfect match was

found. Eric started the research projects with this SME firm for two years. The test of the hand-sized products extremely relies on Eric's research design with the uses of the appliances. In the meantime, Eric provided on-site courses and training for the partner and found that the firm lacked of the theoretical foundation. Eric feels his partner reluctant to progressively improve the quality of the products, though the profitable product of that firm has been dominating the domestic market shares. Throughout interactions of two years, Eric and his student were dissatisfied with the partner's low degree of knowledge and devotion to solving problems. It seems that to close up the cognitive gap between them may partly depend on mutual consistence in evaluation of the importance of knowledge and problems.

Participating in adviser's projects

Frank is an ambitious young professor, who was delighted to make friends with the industrial firms. His students were required to work as the interns at the firms, so that he must visit the plants for the sake of students' safety. Why Frank collaborated with the industrial firms is initially associated with Brian, his adviser. When Frank was a doctoral student, under Brian's advices, he developed software specific to analyzing the data collected at working machines. Brian combined both hardware and software techniques to generate tremendous effects on improving the accuracy and reliability of data analysis. Brian usually asked Frank to join his collaborative projects with the industry. Frank's graduate students are more skillful at hands-on, whereas Brain's graduate students are more mathematically analytic together making up a good research team. Furthermore, Frank's technological university is well-known for entrepreneurships. Many of SMEs' bosses who worked hard to create the economic growth in 1960s-1980s of Taiwan, came from the graduates of his university. Presently, Eric was too young to have the connection with the university alumni. But he is catching up with his colleagues, the senior professors, who always have the social network with the industry.

University leadership and failure of mediation office

The university presidents at Eric's and Frank's technological universities often encourage the faculty to work with industrial partners. In particular, the president at Eric's university strongly emphasized on the significant incomes of the patent granted for the global market by way of telling success stories. On the other hands, the faculty is required to run the budgets of UIC projects with at the least amount of USD $7000. To push the partners to sign the agreement of technology transfer is demanded by the university in order to reach the goal of the university. The top-down leadership seems explicitly existed in technological universities. The UIC mediation office established at any university is responsible for proving the service for partner matching. However, none of the research subjects in this study recognized the good match done by the mediation office. Frank pointed out that the senior or prestigious professors would snatch the good ones from the applicants before the young professors knew it. The four professors felt the same way of counting on themselves instead of dealing with the mediation office.

Cognitive gap between academia and the SMEs in machinery industry

Based on the information revealed by the four research subjects, Mechanical Engineering (ME) involves a life cycle of a machinery product, starting from design, production, controlling, analysis of mechanics (solid and fluid), and quality assurance of the end product. Some departments of ME may group the faculty into different academic tracks. David tried to solve the problems of the new products at the design stage. Brian detected the problems of the machines in the middle stage of production process.

Eric inspected the end product with the reliability procedures. Frank modified the algorithm of software based on analytic results of the data. However, SME firms were not able to distinguish the natures and the types of the problems they had and got used to solve the problems via accumulated experiences and trial-and-errors. SMEs may have not even aware of who is Mr. Right to help them.

According to David's and Eric's reports, their SME partners lacked the theoretical foundation to improve the quality of the products in the machinery industry. By outsourcing the R&D in a cost-effectively way, the SME firms may keep the firms survived rather than growing in the future. David pointed out that R&D is not a matter of an individual's intelligence (i.e., an individual professor's capability). Instead, it is a team of people and the use of hardware as well as software. Most of Taiwan's SMEs cannot afford it. Eric found that his partner did not have sufficient procedures to test out the functions of the products. The high defect rate of the products will not allow the firm to compete at the international market. The cognitive gap between academia and SMEs seriously hinders the firms to grow the capability of innovation of smart products. SMEs are smart to form strategic alliances more widely than larger firms [44].

Personal devotion versus cost-effective means of R&D

The four research subjects greatly committed themselves to the collaborated research projects. The monetary return is not plenty enough to cover the expenses of the team and research work. Four professors run their research labs with the grants to pay off the purchases of the instruments, the supplies, and the computer software as well as the financial support for the graduate students' monthly stipend. In the perspective of time management, if the professor would not have collaborated with the industry, the graduate students will concentrate on using simulated data for wrapping up their thesis, which is individual-based work. However, by working with the industry, the professors often call up the team meetings, scheduling the work, and coordinating the reporting results to the partners.

Four professors regard themselves as the external R&D is the most cost-effective means for the SMEs, because their academic research capability and know-how can solve any of the problems, at expense of lower costs. In particular, the senior professors appreciated the opportunities that their research can be successfully applied to the real world. Mobility is essential for Brian's collaboration with partners. It is easier for David to deliver the design files via Internet for partners. Owing to the hand-held products, Eric tested the partner's products at his research lab with no mobility in demand. The physical proximity may varying with cases. Frank compared the differences in UIC experiences between co-working with the large firms and with the SMEs. Large firms have the personnel who are responsible for checking the schedule and outcomes of collaboration. But the small firms may show little commitment to the contracted projects, schedules, and people.

MANGEMENT IMPLICATION

Collaboration between universities and the industry is a complex phenomenon associating with macro, micro, internal, and external factors, making it difficult to draw the whole pictures. The machinery industry at Taiwan, presently is catching up with the international market of Smart Machines requiring seamlessly to assimilate new technologies and knowledge into new complex product offerings. The SMEs in the machinery industry at Taiwan need to develop R&D capability to fill up the gap. The government moves in the right direction by making the policy to encourage universities to participate in the industrial alliances and partnerships. In this case study, we found out, two out of the four research

subjects, senior generations, are motivated to commit themselves to the UIC projects, on a basis of the accumulated social network and high reputation for specific research. They have mature research and management capability to solve any technical problems for the partners. The other two junior professors obviously acquire more assistance in partner-matching and team psychology engaged in the process of UIC projects. Both young men have inter-displinary backgrounds which are very useful to approaching smart machines, however, they are confined by the characteristics of the partner firms. Resource-dependency theory suggests firms participated in strategy alliances to access the complementary capabilities and resources. One question was emerged in the end of the study: what is the future goal that those firms have, to grow or to survive? In this study, the SMEs collaborated with professors possess limited absorption capabilities so that they hardly look for new trends with a competitive advantage in the future. UIC turns to be a cost-effective survival strategy for SMEs. That is, UIC may be served as external R&D during the downturn. It seems SMEs may feel pessimistic, when the age of Smart Machine is incoming.

Being physically close to the industrial partners may not be a hindrance to self-motivated professors. Additionally, social proximity requires a certain period of time to be developed, such as the connection to the alumni, tracing prior relationships in the industry, knowing students' employers, accumulated brief encounters at meetings and so on. The issue of cognitive proximity is the one of the salient findings derived from the study. It should not be ignored the three major types of cognitive gaps between the professors and the SME firms. First, a gap existed in the knowledge base in the theories about smart machines; the second gap accounts for the affordance of research teamwork with aid of sophisticated appliances and procedures, and finally, the third gap appeared in the devotion of time and attitude to deal with the significance of the problems. When the faculty faced the tenure-tracked performance-based evaluation, the most decisive turn point would be the mismatch of their research focus and the firms that seek for help. This may explain why younger professors might play a passive role in UIC than the senior professors [48].

CONCLUSION

In this case study, the machinery industry in Taiwan provided a specific context which UIC is occurred for gaining the competitive advantages in the age of Industry 4.0. Based on the literature reviews, proximity, strategic alliances, organizational goal and individual motivation were served as theoretical frameworks. Therefore, the professors' engagement in the collaboration with SMEs in machinery industry deepens the understanding of the initiates, the determinants, and the obstacles of UIC at the individual level. The major results of the study identified some dilemmas, such as the professors' excellence of research in reputation may attract the industrial partners. But it also develops the cognitive gaps between the professors and industrial partners. The young professors may feel annoyed with certain types of the problems and characteristics of the partner firms. But this experience will increase social network, and secures their research money. The relevant research to be explored in the future may be related to how to broaden the research-intensive university faculty's social networks, how to eliminate the difficulty of mobility to the distant industrial clusters, and how to improve the effects of partner matching of the mediation office at the university.

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