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Exploring the Effectiveness of Firm's Collaborative Capabilities in University-industry Collaboration

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Abstract The collaboration with academia is important for firm to develop new product in the knowledge-intensive industries. Although both firms and universities can gain benefits, activating a joint research collaboration does not necessarily guarantee its success. Geographic proximity, prior relationship or knowledge proximity with academic partners may be insufficient for sustaining an effective collaboration. This study scrutinizes firm's collaborative capabilities to win the cooperation of academic partners and enhance the inter-organizational coordination in the execution stage of collaboration. Based on the results of multiple-case study, this research would shed light on the management of collaborative innovation and provide practical guidance for managers at firms to develop effective university-industry collaborations.

Keywords: *innovation, collaboration, cooperation, coordination, collaborative capabilities*

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1. Introduction

Discontinuous technology evolution makes it difficult for most firms to possess full sets of knowledge and resources to continuously create new products to respond to radical change in the competitive environment [1]. An effective solution to this problem is to acquire external knowledge through collaboration [2]. Collaboration with academics is regarded as an important source of new ideas, complementary knowledge and skills [3]. University-industry collaboration (UIC) is also a way for firms to reduce R&D cost and risk by stretching limited resources such as human, equipment and facility [4]. A combination of pressures both on firm and university attributes the formation of UIC [5]. Academics seek collaboration with firms to enable them to keep on the leading edge in academia by accessing external resources, obtaining research funds, gaining opportunities for field-testing or identifying new research topics [6].

Although the needs and advantages of UIC have been recognized, these potential benefits are often not realized in practice [7,8,9]. Building university-industry relationship confronts the "two-worlds paradox" [10,11]. Firm and university have very different missions, organizational and institutional culture [12]. Most studies have focused on how university manages UIC by establishing intermediary roles, such as technology transfer offices (TTO) [13,14]. TTO as intermediary or broker promotes the formation of UIC but rarely engages in the execution stage of UIC [15]. Current studies pay limited attention to the role of the industrial part and UIC management in the execution stage of collaboration [7,16,17].

Previous studies have investigated various enablers or preconditions of UIC. Geographical proximity and prior contacts are important factors in the establishment of UIC [18,19]. Geographical proximity can smoothen institutional differences [20] and increase the likelihood of forming intensive bilateral relationships [21]. Scholars also emphasize the importance of prior relationship in overcoming the obstacles between firms and universities, and illustrate the correlation between initial relationship developed before the collaboration, and the outcome of such collaboration [22]. Other enablers of UIC include knowledge proximity [23,24], trust [25], communication [26], motivation [27], and government policy [28].

Despite identifying various enablers or preconditions of UIC, the existing literature presents a fragmented view [16,29], and remains behind in the development of theoretical perspectives [7]. We find that numerous studies focus on partner choice as the main determinant of successful UIC, such as partners with prior relationship or knowledge proximity. Firms and their academic partners may aim for perfect fit and seamless interactions; however, such states are rarely achieved from the beginning to the end [30]. There is a clear gap in the literature regarding how firms develop partnership with academics in the execution stage of UIC, particularly without the precondition of prior relationship or knowledge proximity. How to develop an effective UIC remains largely unexplored [31,32].

Our study employs the perspective of cooperation and coordination to investigate how firms develop effective

partnerships with academics in the execution stage of UIC. Qualitative research is chosen for this study because this method permits in-depth interpretation when it is necessary to understand the dynamic mechanisms. We conduct a multiple-case study in different knowledge-intensive industries in Taiwan, where is at the forefront of pushing UIC [33]. Taiwan is ranked No. 12 in company spending on R&D and No. 17 in UIC among the 138 economies surveyed in the World Economic Forum's Global Competitiveness Report 2016-2017. The industries in Taiwan are composed of numerous small- and medium-sized enterprises (SMEs). Universities serve the important role of not only helping to create and diffuse the knowledge to circulate within the industries but also fostering the corresponding manpower to facilitate industrial upgrading [34]. UIC has been promoted in Taiwan for more than 20 years and SMEs which are the backbone of the economies in Taiwan often involve UIC. We regard this a viable research context to explore how firm manages UIC to achieve a satisfying and productive collaboration.

2. Theoretical Background

In line with the concept of strategic alliance, collaboration is understood in a broad sense as a voluntary arrangement in which two organizations engage in mutually beneficial exchange [23]. Since Gulati et al. (2012) have proposed cooperation and coordination are two indispensable facets of collaboration, cooperation and coordination have received continuous attention in the literature of inter-organizational relationships [35,36,37]. There are clear distinctions between cooperation and coordination. Gulati et al. (2012) define cooperation as the joint pursuit of agreed-on goals and coordination as the deliberate alignment or adjustment of partners' actions to achieve jointly determined goals [38]. Kretschmer and Vanneste (2017) propose that cooperation refers to the alignment of incentives and coordination refers to the alignment of actions [36].

2.1. Cooperation in UIC

Firms that seek to involve academia in innovation processes face the paradox. The academic researchers are likely to provide the most complementary knowledge but are also the most challenging collaborators to work with [39]. Comparing to inter-firm collaboration, UIC is more complex because university and firm have different mission, interest and incentive system based on different institutional logics [40]. The built-in tension is the main goal in university is to create new knowledge for academic status and education, while the focus in industry is to capture valuable knowledge and leverage it for competitive advantage [41]. The other issue of UIC is that firms prioritize rapid progress, while academia prioritize novel research outcomes. UIC is likely to be plagued with weak attitudinal alignment [42].

R&D collaboration between firm and university is an exploratory process and it is almost impossible to specify all efforts and completely predict final results in advance [43]. The nature of divergence and dynamic change of R&D progress would make the objectives and scope of joint-research which had ever agreed on between two parties gradually changed, modified or extended [44]. Misaligned incentives of self-interested agents can cause diminished commitment [45]. Any party who grasps the critical knowledge or resources may have chance to make research outcomes favorable for his own interests and thus the original expected outcomes and commitments may be postponed, deviated or distorted [46]. It should be noted that differences in goals are often not recognized in the initiation stage and they become clear in the execution stage of the collaboration [31]. Bstieler et al. (2015) have emphasized that it is imperative for actor in collaboration to enforce partner to jointly pursuit of agreed-on goals and reduce behavioral uncertainty [22].

Cooperation focuses on the issues of goal alignment and value appropriation between private and common interests [38]. Legal contract is seen as necessary evil to clearly define rights and obligations, and it acts as an umbrella arrangement to encourage confident interaction [22]. Carefully designed contract binds partners to take the necessary action to achieve goals [47], and can lay the groundwork for relationship building and trust formation [48].

The uncertainty in collaborative innovation makes it practically impossible to establish a full set of rules in the legal contract for resolving future problems and conflicts. Any initial contractual deficiency can lead to incentive misalignment [38]. The shadow or invocation of future benefits is a approach to sustain commitment [49]. Psychological contract based on emotional loyalties raises the intrinsic motivation to cooperate [50]. Establishing psychological contract with partners facilitates informal adaptation in the absence of changes to formal contract [38]. There is the need for firms to build up collaborative capabilities to win the cooperation of academic partners, includes meeting the responsibilities ascribed in the written contract and making contributions beyond the contract that facilitate the collaboration to operate more effectively.

2.2. Coordination in UIC

The different institutional norms of the organizations also influence how people perceive and perform their work [40]. Due to institutional heterogeneity, academic researchers and R&D engineers may have different routines, habits and mindsets in ways of doing things [7]. The disparity cause misunderstanding, unproductive frictions or conflicts [51]. Dissimilarity of norms and knowledge may constrain partners' ability to effectively integral the resources and knowledge they bring to the table.

The more novelty the UIC aims at, the greater is likely to be the amount of trial and error. The new problem will continually come one after another. If the cognitive gap between the two parties is too large, the low level of mutual understanding may lead to poor communication [52]. The cognitive gap may lead to conflict and friction in trial selection and diminish the possibility of efficiently identifying valuable solutions [44]. Owing to the accumulation of inefficient and disharmonic coordination, the two parties may doubt the feasibility of collaboration.

Coordination refers to the pooling of resources, the division of labor across partners, and the subsequent integration of the dispersed activities, all of which are critical to the generation of value in a collaboration [35]. Coordination aims to identify and build consensus about task requirements [53]. While the two parties do not have some shared knowledge, it will be difficult for them to combine their individual stocks of knowledge and work together efficiently [54]. Boundary spanning involves the activities, processes, or tools to promote, drive, or boost the flow of knowledge and the exchange of information across the boundaries of different organizations [55]. It helps to develop critical common ground for effective communication and task allocation [43] and result in the generation of new knowledge to facilitate coordination [56]. Cognitive gap between actors can be crossed, bridged, and overcome by sufficient exchange of information and knowledge which entails a mapping from one's cognitive range to another's cognitive domain [57].

Although boundary spanning can promote a high level of information exchange and knowledge transfer, mere exposure to abundant information will not enable actors to absorb valuable knowledge [58]. Recipients' capacity to tackle information loads and assimilate new knowledge is crucial in achieving effective mutual understanding and coordination. Organizational absorptive capacity not only depends on employees' prior knowledge and previous experiences in the organization [59] but also depends on organization's investment in internal knowledge capital [60]. Optimal absorptive capacity is sufficiently high to deal with the highest cognitive gap without deficits in understanding [61]. There is the need for firms to build up collaborative capabilities to enable effective integration of separate knowledge repositories and specialist knowledge between firms and their academic partners.

3. Methodology

Recently finding new perspectives, conceptualization, and theory building in UIC via qualitative research has gained momentum [32,39]. The explorative case study approach enables us to alternate between the theoretical framework and empirical field during data collection and analysis [62]. The main purpose and advantage of this approach is that it does not reduce or average the variety of results. Thus, the multiple-case study approach is useful in investigating how firm's collaborative capabilities influence the outcome of UIC and contributes to theory by developing it further.

3.1. Empirical setting

For examining the effectiveness of firm's collaborative capabilities on the outcome of UIC, there was no prior collaboration between focal firms and their academic partners to avoid influence from prior collaborative experience identified by literature to enhance trust [63], reduce coordination costs [64], or mitigate problems caused by the differences in goals [65]. There is geographic proximity between focal firms and their academic partners. R&D engineers at firms and academic researchers in universities work in the same city. Geographical proximity has been considered the main determinant of interactions between firm and university [21].

University research funded by private companies has been increasing. Comparing to government funding UIC, industrial funding UIC is mission-oriented and contract-based [66,67]. Effective collaboration is more concerned than the relationship establishment in industrial funding UIC. The motivation of these focal firms is mainly to effectively develop new technology for pursuing new business opportunities.

Purposively selected cases include the collaborations between academics in different scientific fields and firms in different industrial sectors to ensure the variance of case selection. Case selection also ensures the variance in terms of firm size since there is a rich debate about the relationship between number of employees and the performance of R&D collaboration [68]. The other criteria in case selection includes the access to key informants directly involved in the UIC.

3.2. Data Collection and Analysis

Face-to-face interviews with key informants were semi-structured to ensure that we covered the same issues in each interview but still allowed for emergent topics. Interviews were conducted in Chinese (local language) and each interview lasted for approximately 60–120 minutes. We conducted interviews from September 2016 to September 2020. Key informants included managers responsible for the establishment and the management of UIC, and engineers who had executed the specific tasks in UIC. We focused on the issues that concerned firms in terms of effective UIC, and the firm's management and involvement in the UIC. The goal of the interviews was to elicit and identify firm's collaborative capabilities that has a positive impact on UIC.

To mitigate the biases of retrospective data collection, we performed triangulation using information from relevant written documents (e.g., meeting minutes, contracts, or reports) [69] and interviews with participants on academic side for verification. We applied descriptive coding as first cycle coding method. Descriptive coding is an approach to analyze basic topic of the data and to form categories for further analytic work. Pattern coding was adopted for development of major themes from the data and the formation of theoretical constructs [70]. All transcribed interviews and secondary data were classified inductively, and annotated deliberatively through several discussions among authors and relevant specialists to reach a consensus about the key concept.

Each case was interviewed independently and in private. Based on these purposive samples, we found that saturation occurred within the twelve interviews and basic elements for meta themes were present within first six interviews. The new data did not add new categories to the coding scheme but rather was variation on already existing themes. There is a certain degree of homogeneity in our purposive samples since the cases are chosen according to some common criteria as control elements. It is consistent with the suggestion that six cases would be sufficient to enable development of meaningful themes, if the aim is to

understand common perceptions and experiences among a relatively homogeneous group [71].

To compare the effectiveness of preconditions identified in literature (prior relationship, or knowledge proximity) and firm's collaborative capabilities on UIC, the commonalities and differences after the within-case analysis and cross-case analysis were presented based on six information-rich cases. The key informants in these cases had the willingness to share more information when we promised that the raw materials (audio recordings and transcripts) were only for authors' study. As some of the data were sensitive to the firms, universities, or informants, we anonymized the company name by naming them with letters from C1 to C6 and corresponding academic partners with letters from P1 to P6.

4. Results

The context and key characteristics of each case were summarized in Table 1. Case 1, 2, and 3 were interdisciplinary collaborations and there was no knowledge proximity between academic researchers and R&D engineers. Case 4, 5, and 6 were problem-solving type collaborations. These three companies initiated UIC with professors in the same knowledge domain.

Table 1. Context of six cases

	Case 1	Case 2	Case 3	Case 4	Case 5	Case 6
Company	C1	C2	C3	C4	C5	C6
Sector	Electronic	Chemical	Optoelectronic	Biomedical	Optoelectronic	Chemical
Professor	P1	P2	P3	P4	P5	P6
University	U1	U2	U2	U2	U3	U4
Scientific field	Biomedical engineering	Biomedical engineering	Biomedical engineering	Biomedical engineering	Optoelectronic engineering	Chemical engineering
Prior relationship before focal UIC	No	No	No	Professor P4 is R&D manager's supervisor in his doctoral degree program	Professor P5 and R&D director are friends and members in the same scientific community	Professor P6 is the supervisor of R&D engineers in their master-degree programs
Knowledge proximity	No	No	No	Knowledge overlapping in syntheses technology of biochemistry	Knowledge overlapping in optoelectronic system	Knowledge overlapping in methodology of chemical inspection
Object of UIC	Design new medical inspection equipment with multifunction	Develop new blood inspection device	Develop new diagnosis machine of urinary tract infection	Develop new material to solve the absorbance problem	Develop new measurement system for material inspection in the production line	Develop sample collection method to expand the inspection limitation
Project funding	All supported by company and milestone payment	All supported by company and milestone payment	All supported by company and milestone payment	All supported by company and milestone payment	All supported by company and milestone payment	All supported by company and milestone payment
Project timeline (Original plan)	Three-year project	One-year project and renewal every year	One-year project and renewal every year	One-year project	One-year project	One-year project
Participators in the company	R&D director and three R&D engineers	Project manager and four R&D engineers	Senior R&D manager and three R&D engineers	R&D manager and two R&D engineers	R&D director and one R&D engineer	General manager and four R&D engineers
Participators in the University	Professor, three master students, and one doctoral student (Partial scope of project was student's research topic for master's degree)	Professor, one master student, one full-time research assistant (Partial scope of project was student's research topic for master's degree)	Associate professor, one master student, and one doctoral student (Partial scope of project was student's research topic for master's degree)	Professor, one master student, and one part-time research assistant (Partial scope of project was student's research topic for master's degree)	Professor and three master students (Partial scope of project was student's research topic for master's degree)	Assistant professor and research assistant
Outcome of UIC & Firm's perception	Termination after one year; Ineffective UIC	Long-lasting partnership for six years; Effective UIC	Long-lasting partnership for three years; Effective UIC	Termination after 10 months; Ineffective UIC	Infeasible research result; Ineffective UIC	Assistant professor joined the company as R&D director; Effective UIC

All six companies spent much time on contract drafting and negotiation. Their major concerns were similar, and these legal contracts contained the following clauses: (1) scope of the research project (i.e., duration, plan, milestones, deliverables, payment, and division of tasks), (2) management of collaborative relationships (i.e., conflict mediation and termination); (3) inventorship and ownership of IP rights; (4) prohibition of spill-over or limitation of freedom to work with other companies on similar topics for a certain period of time, to ensure competitive advantage. In contrast to legal contracts in business collaboration among firms, legal contracts in the UIC did not contain penalty clauses to express the sincerity and concern of the firm about the research results with higher uncertainty. Except for company C6, which insisted on the whole ownership of new patents, the other five companies accepted the universities' requests for co-ownership of new patents, which were derived from the research results in UIC, as they hoped that co-ownership could be an incentive for academic partners to co-create more valuable research results. Among these five companies, company C2 preferred detailed terms to prevent IP disputes, and would rather spend more time to bargain for balance solutions. The clauses about IP rights were much more specific to clarify the scope of foreground and background patents and leave less room to misinterpret the co-ownership of new patents. Company C2 also insisted on having the priority to acquire the full right of co-owned patents with a favorable transfer fee when any third party showed interest in those patents.

4.1. Cooperation and Coordination Failure in Case1, 4 and 5

The scope and budget of UIC in Case 1 were the largest among the six cases. The professor P1 was highly respected in academia, with several publications on inspection technology in top journals. Company C1 invited this professor to initiate a UIC with ambitious targets of creating the first biomedical inspection equipment in the world with multiple functions. For company C1, the motivation for this collaboration was to pursue business diversification opportunities in the biomedical industry. The R&D engineers in company C1 would take over production and commercialization once professor's research team could finish the equipment design and deliver the prototype. In a mark of respect to the professor, company C1 did not monitor the UIC project as strictly as its new product projects in the company. The interactions between the two parties were limited to the regular review meeting, as listed in the contract for milestone payments. The meeting gradually became a mere formality to check that the project was still ongoing. After nine months, a semi-finished prototype with one function was finally demonstrated to test the functionality of the hardware. Until that time, company C1 found that the equipment design did not work stably. The plan to complete full functionality was already delayed by at least half a year. While this project did achieve some technological innovations, company C1 did not perceive this as an effective UIC in terms of schedule, cost, and producibility. There arose a fundamental issue with the different mindsets and ways of undertaking research project between academics and industry. One R&D engineer commented on this problem: "The students thought that it was fine to deliver a prototype that just operated normally for a short time. This might be allowed for academic dissertations or publications. However, we could not deliver an unstable prototype for commercialization." As the master's thesis was a priority for students, the professor's research team focused on academic requirements (unprecedented idea), but not on the business requirement (producible design). On the other hand, how to communicate functional requirements was the big issue between the R&D engineers with electronic background and the academic researchers with biomedical background. Without the effective coordination, both parties failed to detect the problem of stability as early as possible. The slow progress and the difficulty of multi-functional design increased the tensions between the two parties. This collaboration was terminated when the academic researchers finally gave up completing the final part of the project.

In Case 4, company C4 failed to maintain a cooperative partnership even there was prior relationship between two parties. The professor P4 was the R&D manager's supervisor in his doctoral degree program and the initiation of the UIC was smooth. At first, company C4 openly provided information about the specification and design of its product to the professor's research team. After the midterm review meeting, company C4 found that the professor had a different agenda and suspected that he was hiding some key information to reserve business opportunities for himself. Finally, the collaboration was terminated by company C4. The following quote illustrates the cooperation problem: "There was no barrier for us in discussing the experiment design, material selection, experiment steps, task decomposition and experiment results, because we had the same technology background. However, we felt that the professor had a strong interest in business, after realizing the potential of this new product. We worried that they (professor's team) were in competition with us, rather than working as a team. We stopped disclosing more information and terminated the collaboration."

In Case 5, the R&D director in company C5 had a good relationship with the professor P5 for a long time, and they were members of the optoelectronic engineering community. The purpose of the UIC was not only to provide research funding, but also to develop a better solution to the problem of material inspection in the production line. Company C5 provided important industrial chemicals that were difficult to obtain to support this research. At first, company C5 had confidence that the R&D engineers could implement the research results into the practical system in the production line because both parties had optoelectronic backgrounds. However, company C5 finally found that it was difficult to implement the research results, although the academic partners had delivered full reports about the design of the measurement system and demonstrated a small prototype in the research laboratory. The R&D director in company C5 expressed the coordination problem: "The professor was trustworthy and didn't miss the deadline of project. We underestimated the complexity of the transformation from academic results to a practical system. The engineers

in the production line should spend more time to work together with the professor and students and make them understand our critical concern in the production line. We were unable to adjust their (students') design to fit our production line." Although the company closed the project as planned in the contract, it did not successfully implement the results of this project, making it an ineffective collaboration.

4.2. Cooperation and Coordination in Case 2

Company C2 pursued business diversification opportunities in the biomedical industry and surveyed academic inventions that it could commercialize. The professor P2 completed the concept testing of a new blood inspection methodology in the laboratory and searched for industrial partners to translate the concept into a commercial product. The contract negotiation lasted for six months for consensus on patent and publication rights. Company C2 regarded publication in high-ranking journals as an important marketing strategy in the biomedical industry and encouraged the academic researchers to submit papers; however, in mutual interest, it required the researchers to discuss the content with company C2 before submission. The project manager in company C2 stated that, "It was important that the company clearly expressed its targets and simultaneously gave space to the academic partners to create something new or gain some benefits. This reciprocity between us was based on mutual trust." Company C2 also provided reciprocity to enhance academic researchers' willingness to pay more efforts on doing this project, such as supporting them to win innovation competition with the research results. The partial scope of the project was also the student's research topic for his master's degree. Joint supervision of the master's thesis by professor P2 and R&D director in company C2 was one of the means to ensure that the research results simultaneously met the academic and industrial requirements. Company C2 openly shared the experience and skills of optoelectronic design with the academic researchers. Company C2 also offered a job to master student to motivate him to perform better. In addition, although the professor hired a research assistant, company C2 paid her salary. The research assistant was responsible for the two sides and executed the tasks as an employee in the company. With reciprocity and incentives, company C2 successfully maintained a cooperative partnership with professor's research team.

The project manager in company C2 spent much time aligning the research agenda with company strategy and reviewed the project progress rigorously. She emphasized that it was hard to understand one another in this interdisciplinary collaboration. "In the beginning, we tried to understand what the professor was saying. I often literally asked the professor, what did this mean? This would ensure that all of us were thinking along the same lines and taking in crucial information." For effective coordination, she implemented some means to ensure the exchange of more knowledge and experience between academic researchers and R&D engineers to achieve common understanding. Specified formats of project reports, experiment reports, and meeting minutes guided all participators in disclosing complete and detailed information. All documents were in cloud storage to ensure that all participators accessed the same information whenever necessary. These documents also ensured the retention and transfer of new knowledge within the firm. Face-to-face biweekly meetings in the professor's laboratory ensured that R&D engineers and academic researchers became familiar with each other and discussed the tasks sufficiently. In addition to regular meetings, the Instant Messaging (IM) Application (App) – Line was used to intimate about urgent issues, exchange first-hand information, and adjust tasks promptly. One R&D engineer said, "The testing result was sometimes not as predicted. We could immediately inform the status, call for assistance, or make decisions quickly, using the group discussion function in Line."

Project managers and engineers also participated in clinical training in the professor's laboratory to learn blood testing and the operation of clinical instruments. At the end of the second-year collaboration, company C2 hired a new engineer with a background in clinical pathology and business experience in the biomedical industry, to expand its R&D capacity. The master student who participated in this project also joined the company as an R&D engineer after graduation. These two new employees were responsible for the establishment of a biomedical laboratory in company C2 and played the role of boundary spanners to bridge the knowledge gap and transfer new knowledge to the company. The internal training within the company helped other employees who were not involved in the UIC to assimilate new knowledge and generate new ideas by brainstorming from diverse knowledge backgrounds. Company C2 came up with several new patents about product design to extend the professor's original concept to the patent portfolio. Both parties were satisfied with the outcomes of collaboration and maintained a long-lasting partnership.

4.3. Cooperation and Coordination in Case 3

Case 3 shared some similarity with Case 2. Company C3 intended to expand its business to the biomedical industry and met with professor P3 at a biomedical conference. The professor had conceived of a new methodology to inspect urinary tract infection and had just completed the feasibility study in the laboratory. Both parties were willing to jointly develop a new diagnostic product for urinary tract infection, based on the professor's idea and the complementary knowledge. The partial scope of the project was the student's research topic for his master's degree. Joint supervision of the master's thesis by professor P3 and general manager in company C3 was one of the means to ensure that the research results simultaneously met the academic and industrial requirements. Although R&D engineers in company C3 were highly motivated to develop this new product, they lacked biomedical knowledge. The R&D manager invited the professor to conduct cross-training for R&D engineers and students. In this training course, the professor taught basic biomedical knowledge, and senior R&D engineers shared their experience of software design and knowledge of optoelectronic materials with professor and students. This cross-training established a reciprocal relationship and team building. At the project midterm, the

professor got a chance to demonstrate this new inspection technology at an innovation exhibition in German. Company C3 generously provided extra support and assigned an engineer to support the prototype setup in German. The company also supported the professor in winning an academic innovation award in Taiwan. Through these activities, company C3 pushed project progress forward and successfully maintained a cooperative partnership with professor's research team. The R&D manager said, "Although these activities (innovation exhibition and competition) were beyond the scope of collaboration or business, they were also beneficial to us (company C3). We could directly give more comments and jointly designed more competitive product. Based on reciprocity, we trusted that they would consider our best interests, because we are a team."

For effective coordination between academic researchers and R&D engineers, a biomedical laboratory was set up in the company. Academic researchers can conduct experiments and discuss the results directly with R&D engineers in this laboratory. The engineers also learned skills, experience, and knowledge about clinical testing while working together. In addition to biweekly face-to-face meetings on the progress of the project, the teams used the IM app Line to inform about the status, share information, and make collective decisions in time. The R&D manager said, "I often shared business news using Line to help the professor and students understand business requirements. The professor also often shared new technology information, such as biomedical news or latest papers to bring us more biomedical knowledge." Company C3 gradually expanded its R&D capacity through the continuous accumulation of new knowledge through regularly training and learning. Finally, with sufficient knowledge overlapping, R&D engineers and academic researchers jointly created a new design of portable equipment that was better than the professor's original concept. Both parties were satisfied with the collaboration and maintained a long-lasting partnership.

4.4. Cooperation and Coordination in Case 6

The general manager in company C6 looked for a better solution for sample collection to improve the detection limit of the existing product. His friend in chemistry academia recommended professor P6 who had developed unique technology. Coincidentally, professor P6 was also the R&D engineers' supervisor in the master's degree program. The contract negotiation for the entire ownership of the patent rights lasted six months, to ensure the competitive advantage of company C6. Unlike other cases in which the project budget included personnel and material expenses, the budget was only the remuneration for academic researchers engaged in this UIC, and company C6 was responsible for the procurement of all materials. The general manager said, "We were good at selecting electronic components that were stable, producible and cost-effective. The procurement process in the company was also more efficient than that at the university. Academic researchers could focus on research without worrying about materials. We also could ensure the producibility of research results, which comprised commercial components that were selected and verified by our R&D engineers." To maintain the commitment of academic researchers in the collaboration and the commercialization of the research results, company C6 provided an extra incentive that once the professor successfully delivered an effective solution for collecting samples, the company would donate equipment using the research results of this project. This high-end chemical analysis equipment would allow the professor to earn research funding by providing a testing service for academia or industry. These mutually beneficial policies allowed the academic researchers to perceive the benefits of teamwork with company C6. The general manager stated, "In a reciprocal atmosphere, our partners had no hidden agenda and would like to share information in a timely and accurate manner, reveal problems earlier, and jointly solve problems."

For effective coordination, Company C6 adopted some policies to promote knowledge flow between academic researchers and R&D engineers. The four engineers were designated to fully engage in this collaboration and execute the tasks under the professor's supervision. Among them, two were graduates under the professor's supervision in the master's degree program acted as boundary spanners to facilitate communication between the two parties. Company C6 requested that academic researchers executed the tasks in the co-working space in the R&D center of company to ensure the sharing of sensitive information within the company. The general manager explained, "This project required much more integration; under trust, we invited academic partners to execute the tasks in our company. Working together in the same space was crucial. All team members could learn from each other. We also gave them (academic researchers) feedback from a business perspective to adjust the experiment design and testing promptly." Both parties were satisfied with the collaboration. The general manager even invited the professor to join the company as a full-time R&D director after this UIC. The professor accepted the offer and gave up his career in academia. With stronger R&D capacity, company C6 continued to launch new products in the chemical industry.

4.5. Comparison between Ineffective and Effective UICs

The producibility or implementability of the research results is a critical indicator of effective collaboration for firm in industrial-funding UIC. The comparison among cases 2, 3, 4, and 5 shows that the initial conditions (prior relationship or knowledge proximity) do not always guarantee a satisfying UIC. The UIC might end with cooperation failure (Case 4) or coordination failure (Case 5). Case 4 shows that the prior relationship may contribute to the initiation stage of UIC but can't sustain a lasting partnership. How to keep partners' cooperation as one team is challenge for firm during the execution stage of UIC. Case 5 shows that knowledge proximity may contribute to the communication of explicit or bookish knowledge but can't sustain effective coordination to meet firm's expectation. How to integrate expertise, experience, skill, and knowhow is challenge for firm during the execution stage of UIC.

UIC involves multiple academic researchers, including a professor, master student, doctoral student, or research assistant. In Taiwan, the scope of UIC usually includes the research topics of the master's thesis to enforce project completion within one or two years before graduation. This might be a double-edged sword. Without sufficiently aligning the academic researchers' interest with the firm's expectation, the project could easily deviate from the original plan, because academic researchers may intentionally or unintentionally focus on academic requirement. Academic requirement (graduation or publication) is not necessarily in conflict with business requirement (producibility or implementability). The firm in ineffective UIC (Case 1 or Case 5) fail to align partners' interest with its expectation. Firm in effective UIC (Case 2 or 3) pay attention to guide research direction fitting academic and practical requirements through joint supervision of the master's thesis. Academic researchers better understand firm's needs and is better able to work towards those needs.

The professors in universities have higher social status, and most firms will avoid offending academics, as these faculties act as reviewers in government grant R&D programs in Taiwan. Contract negotiation with academics is challenge and UIC contract is usually loose agreement without sanction terms to imply a firm's trust in its academic partners. The project plan appended in UIC contract is usually rough for ambitious goals or uncertain results. Thus, it is difficult to control the outcomes of UIC just relying on legal contract. Firm in effective UIC (Case 2, 3 or 6) deliberately establish psychological contract with academic partners for sustaining their commitment to UIC, biding them to prioritize firm's interests, or aligning their interests (graduation or publication) with firm's business need (producibility or implementability). The reciprocity policy and corresponding activities share the view that the success of both parties is interdependent and joint engagement towards meeting the final market demands is mutual beneficial. Therefore, these firms' academic partners are highly committed to conducting the research project in accordance with firms' expectation for mutually beneficial outcomes. A psychological contract based on reciprocity exchange is a judicious mix of mutual interests to achieve a balance of mutual dependence and build a strategic partnership. There is a transition from transactional-based cooperation to relational-based cooperation in effective UIC, and mutually beneficial cooperation results in a long-lasting partnership.

From firm's perspective, while the cooperation in UIC concerns academic partners' commitment and fully engagement, the coordination in UIC is about the substantial synergies from the complementary knowledge and teamwork to make the research results producible or implementable. In interdisciplinary collaboration (Case 1, 2 or 3), knowledge asymmetry in little overlapping of conceptual or methodological understanding needs to be carefully dealt with. Case 1 shows that knowledge asymmetry not only affects the feasibility of research project, but also the development of cooperation. Firm in effective UIC (Case 2 or 3) have capabilities to establish a bridge of understanding with disparate collaborators and make the knowledge sufficiently exchange across organizational boundaries. To enhance coordination, these two firms adopt the online communication tool (IM app - Line) as boundary object to structure project-based information sharing and enhance frequent communication. It is disarming to disseminate knowledge and information through the sharing of web links, news, pictures, or papers files. The function of group chat is also helpful to solve problems or take decisions jointly in time, regardless of where the actors are. Although there are potential pitfalls (little acquaintance and little knowledge overlapping) which may influence the execution of collaboration, Case 2 and 3 show that knowledge flow shrinks the knowledge gap and value creation from complementary knowledge is achieved.

To ensure that the research results are producible or implementable, it requires feedback from firm with industrial experience or information that may be confidential. Firm in effective UIC (Case 2, 3 or 6) attach importance to the exchange of tacit knowledge and confidential information. For R&D engineers who participate in the UIC, their duties are not only to assimilate new knowledge from academic partners but also to share their experience and guide academic researchers to meet business requirements. Setting rules for spanning the knowledge and organizational boundaries e.g., co-working at the same place or constantly communication on virtual platform, facilitates the efficiency of problem-solving and ensures the producibility or implementability of research results. These boundary spanning activities not only lead to inter-partner learning but also establish cohesion. Manager as a leader of project in effective UIC (Case 2, 3 or 6) plays an essential role as boundary spanner in promoting the exchange of knowledge and information and have the authority to judge the scope of disclosure and disclose the adequate information across organizational boundaries for effective coordination.

Comparing with firms in Case 1 and 5 passively waiting for the handover of the research results (reports and prototypes), the firm in effective UIC (Case 2, 3 or 6) have a clear strategy to expand its R&D capacity for effective coordination and commercialization of research results. The transfer and retention of valuable knowledge is not limited to the formal documentation and includes the activities and processes of interactions used to shape knowledge. During the execution stage of UIC, these firms enhance their current employees' capabilities through thick communication flows and aggressively engaging in the research project. After UIC, firms in Case 2 and 6 even expand their R&D capacity through hiring graduate students who have participated in UIC or even offering job to the faculty for retaining knowhow and continually exploiting new opportunity at firms. Through these newcomers, these firms not only promote the internal dissemination of new knowledge but also expand their R&D capacity to recognize, assimilate and exploit more new knowledge.

While firms in Case 1, 4 and 5 consider UIC just a chance to develop new product or solve problem, firms in Case 2, 3 and 6 regard UIC as an investment equivalent to internal R&D project. While there are differences among our sample cases, the overall pattern of effective UIC is markedly similar. Firm in effective UIC (Case 2, 3 or 6)

pays attention to the development of cooperation and the enhancement of coordination during the execution stage of UIC to achieve a synergistic collaboration and yield the greatest return on the UIC. Even UIC is a risky and costly activity. While firm doesn't have capabilities to sustain the cooperation of its partner, the relationship of UIC may gradually deteriorate to the defensive or even contentious state and the two parties may harbor suspicions about the intention of counterpart. While firm doesn't have capabilities to achieve effective coordination, the research results of UIC may not meet the firm's expectation. In certain respect, UIC may be terminated or close with compromise and the infeasible research results are put on the shelf. Our sample cases distinguish the importance of cooperation and coordination in UIC.

5. Discussion

While previous studies highlight preconditions that give rise to successful UIC, this study tries to extend the discussion and focus on the collaboration process involved, which is delicate and should be handled with care. Our sample cases show that UIC is not just a chance or opportunity without risk or loss. Firms face not only the uncertainty of research results concerning the producibility or implementability, but also the intention of their partners and potential costs associated with relationship termination. Literature argues that firms should search for a partner with the right level of ability and willingness [72]. But our sample cases show that even a partner with a high willingness in the initiation stage of collaboration, the willingness may deteriorate gradually during the execution stage of collaboration. Prior relationship does not guarantee the sincerity and future intention of partner. Firms must have capabilities to weed out of uncooperative or opportunistic behavior and incentivize fully engagement and lasting commitment. Our sample cases also show that even academic partners are excellent scholars of profound learning and great abilities, they may not deliver the research results as firm's expectation while they don't have clear understanding of firm's objectives or business requirement. Knowledge proximity also does not guarantee the producibility or implantability of research results. Firms must have capabilities to create common ground and facilitate effective coordination to achieve expected benefits of UIC. This study scrutinizes firm's collaborative capabilities to win the cooperation of partner and enhance the inter-organizational coordination during the execution stage of UIC to yield the greatest return on the UIC.

5.1. Collaborative Capabilities to Develop the Cooperation

Cooperation comprises actor's willingness to act in benevolence to the relationship and not against it. In the initiation stage of UIC, contract negotiation is a challenge because of inequitable bargaining positions between firms and universities. Firms with weaker bargaining power may struggle to gain agreement to their terms. The goals and tasks should be sufficiently negotiated, especially when firms rely on the deliverables of UIC to pursue business opportunity. Firm's collaborative capabilities in the initiation stage of UIC embody in the employees' functional competence (excellent negotiator with technical expertise in contracting) and clear policy about give and take to seek a common ground and reach an agreement to settle a matter of mutual concern.

High cooperation and trust are not instructions in the contract and not spontaneously generated. It's hard to monitor and penalize non-cooperative behaviors of academic partners since UIC involves layers of commitment which operate at personal and organizational level. Commitment is a volitional psychological bond reflecting dedication to and responsibility for the common goal [73]. Commitment concerns the willingness of partners to continue the relationship. Cooperation is a team-spirit to aim at mutual goodwill and mutual help, while not sacrificing the autonomy of partners. Cooperation promotes collinearity and coherence as one team. Cooperation is the degree of interest in the success of counterpart, goal congruence and stable partnership. Firms in synergistic UIC are good at obtaining high performance from partners by being sincere in striving for maximizing value creation for each other. Firm's collaborative capabilities in the execution stage of UIC embody in the employees' leadership competence (influential leader with technical expertise in motivating people) and clear policy about reciprocal exchange to establish a psychological contract with partners for sustaining their responsiveness, enthusiasm, and commitment. Reciprocity constitutes a credible signal informing academic partners that there will be high-value prospects for lasting cooperation with firm.

5.2. Collaborative Capabilities to Enhance the Coordination

The purpose of UIC is to combine specialized and complementary knowledge for innovation. Coordination is integrating process in an orderly arrangement of group efforts to accomplish the common objective. From firm's perspective, the producibility or implementability of research results is more critical than the transferability and replicability. Academic researchers must have clear understandings of firm's objective and business requirement. Effective coordination is rooted in shared understanding and cognitive closeness to manage interdependency of tasks. Firm's collaborative capabilities in the execution stage of UIC embody in the employees' boundary spanning ability to facilitate and manage knowledge inflows and outflows between two organizations. Firm's collaborative capabilities in the execution stage of UIC also embody in the clear policy about mingling with all participants and promoting mutual communication and interaction across organizational boundaries.

The knowledge intensive nature of UIC requires rigorous integration of scientific knowledge and engineering discipline. Firms must have capabilities to probe the different understandings, reorganize the heterogeneous knowledge, overcome the cognitive gap, and develop a contextual understanding of the way things work in both parties for reaching a proper coordination fit.

The full project knowledge must be retainable as corporate assets. Critical knowledge assets must be deployed and capable of enhancing firm's competitiveness once a UIC project is completed. Firm's collaborative capabilities in the execution stage of UIC embody in the employees' cognitive capability and learning capacity for external knowledge assimilation, recombination, integration, and exploitation. Firm's collaborative capabilities in the execution stage of UIC embody in the clear policy about expanding its absorptive capacity by developing exiting employees or recruiting talented employees to maximize the benefits from UIC.

5.3. Interplay between Cooperation and Coordination in Synergistic UIC

Cooperation and coordination are not built separately over time. Cooperation is the willingness of individuals and foundation for coordination. The absence of cooperation may lead to the resistance of knowledge sharing, lack of communication or misinformation. As the level of familiarity and cooperation increase, it will improve the quality of coordination and reduce coordination costs in turn. When two parties can rest assured of close cooperation, they may share more high level of knowledge, skills, and knowhow and co-evolve their capabilities for effective coordination. Open communication and information sharing increase transparency and help to build partnership even if an initial lack of acquaintance is experienced between the two parties. Effective coordination represents a collective obligation and shared commitment to the project. The ongoing coordination can help in getting a positive cooperation climate. Cooperation and coordination may co-evolve and exert a joint impact in the synergistic UIC.

The development of cooperation and enhancement of coordination need to be understood in terms of the capability to which it contributes, not just the activities that take place. As illustrated in the Figure 1, we propose a comprehensive framework aimed at capturing what constitutes firm's collaborative capabilities to develop the cooperation and enhance the coordination to achieve a synergistic UIC. Firm's collaborative capabilities include the collective skills, abilities, and expertise of employees and represent the ways that people and resources are brought together to deliver expected value. Firms must ensure to dispose of sufficient individuals placed in the right functions or dedicated teams for aligning multiple interests and bridging the gaps of understanding. Firm's collaborative capabilities also include the clear UIC strategy and corresponding policies. Executive managers define strategy, midlevel managers execute strategy, and frontline participators achieve tactical results. A synergistic UIC is a highly interactive process to achieve goals benefiting mutual expectations and is based on jointly striving for the creation and delivery of value for the final commercial application.

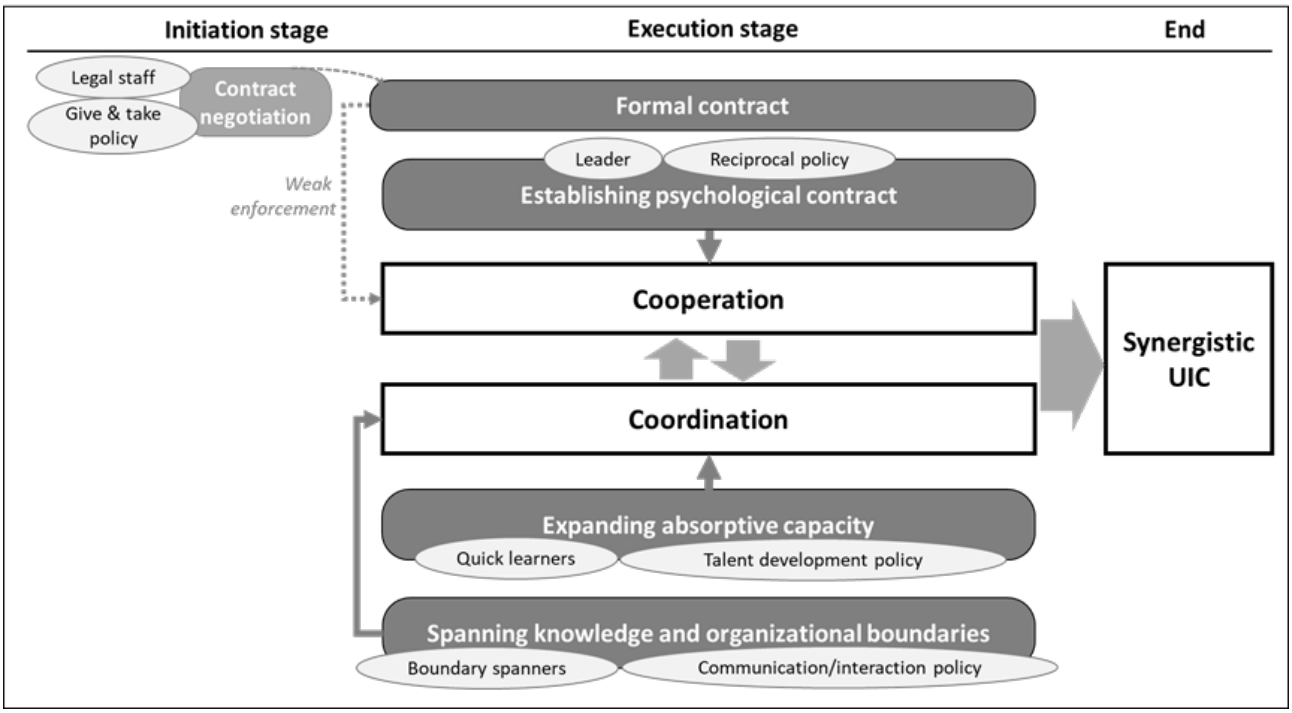

Figure 1. A framework of firm's collaborative capabilities to develop the cooperation and coordination in synergistic UIC

6. Conclusion

We are now entering a knowledge-driven economy and knowledge-intensive industries are at the core of growth. Although universities are potentially valuable collaborators in R&D innovation, it is not easy for firms to sustain satisfactory collaboration with academic partners [4,74]. An effective UIC does not just happen and must be carefully planned and nurtured. Based on the perspective of cooperation and coordination from strategic alliance theory, we explore the effectiveness of firm's collaborative capabilities on the outcome of UIC. Collaborative capabilities can be defined as a firm's abilities to leverage other actors' knowledge and resources [75,76]. Collaborative capabilities are continuous construct that may vary with the characteristics of employees and

policies at firms. This study presents an analysis of the collaborative capabilities influencing the outcome of collaboration and partnership between firms and academics. It suggests that firms with high level of collaborative capabilities are likely to achieve better performance of UIC.

This study makes three important contributions to the literature. First, the multiple-case study in knowledge-intensive industries shows that the initial conditions (prior relationship or knowledge proximity) are insufficient for sustaining effective collaboration. On the contrary, although there are no favorable preconditions between firms and academics, firms can still develop an effective UIC and long-lasting partnership through their collaborative capabilities. The partner proximity (geographic proximity, knowledge proximity, or prior relationship) may make it easier to form a UIC and have a positive impact in the initiation stage; however, it has limited impact on the development of a partnership, and the outcomes of a UIC. This study contributes to the current debate on the antecedents or prerequisites of a successful UIC by investigating the importance of firm's collaborative capabilities.

Second, while most research to-date has concentrated on antecedents or prerequisites of a successful UIC, there is a lack of a theoretically based integrative framework. We propose an integrated conceptual framework of firm's collaborative capabilities to develop the cooperation and enhance the coordination for a synergistic UIC. Negotiating a win-win legal contract and establishing a psychological contract are complements to simultaneously enforce and motivate academic partners to sustain their commitment and willingness to invest in partnering with firms. Spanning knowledge and organizational boundaries and expanding firm's absorptive capacity are indispensable to develop mutual understanding for achieving the desired outcomes with minimal losses. The multiple-case study in knowledge-intensive industries shows that collaborative capabilities are quite independent of company scale but is related to employees' competencies, UIC strategy and corresponding policies. This study constitutes a new contribution to the body of knowledge regarding the management of R&D collaboration between organizations with different institutional logics or different scientific disciplines.

Third, our empirical study also demonstrates that cooperation failures and coordination failures are distinct from each other, and they may occur or co-occur in a UIC. This study also advances extant knowledge on cooperation and coordination by providing insights into the context of a UIC. Although cooperation and coordination are touted as practices for successful inter-organizational relationships, the literature seems to narrow the focus on business relationships among firms in the context of horizontal alliances or buyer-supplier relations only [35]. In addition, based on the perspective of cooperation and coordination to investigate firms' collaborative capabilities, especially, in the execution stage of a UIC, this study responds to recent calls that advocate systematic research to fully understand the success of the UIC [31,32,77].

Lastly, this study clarifies the problems that firms may encounter in UIC. Firms must recognize the distinctions between cooperation-related issues and coordination-related issues to adopt the corresponding solutions. This study highlights the importance of firm's engagement in UIC and reminds managers to pay equal attention to develop the cooperation and enhance the coordination during the execution stage of collaboration. This study would like to provide practical advice and good practices for practitioners. The conceptual framework can be introduced in organizations of any size to build beneficial partnership with academics. We conducted a primary study based on the dyadic relationship between a firm and its academic partners. This study identifies new research opportunities in UIC management fields and offers suggestions for developing a comprehensive understanding of collaborative innovation. Future investigations could extend to multiple relationships, such as the R&D consortium or triple helix collaboration among universities, firms, and governments, to reveal more insights. Finally, while the framework of cooperation development and coordination enhancement here focuses on the collaboration between firms and academics, there may be broader applicability beyond the UIC.

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