International Journal of Science and Engineering Vol.3, No.1 (2013): 1-12

Special Issue

Intellectual Property in Inter-firm R&D Collaboration, an Examination on the Role of IP Management Core Components

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***Abstract*--Inter-firm R&D collaboration is valuable for companies when it helps them to gain complementary intellectual resources, access to diverse markets, share product development's cost, shorten the time to market of new products, and avoid redundant expenditures. This kind of collaboration could be considered as a good way responding to the modern business world today which is dynamic, complex, and intensively competitive. This research therefore focus on the role of Intellectual Property shared and used in Design service where inter-firm R&D collaboration is major activity, the supporting functions of IP management's core components developed in previous research. The questionnaire was sent to 494 participants, all of them are heads of marketing department, R&D department, manufacturing department and engineering department. There are 41 valid samples (response rate of 8.3%) that be analyzed by the SPSS analysis and complete questionnaires by the quantitative analysis. Conducting a survey from new product development managers of Taiwan's high-tech industry, this result shows that knowhow-related Intellectual Property has positive effects on indicating factors of design service performance such as time to market, productivity, quality, and efficiency. Another result indicates that four of IP management's core components are positive associated with the performance of design service. Those core components are: Legalization capability, intra-firm relationship capability, collaboration formation capability, and main goal of collaboration.**

***Index Terms*--Collaborative Product Development (CPD), Design service, IP management's core components, Intellectual Property (IP)**

I. INTRODUCTION

The modern business world is dynamic and complex andcompetition is globalized. The expansion of multinational firms and the business collaboration between firms have led to the raise of competition among companies. Therefore, in many industries it is not wise to merely sell and protect product locally. Furthermore, the changing nature of the market, increasingly competitive global competition, highly complexity of product, a dramatic reduction in transportation and information costs have forced many firms to outsource a part of their workload and collaborate with each other. Firms have to respond those changes the sooner the better if they want to stay competitive.

Involving suppliers, customer and other partners in new product development efforts enables a firm to share the costs of product development, access diverse markets, reduce time-to-market, and conduct an effective and efficiency product development process [22, 33]. As a main consequence of larger innovative activities taking place beyond company borders, management's focus has to shift from intra-firm coordination to the coordination of complex innovation [73]. Frohlich et al. [31] demonstrate empirically that firms with highly integration (i.e., firms that integrate both suppliers and customers into the activities of the focal firm) are likely to have a strongest relation with the improvement of company performance in comparison with firms which integrate only suppliers or only customers.

Enterprises could start to collaborate with customers, suppliers, and other partners to acquire missing information, know-how, complementary and necessary resources [39, 54]. Previous study showed that firms exploit their Intellectual Property such as technology and knowledge to leverage existing technological capabilities outside their boundary, to benefit from patents, to set industry standards and to guarantee freedom to operate by establishing cross-licensing agreements with other partners [48]. Another strategy we found from literature review which firms might use is technology exploration strategy. Firms explore external intellectual resources to enhance their current technological development efforts which can help them to stay competitive in the market. Hence, Bader [53] stated that

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DOI：10.6159/IJSE.2013.(3-1).01

Intellectual Property had become a good mechanism for influencing returns-on-investments and sustainability of firms. There has been an increasing numbers of Joint patenting amongst companies in inter-firm collaborations [35]. However, there are very few past studies exploring how Intellectual Property can help firms in Collaborative product development process. The main purpose of this study is to explore the important role of Intellectual Property used in collaborative product development.

Firms can generate their knowledge property internally through the innovation process, they can also acquire new Intellectual Property from outside by collaborating with other partners, by this way they can co-create new intellectual assets as an outcome of inter-firm collaboration. Firm can use their own Intellectual Property internally to multiple its value through collaborating with other partners, they can also use their Intellectual Property externally to keep their competitors from selling or out-licensing [53]. Hence, management of Intellectual Property has become an increasingly important success factor for collaborative product development process among firms. Bader [53] developed a set of core components for managing Intellectual Property in R&D collaboration. The set was divided into 3 categories: Motivation-related core components, Performance-related core components and Structure-related core components. He proved that these core components support for the managing of IP in R&D collaboration. However, there are no studies focusing on the role of these components in terms of the use of Intellectual Property in collaborative product development. One of the goals of this study is to explore how these IP management's core components facilitate the use of Intellectual Property in R&D collaborations.

II. Literature Review

A. Intellectual Property and Design Service Performance

According to World Intellectual Property Organization (WIPO), Intellectual Property refers to creations of the mind. There are two types of Intellectual Property: Industrial property and copyright. In this study we focus on industrial property that contains industrial designs, patents or inventions, know-how and geographic indications of source. Previous studies which are related to knowledge-creating view consider organizational know-how as one of the most valuable resources for firms. Those intellectual resources not only help a firm to stay competitive on its markets, but also keep key elements for the access and development of new know-how. Caloghirou [79] stated that openness of firms to external knowledge and information resources is one of the significant factors to estimate the potential of their innovation. Chesbrough [16] found that there are more and more firms do not count only on their intellectual resources, instead of that, they conduct their inter-firm R&D collaboration strategy to complement their internal resources to enhance their innovation capability and make their new product development process more effect and efficient. As a result of these firms' strategies, the number of joint IP has been increasing over time [47].

Technical knowledge is the key asset which technology-based firms can use to develop their new product. By using and applying effectively the technology knowledge, these firms can create new feasible product designs, this kind of know-how also helps firms in decision-making process which is a crucial factor for new product development project [38]. Hence, firms develop quickly their new Intellectual Property related to what already existing and firms' new products are associated to those have been developed [72]. It is improbable that firms will have a basal revolution in their set of intellectual resources and capabilities but rather a continual development [32].

With this technological knowledge base, a firm is able to obtain a better outcome [37] and minimize the initial learning expense in innovation process by applying previous technological know-how and experience. Promisingly, with the better obtained outcome, a firm can have a greater application to the markets [65]. Leenders et al. [51] showed empirical evidence to prove that the active and proper consultation of codified experience and accessible organizational knowledge base are positively related to the success of product development. These intellectual resources are available for its members, who can put them into practice during new product development process. The previous studies [4, 41] founded that firms' efforts to obtain external knowledge have become essential because of the following reasons: (i) the product lifecycle has shortened [30] and (ii) the effectiveness of closed, exclusive innovation activities has reduced [16].

Soh [70] stated the innovation process is an information-intensive activity that involves the absorption, processing, and integration of information so as to bring into existence new products and services. The author also argued that a firm with efficient access to competitive information about other firms, information about misallocated resources among other participants in the market can gain many opportunities to create or to enhance its products. If firms discover information about opportunities which are created in the process of technological innovation, they will capitalize upon those opportunities because the new combination of existing resources can make profits.

Cusumano et al. [20] determined that the information shared among a focal firm and its collaborating firms had served as a heuristic context for solving continuous problem solving in the industry of video-cassette recorder. Yassine et al. [1] also stated that the information shared among partners are very important because it facilitates and influents decision-making in product development process which involving hundreds of decisions in strategy, manufacturing, marketing and customer service. Krishnan et al. [49] determined types of information needed in product development process such as information about production cost, available technology and customer need. Further, this product specification information will be used for detailed design and prototyping activity. By sharing sufficiently the significant information among partners, firms can have better decisions to develop better products. In collaborative product development projects, many department and firms are called

in to develop new product or service; therefore, these projects increase the information needs of NPD team members to reduce task-related uncertainty and equivocation in product development process [82].

Thus, we obtain the following hypothesis:

Hypothesis 1: *Intellectual Property in inter-firm R&D collaboration is positively related to design service performance*

B. The effects of IP Management's Core Components on the use of Intellectual Property

In this research, we reviewed a set of core components for managing Intellectual Property in R&D collaboration developed by [53]. The set was divided into 3 categories. Category 1- Motivation-related core components: Main goal of collaboration, prior experience with collaboration, information asymmetry and trust. Category 2- Structure-related core components: Strategic compatibility, implementation capability, complementary commercialization capability. Category 3- Performance-related core components: Collaboration formation capability, intra-firm relationship capability, legalization capability.

Bayona C. et al. [7] determined motivations of firms for their cooperative R&D collaboration, such as complexity of technological development which means that firms cannot afford to develop their technological complex products but they need to collaborate with other partners in R&D development process. This can enable them to have access to new technological knowledge and complementary technology. Beside that motivation, there are also other factors such as the reducing and sharing of risks, product development costs, uncertainty, costs and other motivations which are related to market access and finding for opportunities. Bader [53] argued that "the higher the expected outcomes of an inter-firm R&D collaboration, the more important the individual Intellectual Property exploitability of the collaboration partners becomes".

Through previous cooperative R&D activities with its partners, a firm can gain more and more experience related to R&D inter-firm collaboration which enables the firm to deal with issues might happen in its collaborative product development process. Anand et al. [2] noticed that prior experience with inter-firm R&D collaboration can help a firm to be capable of knowing when it is the best time to enter the collaboration, of choosing the most suitable collaboration partners, and of managing a inter-firm collaboration. Furthermore, this valuable prior experience with inter-firm R&D collaboration influences collaboration partners' capability to administrate issues related to Intellectual Property [53].

At the beginning of inter-firm R&D collaboration, patent information seems to be very important to a firm. Bader [53] also argued that in cooperative product development "information on Intellectual Property that is publicly available and enriched with specific R&D collaboration know-how reduces information asymmetry and fosters trust between the collaboration partners".

One of the most important conditions in collaborative product development is trust It is a precondition to start a inter-firm collaboration. Liu et al. [52] indicated that a relationship built merely on legal contracts may make it difficult to facilitate effective knowledge transfer. Previous research have determined that inter-firm relationships can generate opportunities for the firms to access to external knowledge and use the acquired knowledge for their own new product development [24, 56]. In addition a firm once develops the mutual trust between it with its partners, the trust can increase knowledge exchange and reduce free-riding [80].

Bader [53] argued that "the better the strategic, compatible fit between the collaboration partners, the more likely it is that a balanced Intellectual Property model can be found for the R&D collaboration partners to support learning and innovation". One of main reasons makes a firm to have inter-firm R&D collaboration is the insufficiency of resources or competencies which are important criteria for choosing collaboration partners. By choosing highly fitting collaboration firms which have complementary intellectual resources, shared Intellectual Property can be more valuable and meaningful to a focal firm. Wu et al. [78] demonstrated that a firm can access more available resources from its support firms when those companies are more willing to collaborate with it. This helps the firm to improve its dynamic capabilities.

Using Intellectual Property in inter-firm R&D collaboration may lead to complicated issues, and those issues may not be handled easily by legal staff alone, but R&D and marketing people should be involved in to solve those legal issues together. According a study of [53] about IP management in R&D collaboration, the better the relations between departments in a focal firm are, the more efficient and effective the evolution of the collaborative Intellectual Property decision-making processes and procedures. Lee et al. determined that people in different departments are more willing to engage in social exchange and cooperative interaction, such as sharing information, knowledge and resources, asking for support, having unplanned meetings if trust and friendship among them are good. The high level of trust and friendship among staff also give individuals involved more confidence needed to turn ideas into winning projects and make people more willing to support and encourage innovative ideas [55].

With all above in mind, we obtained the following hypothesis:

Hypothesis 2: *IP management's core components have a positive effect on the use of Intellectual Property in inter-firm R&D collaboration.*

C. The effects of IP Management's Core Components on Design Service Performance

Inter-firm R&D collaboration can created opportunities such as reducing uncertainty, reducing product development cost and realizing economies of scale and scope [8]. However, this kind of collaboration also leads to some issues like transaction costs, the transfer prices of intangible goods as information on know-how and some other legal issues related to Intellectual Property such as infringement, patent ownership between a focal firm with its supporting partners.

Management of intellectual assets has therefore become a very significant factor of the success of inter-firm R&D collaboration [53]. As a sequence, the core components for managing Intellectual Property will play important roles in collaborative new product development of a firm.

By collaborating with other partners and even with competitors, firms can gain advantages which the collaboration brings back to them such as accessing to complementary intellectual resources, reducing uncertainty and time to market. Dixi and Nalebuff [21] stated that the collaboration among competitors is only realizable and meaningful when a win-win situation is created and their customers are aware of the added value. One of important core components for IP management is prior experience with collaborations, which is knowledge about how to choose out a suitable partner, when is the best time to enter a collaboration and the way to manage an inter-firm collaboration. Those help firms to have a better ability to maintain and extend existing collaboration relationships and to enter further future collaborations [58]. The successful history of collaboration also helps firms to improve their reputation which makes them more reliable and more attractive to new partners [61]. Kale et al. [46] determined that alliance experience is a significant factor makes alliance succeed and found that successful alliances result from managers' learning methods to cooperate with their firm's partners to share knowledge [68].

Trust is one of important preconditions that firms should have to start an inter-firm cooperation [71]. Duncan et al. [23] demonstrated it is difficult to maintain relationships that are lack of trust. Trust facilitates more open communication, information sharing and conflict management [11]. Furthermore, trust may reduce transaction costs like acquisition costs, management costs [9]. Trust is also acknowledged a significant element which enhances business performance [6]. Anderson et al. [5] emphasized, "Once trust is established, firms learn that coordinated, joint efforts will lead to outcomes that exceed what the firm would achieve if it acted solely in its own best interests".

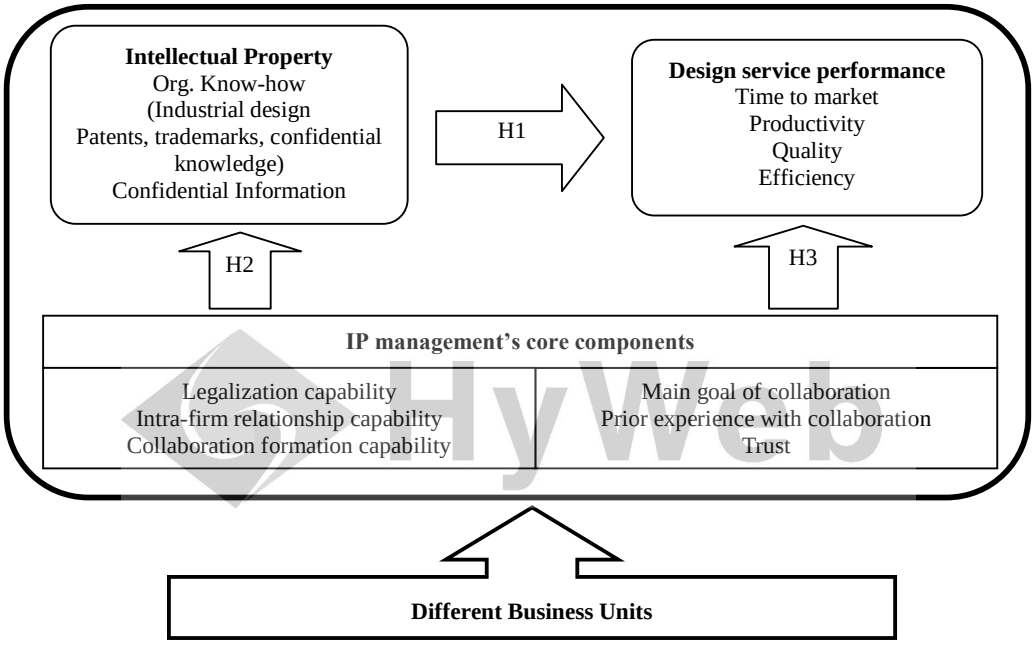
Figure 1. Research framework

To be successful in collaborative product development, firms should concern about and improve their collaboration formation capability. They can build up innovation network as an effective function which enables participating firms to have dynamic interactions in stages of cooperative R&D [50]. Segrestin [66] demonstrated three conditions that all participating partners should have in order to guarantee the success of inter-firm collaboration: a common purpose to justify the collaboration, the willingness to collaborate and means of communication. The involving of many employees from different departments in collaborative product development process is considered to be beneficial to new product development performance. This can reduce much of uncertainty and equivocality in NPD process [3, 25]. Pilar Fernandez et al. [29] noticed that elements which facilitate smooth communication and decrease any conflicts between members of the different departments involved in the new product development process may improve the effectiveness of NPD programs.

In inter-firm R&D collaboration, a focal firm and its support partners exchange needed intellectual assets such as confidential information and important know-how. Therefore, requirement for legal procedures is a must, as a sequence, legal devices and formal rules are tangible instruments for cohesion of inter-firm R&D collaboration [53]. Segrestin [66] stated that firms use legal tools to define the conditions of enter or exit from inter-firm collaboration; in addition, the instruments help firms to identify opportunities or results they get from the collaboration as well as the sharing procedures or risks. According to the prior literatures, this research developed the following hypothesis:

Hypothesis 3: *IP management's core components have positive effects on Design service performance.*

The concept framework has been presented in Fig. 1



III. RESEARCH METHOD

This study adopts structured questionnaire survey as the research method to test the hypotheses developed. We firstly refine the measurement scales of each item and verify these dimensions. The research also adopts Explanatory factor analysis, validity test, and reliability test to extract items, factors, and dimensions. To achieve high validity to support the research analysis, we conduct principal component factor analysis, varimax, and factor loading to confirm the factors and dimensions. We also check reliability of the measures by Cronbach's α and item-to-total correlation to examine the internal consistency.

A. Sampling

Taiwan's high technology industry was chosen as a highly fitting sample for our structured questionnaire survey since this industry has an excellent context of inter-firm R&D collaboration in which we can explore the role of joint Intellectual Property and IP management's core component toward the performance of collaborative product development.

The sample design principle is based on the suggestion of Cooper and schindler [18]. An informant survey [60] was undertaken, with participants from the industries selected based on the "Science Park Annual Report" in conjunction with their ranking in the top 1000 companies listed in the 2010 edition of Taiwan's "Common Wealth" magazine. We established the criteria of the sample by comparing it to other high-tech firms, focusing on the companies' age, size (full-time employees), and annual sales. Second, the firms under investigation had to exceed the criteria of having annual sales of U.S. $100 million, at least 100 employees, and over 5 years activity in Taiwan. According to these criteria, 149 high-tech companies in the Science Park are qualified for this research.

TABLE I. CONSTRUCT MEASURES VALIDITY AND RELIABILITY ANALYSIS

Constructs	Items	Factor loading	Eigen-value	Explanatory(%)	Item-total correlation	Cronbach's alpha
Knowhow-related IP	IP1	0.849	2.189	36.49	0.658	0.784
	IP2	0.862			0.695	
	IP3	0.772			0.528	
Confidential information-related IP	IP4	0.889	2.062	34.37	0.663	0.761
	IP5	0.644			0.426	
	IP6	0.913			0.737	
Legalization capability	LE2	0.710	3.166	15.83	0.647	0.821
	LE3	0.710			0.659	
	EXP3	0.708			0.596	
	STR1	0.685			0.667	
Intra-firm relationship capability	INT1	0.828	2.764	13.82	0.632	0.852
	INT2	0.870			0.848	
	INT3	0.685			0.695	
Collaboration formation capability	COL1	0.818	2.689	13.44	0.689	0.790
	COL2	0.636			0.618	
	IMP1	0.819			0.562	
Main goal of collaboration	GO1	0.605	2.656	13.28	0.498	0.794
	GO2	0.838			0.643	
	COL3	0.653			0.605	
	NF1	0.825			0.698	
Prior experience with collaboration	INF3	0.699	2.478	12.39	0.596	0.817
	INF4	0.820			0.613	
	EXP1	0.589			0.665	
	EXP4	0.635			0.681	
Trust	LE1	0.675	1.975	9.87	0.546	0.707
	INF2	0.808			0.546	
Time to market	T1	0.825	2.130	21.30	0.380	0.762
	T2	0.805			0.583	
	E2	0.742			0.579	
Productivity	P1	0.820	2.116	21.16	0.669	0.768
	P2	0.815			0.564	
	P3	0.770			0.583	
Quality	Q1	0.810	1.919	19.19	0.696	0.820
	Q2	0.898			0.696	
Efficiency	C	0.794	1.708	17.08	0.591	0.743
	E1	0.886			0.591	

The questionnaire-survey was sent to 494 participants, all of them are heads of marketing department, R&D department, manufacturing department and engineering department. There are 41 valid samples (response rate of 8.3%) that be analyzed by the SPSS analysis and complete questionnaires by the quantitative analysis.

B. Measure of constructs

All items in the questionnaire were framed as five-point Likert-style questions (with answer ranging from 1="strong insignificance" to 5="strong significance").

About the construct of Intellectual Property, we use total 6 items divided into two factors which are Knowhow-related Intellectual Property [12, 81, 75, 36, 14] and Confidential information-related Intellectual Property [14, 13].

We developed 6 dimensions for the construct of IP management's core components and there are twenty four items were used and divided into six factors: Legalization capability [66, 53]; Intra-firm relationship capability [29, 53]; Collaboration formation capability [66, 53]; Main goal of collaboration [21, 53]; Prior experience with collaboration [2, 35]; and Trust [42, 64].

Finally we use total ten items as observed variables for the construct of design service performance. All of these items were divided into four factors which are: Time to market; Productivity; and Quality and Efficiency [57].

This study used Exploratory Factor Analysis to test the validity of items and variables. Besides that we also tested the reliability of them with the following criterions: Eigenvalue is greater than 1 [45]; Factor loading is greater than 0.5 [77]; Cronbach's α is greater than 0.35 [19]; Item-to-total correlation is greater than 0.35 [63]. The result of factor analysis and reliability test is shown in Table I.

IV. Research Results

A. Descriptive Analysis

A total of 36 items and 12 factors are extracted in the dimensions of Intellectual Property, IP management's core components, and collaborative product development performance after factor analysis. In this section we conducted descriptive analysis including mean and standard deviation (Std. Dev.) for these items and factors. The analysis result indicates that the mean values of items belonging to the factor Knowhow-related IP are higher than 4. It seems that Intellectual Property related to knowhow, industrial design, patent, and confidential knowledge plays a main resource to be interchanged in Inter-firm R&D collaboration. In contrast with above items, items belonging to the factor confidential information-related IP have the mean values below 4. There were some managers in their feedbacks explained the reason. Although partners had joint the collaborative R&D contract, it is not easy at all for them to share their confidential information to the focal firm.

The results also show that in inter-firm R&D collaboration, the intra-firm relationship capability plays an important role. Besides, knowledge and information are main sources being transferred between a focal firm and its partners. Therefore, managers joining R&D activities really concern about the specifications ownership rights, rights of use and licensing rights; the ability of managing Intellectual Property; and the willingness to collaborate of partners.

The results show that the items of on time delivery, quality, and cost of production have their mean values higher than other items. This shows that those items are important indicators for the performance of design service. Managers of R&D projects should concern about delivery time, quality of new product, and cost of production when evaluating the performance of whole collaborative R&D process.

B. Comparisons of Each Factor between the Different Business Units

We conducted Analysis of Variance to see whether different departments have different views on factors used in this study as shown in Table II. We concluded that different departments (R&D department, marketing department, manufacturing department, and engineering department) do not have significant differences on all the factors in this study because all the P values are higher than 0.05, difference of the means among 4 departments are not statistically significant.

This finding is consistent with previous research [69] since it indicated that firms may use coordinating mechanisms such as standardized reporting and documentation, formalized work processes (e.g., project reviews), problem-solving meetings, and integrative leaders, to ensure that knowledge, views of cross-functional team's members are shared and integrated.

C. Interactive Effects between Dimensions

In this section, we identified the influences and interrelationships among the factors. Stepwise regression analysis was used to realize the effects and interactions. The effects of Intellectual Property on Design service performance, IP management's core components on Intellectual Property, and IP management's core components on Design service performance are described below.

1) The effects of Intellectual Property on Design service performance:

To investigate the effects of Intellectual Property on collaborative product performance, we used the factors of IP as independent variables and the factors of CPD performance would be used as dependent variables to build the regression models shown below:

M_1: Time to market $=\alpha_1+\beta_{11}*A_1+\beta_{12}*A_2+\varepsilon_1$

M_2: Productivity $=\alpha_2+\beta_{21}*A_1+\beta_{22}*A_2+\varepsilon_2$

M_3: Quality $=\alpha_3+\beta_{31}*A_1+\beta_{32}*A_2+\varepsilon_3$

M_4: Efficiency $=\alpha_4+\beta_{41}*A_1+\beta_{42}*A_2+\varepsilon_4$

Where:

A_1 = Knowhow-related Intellectual Property

A_2 = Confidential information-related IP

αi = Intercept βij = Slope εi = Error

From the result shown in Table III, we see that Knowhow-related Intellectual Property has a positive effectives on Time to market of new collaborative product (β = 0.31, R2 = 0.073, F-value = 4.145 > 4.09, and P-value = 0.049 < 0.05), the factor of Knowhow-related Intellectual Property explains for 7.3% of the variance in the factor of Time to market (R2 = 0.073). Similarly, Knowhow-related Intellectual Property also has positive effects on Productivity (β = 0.46, R2 = 0.192, F-value = 10.483 > 7.33, and P-value = 0.002 < 0.01); Quality (β = 0.384, R2 = 0.125, F-value = 6.739 > 4.09, and P-value = 0.013 < 0.05); and Efficiency (β = 0.406, R2 = 0.143, F-value = 7.697 > 7.33, and P-value = 0.008 < 0.01) of Collaborative product development process. The item Knowhow-related Intellectual Property explains for 19.2% of the variance in the factor of Productivity; 12.5% of the variance in the factor of Quality; and 14.3% of the variance in the factor of Efficiency.

The regression analysis also showed that the factor of Confidential information-related Intellectual Property has no relationship with indicating factors of design service performance.

TABLE II. THE COMPARISONS OF FACTORS BETWEEN DIFFERENT BUSINESS UNITS

Factors	Working department				F	P
	R&D N=17	Marketing N=6	Production N=13	Engineering N=5		
Knowhow-related Intellectual Property	4.020	4.056	4.410	3.867	2.093	0.118
Confidential information related IP	3.863	3.667	3.615	3.267	1.538	0.221
Legalization capability	3.750	3.875	3.865	3.650	0.244	0.865
Intra-firm relationship capability	3.922	3.722	4.308	3.933	2.146	0.111
Collaboration formation capability	4.078	3.611	4.128	3.933	1.926	0.142
Main goal of collaboration	3.926	3.875	3.769	3.500	1.166	0.336
Prior experience with collaboration	3.779	3.917	4.135	3.750	1.468	0.239
Trust	3.765	3.500	3.923	3.700	0.770	0.518
Time to market	4.157	3.833	4.051	3.600	1.401	0.258
Productivity	3.686	4.056	4.128	3.667	1.344	0.275
Quality	4.059	3.833	4.308	4.300	1.041	0.386
Efficiency	4.088	3.750	3.923	3.800	0.723	0.545

TABLE III. THE EFFECTS OF INTELLECTUAL PROPERTY ON DESIGN SERVICE PERFORMANCE

Model	M_1	M_2	M_3	M_4
Dependent Variance / Independent Variance	Time to market	Productivity	Quality	Efficiency
IP_A Knowhow-related IP	0.31*	0.46**	0.384*	0.406**
R^2	0.073	0.192	0.125	0.143
F-value	4.145	10.483	6.739	7.697
Critical value of F	4.09	7.33	4.09	7.33
P-value	0.049*	0.002**	0.013*	0.008**
*：P<0.05；**：P<0.01；***：P<0.001				

TABLE IV. THE EFFECTS OF IP MANAGEMENT'S CORE COMPONENTS ON INTELLECTUAL PROPERTY

Model	M_1	M_2
Dependent Variance / Independent Variance	Knowhow-related Intellectual Property	Confidential information-related Intellectual Property
IPM1 Legalization capability	0.448**	0.560***
R^2	0.180	0.296
F-value	9.788	17.807
Critical value of F	7.33	12.7
P-value	0.003**	0.000***
*：P<0.05；**：P<0.01；***：P<0.001		

TABLE V. THE EFFECTS OF IP MANAGEMENT'S CORE COMPONENTS ON DESIGN SERVICE PERFORMANCE

Model	M_1	M_2	M_3	M_4
Dependent Variance / Independent Variance	Time to market	Productivity	Quality	Efficiency
IPM1 Legalization capability	0.308*			
IPM2 Intra-firm relationship capability			0.397**	
IPM3 Collaboration formation capability	0.411**	0.416**	0.319*	
IPM4 Main goal of collaboration				0.373*
R^2	0.328	0.151	0.346	0.117
F-value	10.768	8.139	11.593	6.295
Critical value of F	8.33	7.33	8.33	4.09
P-value	0.000***	0.007**	0.000***	0.016*
* : P<0.05 ; ** : P<0.01 ; *** : P<0.001				

2) The effects of IP Management's core components on Intellectual Property:

M_1: Knowhow-related Intellectual Property $=\alpha_1+\beta_{11}*A_1+\beta_{12}*A_2+\beta_{13}*A_3+\beta_{14}*A_4+\beta_{15}*A_5+\beta_{16}*A_6+\varepsilon_1$

M_2: Confidential information-related IP $=\alpha_2+\beta_{21}*A_1+\beta_{22}*A_2+\beta_{23}*A_3+\beta_{24}*A_4+\beta_{25}*A_5+\beta_{26}*A_6+\varepsilon_2$

Where

B_1=Legalization capability

B_2=Intra-firm relationship capability

B_3=Collaboration formation capability

B_4=Main goal of collaboration

B_5=Prior experience with collaboration

B_6=Trust

From the result shown in Table IV, we see that the factor Legalization capability has a positive effect on the factor of Knowhow-related Intellectual Property (β = 0.448, R^2 = 0.180, F-value = 9.788 > 7.33, and P-value = 0.003 < 0.01). Legalization capability explains for 18% of the variance in the factor of Knowhow-related Intellectual Property (R^2 = 0.180).

The factor of Legalization capability also has a positive effect on the factor of Confidential information-related Intellectual Property (β = 0.560, R2 = 0.296, F-value = 17.807 > 12.7, and P-value = 0.000 < 0.001). Legalization capability also explains for 29.6% of the variance in the factor of Confidential information-related Intellectual Property (R2 = 0.296).

The regression analysis result indicates that the factors of Intra-firm relationship capability, Collaboration formation capability, Main goal of collaboration, Prior experience with collaboration, and Trust have no relationship with the factors of Knowhow-related Intellectual Property and Confidential information-related Intellectual Property.

3) The effects of IP Management's core components on Design service performance:

M_1: Time to market $=\alpha_1+\beta_{11}*A_1+\beta_{12}*A_2+\beta_{13}*A_3+\beta_{14}*A_4+\beta_{15}*A_5+\beta_{16}*A_6+\varepsilon_1$

M_2: Productivity $=\alpha_2+\beta_{21}*A_1+\beta_{22}*A_2+\beta_{23}*A_3+\beta_{24}*A_4+\beta_{25}*A_5+\beta_{26}*A_6+\varepsilon_2$

M_3: Quality $=\alpha_3+\beta_{31}*A_1+\beta_{32}*A_2+\beta_{33}*A_3+\beta_{34}*A_4+\beta_{35}*A_5+\beta_{36}*A_6+\varepsilon_3$

M_4: Efficiency $=\alpha_4+\beta_{41}*A_1+\beta_{42}*A_2+\beta_{43}*A_3+\beta_{44}*A_4+\beta_{45}*A_5+\beta_{46}*A_6+\varepsilon_4$

Where

B_1=Legalization capability

B_2=Intra-firm relationship capability

B_3=Collaboration formation capability

B_4=Main goal of collaboration

B_5=Prior experience with collaboration

B_6=Trust

From the result shown in Table V, we see that the factor of Legalization capability has a positive effect on the factor of Time to market (β_1 = 0.308, R^2 = 0.328, F-value = 10.768 > 8.33, and P-value = 0.000 < 0.001). Legalization capability explains for 32.8% of the variance in the factor of Time to market (R^2 = 0.328).

The factor of Intra-firm relationship capability has a positive effect on the factor of Quality (β = 0.397, R^2 = 0.346, F-value = 11.593 > 8.33, and P-value = 0.000 < 0.001). Intra-firm relationship capability explains for 34.6% of the variance in the factor of Quality (R^2 = 0.346).

The factor of Collaboration formation capability has positive effects on the factors of Time to market (β = 0.411, R^2 = 0.328, F-value = 10.768 > 8.33, and P-value = 0.000 < 0.001); Productivity (β = 0.416, R^2 = 0.151, F-value = 8.139 > 7.33, and P-value = 0.007 < 0.01); and Quality (β = 0.319, R^2 = 0.346, F-value = 11.593 > 8.33, and P-value = 0.000 < 0.001). Collaboration formation capability explains for 32.8% of the variance in the factor of Time to market; 15.1% of the variance in the factor of Productivity; and 34.6% of the variance in the factor of Quality.

The factor of Main goal of collaboration has a positive effect on the factor of Efficiency (β = 0.373, R2 = 0.117, F-value = 6.295 > 4.09, and P-value = 0.016 < 0.05). The factor of Main goal of collaboration explains for 11.7% of the variance in the factor of Efficiency (R2 = 0.117).

The factors of Prior experience with collaboration, and Trust have no relationship with the factors of Time to market, Productivity, Quality, and Efficiency.

V. DISCUSSION AND CONCLUSION

We have two interesting results through regression analysis. The first result is that the factor of knowhow-related Intellectual Property has a positive relationship with design service performance. This means that knowhow-related IP has positive impacts on new product development

time, productivity, new product quality, and the efficiency of inter-firm R&D collaboration. This finding is consistent with past studies. Base on key technological knowledge asset, technology-based firms can use to develop their new product. By using and applying effectively the technological knowhow, these firms can create new feasible product designs; have a more efficient decision-making process which is a crucial factor for new product development project [38]. According to this finding we are in agreement with [37] who argued that by effectively using developed technological knowhow and previous experience, a firm is able to obtain a better outcome and minimize the initial learning expense in innovation. This finding is also supported by [74] who noticed that technological knowhow can reduce the risk of useless replications of innovation attempts and experiments.

The second finding indicated that the factor of confidential information-related IP does not have any relationship with the performance of design service. This result seems to be not consistent with previous researches. Based on the comments of some specialists in our survey, they noticed that even though inter-firm R&D collaboration can bring to focal firms advantages but in fact getting information from partners is not easy since they are not willing to share all of their confidential information. The explanation of this phenomenon can be found in the research of [40] who show out some reasons such as protecting the company's strategically important knowledge, making their company attractive to other collaborating partners.

Based on the result in Table V, we found that the component Legalization Capability has positive relationships with the factor of knowhow-related IP and the factor of confidential information-related IP. This means that defining results, opportunities, sharing procedures and risks related to Intellectual Property at the early stage of inter-firm R&D collaboration are an extremely important precondition for a focal firm and its partners. Besides, ability of administrating R&D collaboration also plays a meaningful role since Intellectual Property will be shared and transferred among partners. Segrestin [66] noticed that firms use legal tools to define the conditions of enter or exit from inter-firm collaboration.

The regression analysis result showing the relationship between IP management's core components and design service performance indicates that Legalization capability of a focal firm and its partners can help to shorten time to market of CPD. Besides, Inter-firm relationship capability of a focal firm has a positive relationship with new products of its collaborative R&D programs. There is another important finding we found that collaboration formation capability has positive effects on design service performance's indicators, such as Time to market, productivity and quality. This significant finding is consistent with previous researches which noticed that collaboration partners count on elements when collaborating such as the willingness to collaborate, means of communication [66] which provides partners mechanisms to develop strategies, align perceptions and expectations, and solve disputes in inter-firm collaboration [76]. Finally, our last finding in this study is that the factor of Main goal of collaboration has a positive relationship with efficiency of design service. This is also agreed by past literature which noticed that collaboration is only meaningful when a win-win situation is created and the customer perceives the added value [21].

Previous literature in Intellectual Property mainly focused on IP Strategy and Portfolio Management [28, 67, 43], IP Acquisition [26, 27], IP scanning and Monitoring [59, 26, 62], Collaborative standardization [44, 22, 17, 10]. This study turned to another research stream which explored the effects of Intellectual Property on the performance of Inter-firm R&D collaboration. Based on the result showing that IP not only enhances efficiency of NPD projects, but also has positive and direct effects on time-to-market, productivity, and quality of new product. Managers of NPD projects therefore have a better awareness of IP's roles in Inter-firm R&D collaboration.

Previous studies determined that legal procedures play a dominant role, such as formal rules have often proved tangible instrument for collaboration's cohesion [53]; legal instruments define the conditions of entry into or exit from a collaboration, results, risks or opportunities and sharing procedures [66]. This study made a next contribution to practice when we found that legalization capability has a positive effect on time-to-market of CPD programs. It also facilitates the use of IP in stages of inter-firm R&D collaboration. Managers who take part in such a collaborative R&D should improve and pay more attention on legal instruments to give guidelines to IP issues and keep CPD contracts and regulations short, clear and practical. This helps firms to avoid infringement risks and future disputes; to make IP be shared and used smoothly.

A lot of past researches determined that cross-functional NPD teams facilitate product development. This study extend this finding toward Inter-firm R&D collaboration context since our results confirmed that Intra-firm relationship capability has a positive effect on product quality. Managers of CPD projects should manage not only interaction among collaborating partners but also the atmosphere of in-house cross-functional NPD team which contributes to NPD success by bringing experts together with different visions, skills, and knowhow; facilitating the exchange of knowledge among members; and exploiting complementarities.

Previous study has noticed that building up innovation network as an effective function can enables participating firms to have dynamic interactions in stages of cooperative R&D [50, 53]. Segrestin [66] also demonstrated conditions that all participating partners should have in order to guarantee the success of inter-firm collaboration. Our research made one step further when the study results confirmed that collaboration formation capability has positive effects on the dimensions of design service performance such as time to market, Productivity and Quality. Managers in collaborative R&D project should be noticed important factors which may decide the success of the projects. Those factors include communication networks between focal firm and its collaborating partners, selection of collaboration partners, and all of collaboration partners

should have experienced staff within early stages of the collaboration process.

We have conclusions shown in the Table VI for three hypotheses:

TABLE VI. THE PURIFICATION OF THE HYPOTHESES

Hypotheses		Result	Method
H_1:	Intellectual Property in inter-firm R&D collaboration is positively related to Design service performance.	Partially Supported	Regression Analysis
H_2:	IP management's core components have a positive effect on the use of Intellectual Property in inter-firm R&D collaboration.	Partially Supported	Regression Analysis
H_3:	IP management's core components have positive effects on Design service performance.	Partially Supported	Regression Analysis

VI. LIMITATIONS AND FUTURE RESEARCH

The response rate of the survey in this research is quite low, this can negatively affect the credibility of our survey's results. In this study's result, some factors do not have a significant influence on the dimensions of design service performance. This study may have developed some incorrect observed variables which caused the imprecision results. The future study can developed more relevant observed variables of factors in this research and use them for other research goals. Besides, this research use the quantitative method to explore the roles of IP management's core components, future study can use case study method to make comparisons and rank the important level of those components in inter-firm R&D programs.

This study explored the role of Intellectual Property and IP management's core components in inter-firm R&D collaboration. To get more practical achievements, future research can focus on building up a collaborative management model. Clients of design service companies are highly integrated in collaborative product development process, especially at the concept stage, design stage and the validation stage of the process. Therefore future study can make another contribution to practical by exploring the role of Customer Relationship Management toward the performance of Inter-firm R&D collaboration.

ACKNOWLEDGMENT

The authors gratefully acknowledge the financial support provided to this study by the NSC 97-2410-H-024-004-MY3.

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