A Study on Industry-University-Public Research Institutes Collaboration and Policy Issues

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1. Research Background and Purpose

Industry-University-Public research Institutes(IUP) collaboration is recognized as a key factor through which business in industries can enhance their competitiveness in the face of increasing market uncertainty, technological innovation, and the growing cost of research and development (R&D). However, few IUP projects achieve the intended outcomes or succeed in coordinating voluntary participation from of all actors involved innovation, due to various conflicts of participants's interest. Despite these limitations, the strategic approaches to IUP collaboration is needed more, in consideration of the need to create new engines of economic growth, the significance of effective technological convergence, and the uneven distribution of R&D resources.

In response to these factors, innovation actors(business, university, government etc) have turned to more open-minded paradigms

of innovation. There has been a gradual, but irreversible, paradigm shift in terms of technological innovation by businesses, from the traditional closed innovation to open innovation. With the expanding and evolving network of open innovation coming to accept participation from increasingly diverse actors, including businesses, universities, and research institutes, IUP collaboration that is open to multiple innovative actors is becoming increasingly important.

Such IUP collaboration is even more significant in new industries(ICT, bio, nano etc.) that are facing market uncertainty and undergoing destructive innovation. The open innovation taking place in these new industries, the evolution and growth of which crucially depends on creative destruction and technological convergence, requires increasing ranges and quantities of innovation resources (including ideas and early R&D) and features increasingly complex and extensive matchmaking mechanisms among innovative actors seeking partners and technology. The success of businesses today is depend on finding appropriate collaboration partners in a cost-effectiveness, so businesses are looking for ways to establish and design more cost-effective systems of innovation.

As the demand for effective and efficient IUP collaboration systems continues to rise, it is necessary to develop such systems in order to maximize the positive synergy among all participants in collation. Especially, it is important to ensure consistency and partnership between Korea's policy and business's demand on IUP collaboration.

The purpose of this study is to identify the characteristics and features of the IUP collaboration system for Korean businesses, so that the Korean government's R&D investment can effectively sup-

port all stages of the innovation, from R&D to commercialization.

The main subjects of our analysis are businesses, as the leading actors of collaboration, and their partners, i.e., other collaborating company, universities, and public research institutes in Korea. Businesses, universities, and public research institutes abroad are not considered in this study. As the expectations and goals of IUP collaboration differ significantly depending on the perspective adopted (that of the university's, the public research institute's, or the business'), the issues and characteristics of IUP collaboration also differ significantly depending on whose side we take.

This study considers various types of IUP collaboration, including R&D, technology transfer, commercialization, human resource development, human resource exchange, and information exchange. These different types of IUP collaboration may take place individually or in conjunction with one another, which makes it difficult to differentiate between the different types of collaboration with perfect clarity in every case. R&D tends to be the most common type of IUP collaboration, and is thus given a more extensive treatment in this study than the other types.

2. Current Issues in IUP Collaboration in Korea

According to a recent international survey on national capabilities related to scientific and technological innovation, South Korea ranked fifth in 2015, coming in second place in terms of IUP collaboration. The World Economic Forum (WEF, 2015), on the other hand, ranked South Korea 26th among the 140 countries surveyed in terms of national competitiveness, with South Korea's capacity

for IUP collaboration coming in at 26th place once again. At any rate, South Korea tends to stand among today's world leaders of IUP collaboration and innovation. However, much of IUP collaboration in this country takes place not spontaneously among willing participants, but as part of the national policy R&D projects led by the Korean government.

With the goal of identifying the current status and issues of IUP collaboration, based on the experiences of Korean businesses, this study distributed copies of a self-answered questionnaire to businesses, and received completed copies from 462 of them. All these businesses confirmed that they had participated in joint R&D projects organized by the government. Of these, 16.7 percent had also engaged in information exchanges; 13.3 percent, technology transfers; 10.8 percent, human resource development; 10.2 percent, facility and equipment sharing; and only 2.8 percent, human resource exchanges.

Most of these businesses were above average in terms of their capabilities for undertaking IUP collaboration projects. The average score for the determination of chief executives and technological competency were 4.2, respectively, out of five; the capabilities of R&D personnel and collaboration networks, 3.9, respectively ; the competency of technology management personnel, 3.8; knowledge of intellectual property rights (IPRs) and related laws, 3.7; and financing capacity, 3.4.

Most of these businesses obtained the information they needed to participate in IUP collaboration projects from public-sector technological support agencies (45.7 percent) or by attending briefings, expositions, seminars, and workshops held in Korea or

overseas (33.8 percent). Of the businesses, 14.1 percent secured information from online sources, such as the National Science & Technology Information Service (NTIS); 5.9 percent, through their own connections or propositions from partners; and only 0.4 percent, from private-sector consulting or technology brokerage firms.

When asked about their objectives for participating in IUP collaboration projects, technological considerations far outweighed economic or strategic objectives. As for the stages in which IUP collaboration usually takes place, 53.8 percent of the businesses indicated the development stage, while 21.0 percent selected the product/process application and testing stage. In other words, IUP collaboration tends to occur late in the R&D cycle. In addition, 62.9 percent of the businesses answered that they participated in IUP collaboration in order to develop new products, while only 30.3 percent did so to improve existing products.

The technologies targeted by IUP collaboration projects tend to be above average in terms of originality (3.9 out of five), amenability to convergence with other technologies (3.8), and applicability (3.7). In summary, businesses tend to participate in IUP collaboration in order to secure access to original technologies and facilitate technological convergence, rarely engaging in any form of radical innovation. Moreover, businesses tend to invest in IUP collaboration projects conducted for relatively stable, less innovative technologies that are not as unpredictable (2.9) or short-lived (2.5) as high-risk, high-return technologies.

The survey also revealed the central importance of public research institutes, which were found to have played leading roles in 47.0 percent of industrial-research collaboration projects and 40.7

percent of IUP collaboration. In selecting their collaboration partners, businesses particularly emphasize the capability of their potential partners to engage in the development of new and existing technologies. Physical proximity to these partners had no inhibiting effect on their collaboration.

In general, businesses benefitted more than they expected from IUP collaboration, and projects carried out for reasons related to technological development tended to achieve more favorable outcomes than those motivated by economic or strategic factors. However, IUP collaboration projects tended to be less effective with respect to the development of products actually viable on the market. Nevertheless, these projects did improve indicators of business competitiveness, including networks with partners, competency of R&D personnel, organizational knowledge, expansion of hiring of R&D personnel, and increased operating profits. While the businesses identified no significant obstacles to their IUP collaboration, they did express concerns over the risk of leakage of confidential trade information and the difficulty of managing IUP collaboration projects.

IUP collaboration in Korea is currently undergoing a transition from the former government-initiated, top-down model to a newer more demand-oriented, bottom-up model. To identify the characteristics of government-subsidized IUP collaboration projects, we distinguished between government-subsidized projects and projects without such subsidies.

Most businesses (51.1 percent) participated in IUP collaboration projects subsidized by the government, rather than organizing projects on their own. Only 36.4 percent of the businesses that

participated in the poll expressed any willingness to organize their own IUP collaboration projects in the future, even in the absence of government support. Numerous businesses take part in such projects not for the sake of collaboration per se, but to benefit from the financial subsidies the government provides.

When asked to select the type of IUP collaboration projects they wanted the government to subsidize, an overwhelming majority (77.7 percent) of the businesses chose R&D projects, followed by 17.4 percent that chose technology transfer and commercialization projects and 15.8 percent that chose human resource development projects. Of the businesses polled, 66.0 percent answered that they were satisfied with the current level of government support. The satisfaction rate was the highest among medium-sized companies and lowest among large companies, with small companies located in the middle. Of the dissatisfied companies, 44.4 percent pointed to the level of support as the main reason for their dissatisfaction; 33.3 percent, the evaluation and management procedures; 5.6 percent, the lack of information on government-subsidized projects; 5.6 percent, the lack of government support for the entire R&D cycle; and 2.8 percent, the short duration of support.

As for businesses' perception of the effectiveness of IUP collaboration projects in helping them achieve their objectives, government-subsidized projects fared slightly better than non-subsidized projects in terms of solving technological difficulties, achieving standardization, and carrying out human resource development. Government-subsidized projects, however, fared slightly worse in terms of assisting businesses with market entry and increasing exports. Among the businesses that rated government-subsidized

projects as more satisfactory than expected, government-subsidized projects fared better than non-subsidized ones across the board except in terms of market dominance. However, non-subsidized projects fared better than subsidized ones in terms of businesses' perception of how well their market-related goals were satisfied or achieved.

The area of IUP collaboration that businesses indicated was in the greatest need of government support was financing (88.5 percent). Provision of information and human resources were also chosen as areas in need of government support.

We identified the following major problems with IUP collaboration in Korea today. First, businesses and industries have, at best, weak relationships with academia and the research community. Communication between the two takes place not in any systematic manner, but often via informal channels. In other words, there is no effective platform that enables industries to look for and find appropriate partners. Second, the existing system of IUP collaboration is more perfunctory than functional. In Korea, industries take only a secondary role in launching IUP collaboration projects, which are designed on large scales and subsidized by the government. Academia has a greater role in defining the specific goals and technicalities of these projects than industries. Third, IUP collaboration projects seldom lead to the development and commercialization of viable technologies. The products of academia and the research community's R&D efforts often lack market viability from the perspective of businesses, and the existing brokers of technology transfers lack competency. Most businesses, aside from large, well-funded corporations, are compelled to produce

tangible, short-term results, and therefore neglect the promising yet underdeveloped technologies pursued by academia and researchers. Fourth, the system of government support requires significant reform. The difficulties involved in utilizing jointly owned IPRs, the limits of human resource exchanges, and the intricacies of dividing returns often serve to limit businesses' active participation in IUP collaboration projects. In addition, the simplistic system of incentives and evaluation, focusing on the quantitative aspects of performance, induces participants to focus solely upon quantitative results.

Based on these problems so identified, we suggest the following measures to strengthen IUP collaboration and increase businesses' participation in it.

First, strategies tailored to businesses of different sizes are needed. Firms of different sizes require different types of IUP collaboration and support. Second, policy support is needed especially for IUP collaboration projects with the potential to create new industries. This would require encouraging technologically advanced firms to participate in IUP collaboration projects so that they can assist in launching such new industries. Third, financial support for small and medium enterprises (SMEs) also needs some reform. The Korean government has already devised and provided a wide range of support for SMEs, but still needs to monitor, adjust, and update the forms of support provided for these enterprises over time in response to changes in the market environment. Fourth, services that provide technological information and facilitate technology transfers also require improvement. Although the Korean government provides technological information on IUP collabora-

tion projects via the NTIS, relatively few businesses are aware of this fact. Policymakers thus need to find out why the NTIS is not better known and strive to increase its utility to businesses. Furthermore, private-sector technology brokers need to be fostered as a means of enabling businesses to initiate and lead IUP collaboration projects, rather than relying on public sector actors to do so. Fifth, the functions of public research institutes need to be enhanced, as they play central roles in ensuring the effective and productive results of IUP collaboration projects. Sixth, support is needed for the commercialization and market launch of the products of IUP collaboration projects. Support for marketing, commercialization, and enabling businesses to pioneer new markets and channels of distribution in Korea and abroad is crucial to preventing the innovative outcomes of collaboration from faltering and being forgotten. Seventh, stronger protection measures are required for confidential trade information. Such protection and security measures for technology are necessary for fostering a healthier environment that is more conducive to IUP collaboration. Eighth, government support needs to be streamlined and channeled into fostering an environment that encourages active and voluntary collaboration among industries, academia, and the research community. The goal of this is to reduce dependency on the government by allocating government resources to only appropriate areas of support.

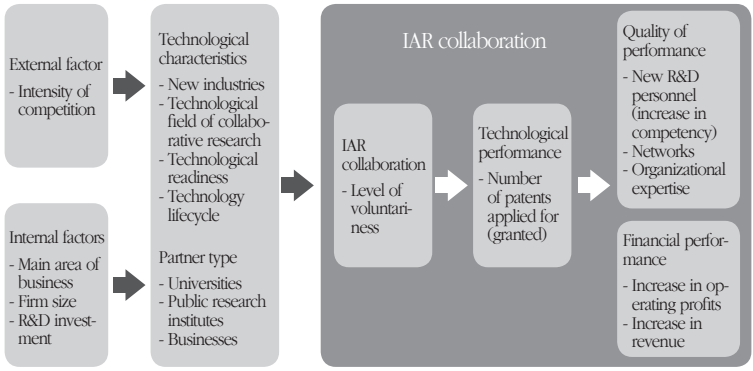
3. Factors of Businesses' Performance in IUP Collaboration

Using the data provided by the Korea Institute of Industrial Economics and Trade (KIET)'s 2016 Survey on IUP Collabora-

tion Involving Businesses and the Korean Enterprise Data (KED), we performed a quantitative analysis on the dependent variables (technological, quality, and financial performance as well as the voluntary participation of collaboration) and explanatory variables of businesses involved in IUP collaboration. Figure 1 visualizes the environment of IAR collaboration used in our analysis. The external factors—attributes of businesses, technological characteristics, and attributes of IUP collaboration—were used as explanatory variables. Depending on the nature of the given dependent variables, the Poisson regression, ordered probit, and ordinary least square (OLS) models were used.

Our analysis reveals the following. First, the voluntary participation of collaboration is a major decisive factor of the technological and financial performance of businesses involved in IUP collaboration projects. Voluntary participation, however, had no significant influence on the quality of businesses' performance. This tendency was especially pronounced in the case of SMEs.

Figure 1. Structure of Empirical Analysis of IUP Collaboration



On the other hand, voluntary participation exerted little influence on the financial performance of large corporations. The nature of the target technologies and the sizes of firms were also factors that influenced SMEs decisions whether to participate voluntarily in IUP collaboration projects. In particular, small firm size was a factor that often inhibited firms' voluntary participation. It was also found that measures are needed to foster the active participation of hi-tech businesses.

Whether businesses are active in new industries also significantly influences those businesses' technological performance and the quality of their performance. This factor, however, does not have similar effects on financial performance, and therefore fails to induce more voluntary participation from businesses. Policy measures are thus needed to enable businesses in new industries to continue investing and participating in IUP collaboration, despite the absence of short-term financial gains, thus allowing them to grow in the long term.

Furthermore, businesses that belong to the hi-tech group tend to perform better than others. This factor exerts a positive influence on all aspects of SMEs' performance and contributes to increasing the number of patents applied for and granted, number of new R&D personnel hired, and operating profits, in the case of large corporations. SMEs in the hi-tech group also tend to participate more voluntarily in IUP collaboration projects, because, by doing so, they can expect to improve not only the quality of their performance and technology but also their financial gains.

Finally, collaboration between industries and academia, between industries and research institutes, and among industries,

Table 1. Summary of Empirical Analysis

Variable	Tech. performance		Quality of performance (economic competitiveness)								Financial performance				Level of voluntariness	
	Patent activities		New R&D personnel hired		Improvement in R&D competency		Networks formed		Organizational expertise gained		Increase in revenue		Increase in operating profits			
	SMEs	LCs	SMEs	LCs	SMEs	LCs	SMEs	LCs	SMEs	LCs	SMEs	LCs	SMEs	LCs	SMEs	LCs
Level of voluntariness	+	+									+		+			
Industry-industry collaboration dummy variable		-	-		-						-		-			
New industries	+	-	+	+	+		+		+							
Technological field	+	+			+		+						+	+	+	
Technological readiness	+	+														
Technology lifecycle	-											-				
R&D cost in initial year of collaboration	+	+														
Firm size (KED)	+	+													+	
Intensity of competition	Inverse U-shaped									-			-	Inverse U-shaped		

academia, and research communities all achieve better outcomes than industry-industry collaboration. The three foregoing types of collaboration are decisive factors in improving technological performance, raising the number of R&D personnel hired, and increasing operating profits, in the case of SMEs. This suggests that businesses can benefit from the spillover effect generated by IUP collaboration in terms of the knowledge capital possessed by universities and public research institutes.

4. Cases of IUP Collaboration in Korea and Abroad

We attempted to analyze and understand the evolving patterns and characteristics of IUP collaboration between Korean and international companies in the biotechnology and ICT industries, the two leading industries of creative destruction and convergence.

Figure 2-1 shows the typology of IUP collaboration projects according to the degree of openness. The least open (i.e., closed-type) IUP collaboration projects admit only limited numbers of participants, also collaboration and innovation proceeds according to the clearly defined terms of contracts. The relationship between the technology supplier and the demander is more unilateral than bilateral, while the supplier catering to the demands of the customer.

Open-type IUP collaboration projects, on the other hand, are more conducive to cooperative relationships of collaboration. Open-type projects can be further divided into medium-open and complete-open projects. The former type evolves around the partnership between multiple technology suppliers and a single

customer, while the latter centrally features platforms that enable multiple technology suppliers and multiple customers to interact and collaborate with one another.

Table 2. The Characteristics of IUP Collaboration Projects in Korea and Abroad

Case		Openness			Tech. concentration		Industry		Innovation		Partners		Degree of participation	
		Closed	Medium-open	Complete-open	Low	High	Main industry	New industry	Incremental	Destructive	Proximity	Technology	Low	High
Abroad	NIH I-Corps	○				○		○	○				○	
	Pfizer CTI		○	○		○		○		○	○	○		○
	Johnson & Johnson JJIC		○	○		○		○		○	○	○		○
	Intel Lablet		○	○		○		○		○	○	○		○
	Eli Lilly OIDD		○	○		○		○		○		○		○
	Apple Health-Kit			○	○			○		○		○		○
	Google Fit			○	○			○		○		○		○
In Korea	KIST Bridge	○				○	○		○			○		○
	AmorePacific Joint R&D	○	○			○	○	○	○		○			○
	Hanmi Ventures Investment		○			○		○		○	○	○		○
	KICOX Mini-Cluster	○				○	○		○		○		○	
	Seoul IAR Collaboration Project	○				○		○	○	○	○		○	

Source : KIET.

In this study, we survey and analyze seven global examples of IUP collaboration (NIH I-Corps, Pfizer CTI, Johnson & Johnson JJIC, Intel Lablet, Eli Lilly OIDD, Apple HealthKit, and Google Fit) and five examples in Korea (KIST Bridge, AmorePacific Joint R&D, Hanmi Ventures Investment Program, KICOX Mini-Cluster, and Seoul IAR Collaboration Project).

Our analysis reveals the following three policy implications. First, companies are increasingly taking leadership roles of IUP collaboration projects in advanced countries. Second, major multinational corporations launch and lead IUP collaboration projects mainly for enhancing their capability for innovation in new industries and businesses. Third, the Fourth Industrial Revolution and the growing tendency toward destructive-, convergence-oriented innovation are radically widening the openness of IUP collaboration arrangements.

The active participation of businesses is the most important factor of the success of IUP collaboration. IUP collaboration projects led by businesses outperformed government-led projects in terms of economic impacts, participants' satisfaction, and sustainability.

Also, our case analysis reveals that, outside Korea, IUP collaboration takes place quite actively, toward radical and destructive innovation, under the leadership of multinational corporations. These corporations undertake IUP collaboration in an effort to find and secure external sources of technological competitiveness, which they lack internally. This is why the majority of IUP collaboration projects abroad take place either in new industries or on the initiative of corporations seeking to launch into new areas or models of business.

Finally, IUP collaboration projects in advanced countries, led by multinational corporations, are also becoming increasingly open. Most IUP collaboration projects related to new industries are medium- or complete-open types and show a growing preference for open platforms. IUP collaboration projects based on open platforms enable collaboration across completely different disciplines and industries, which in turn leads to the production of new technologies or products through convergence. Such platforms tend to weaken the importance of physical proximity among the partners and technological concentration involved.

Compared to the other abroad examples, IAR collaboration projects in Korea are still largely initiated by the government or the public sector, while participating companies showing relatively little demand for or receptiveness to the new technologies developed through the projects. So far, the majority of IUP collaboration in Korea takes place in the form of closed-type projects.

In order to foster IUP collaboration and use the projects to increase the competitiveness of industries, it is crucial to enhance the active participation of businesses and tailor policy support toward introducing a collaboration system that actually caters to businesses' needs. It is also important to make IUP collaboration projects more open, so that they may lead destructive innovation and convergence.

5. Policy Measures to Strengthen Businesses' Voluntary Participation

First, policy measures are needed to foster the voluntary partic-

ipation and initiatives of businesses. Despite the many benefits it offers, IUP collaboration isn't carried out smoothly, due to the conflicts of interest and the transaction costs among the partners involved. Active participation is especially not realized when one or more partners judge that they have little to gain from collaboration.

It is also important to facilitate communication by fostering networking among partners via diverse channels. Incentives should be provided for all participants in a systematic manner so that, the more actively they participate, the greater the benefits they gain. Specifically, tax system should be differentiated by the level of R&D collaboration, and the evaluation system needs to be improved to ensure that researchers undertaking collaboration activities are rewarded according to their contributions. In addition, policy measures and platforms should also be introduced to induce the voluntary participation of all partners.

Second, more demand-oriented IUP collaboration need to be organized. The interests and goals of universities and public research institutes differ from those of businesses. Therefore, to foster businesses' voluntary participation in IAR collaboration, it is important to tailor the structures and outcomes of collaboration projects to businesses' needs.

In order to ensure demand-oriented IUP collaboration, it is crucial to select the technologies to be developed by considering the actual usage and application of each technology in planning stage. It is also important to allow businesses to lead projects that are focused on technology application or commercialization-oriented research. Brokers' roles are also important in ensuring the successful transfer and commercialization of technologies, as they serve to

narrow the gap between the actual results achieved by universities and/or research institutes and businesses' expectations.

Third, it is important to increase the openness of IUP collaboration. This requires the establishment of an ecosystem and platform that provide all resources necessary for collaboration among all willing partners, enable partners to decide target technologies and partners with ease, and allow effective collaborate among all participants throughout the entire innovation stage, from planning and R&D to commercialization.

Such an ecosystem will crucially feature technology intermediaries or brokers that can help interested parties search through and find matches amid the scattered technological, human, and material resources. Such a system should minimize the costs of

Table 3. Policy Measures to Strengthen the Voluntary Participation of Businesses

Aims	voluntary participation	Demand orientation	Openness
	⇩	⇩	⇩
Policy measures	1. Foster networking and communication via multiple channels 2. Differentiate tax system according to levels of R&D collaboration 3. Devise an effective incentive system to promote participation of R&D collaboration 4. Facilitate the use of jointly owned IPRs 5. Strengthen protection for technologies developed through R&D collaborations	1. Encourage demand orientation in the planning stage 2. Let businesses lead IAR collaboration 3. Increase public research institutes' collaboration with private-sector entities 4. Provide additional R&D support 5. Ensure the efficient operation of TLOs in public research institutes and universities	1. Establish an integrated information network to facilitate the matching of technologies and partners 2. Encourage the efficient sharing of research facilities and equipment 3. Increase linkage of TLOs to enhance TLO competency

search and transactions and help multiple technology givers and recipients optimize their collaborative activities. The importance of open platforms cannot be overemphasized in terms of fostering the active participation of SMEs.