Untangling the Boundaries in Technology Collaborations: The Deviation Effects of "Project Autonomy" on Innovations through Collaborations

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Abstract--**In line with rising number of collaborations among organizations, many researchers investigated the effects of relational factors (e.g. trust relationship) between parent firms. In contrast with this trend, this paper separately captures management-level (parent firms) and operational-level (projects) in collaborations, and investigates the effects of relationships between these two levels. In this setting, parent firms have responsibility for contract and conflict resolution, and project for R&D activities. The concept of "project autonomy", which means the extent to authority and freedom of a project to make its own decisions about purpose and procedure about R&D activities, is the indication of one of those relationships.**

The result of analysis using patent-based measure suggests two points. First, high project autonomy promotes the technological outcome through integration inside projects. Because collaborative projects are composed of members from different organizations, autonomous decisions may set on integration of organizational routines. Second, low project autonomy promotes the integration between projects and own firm, which is needed to commercialize through linking technological outcome with complementary resources. Combining with these two points, it is suggested that these points are not accomplished simultaneously due to project autonomy. High failure rate of technology alliance may be explained from this aspect.

I. INTRODUCTION

The objective of this study is to reveal the processes and success factors of innovations through joint R&D or inter-organizational collaboration. In particular, this study primarily considers the commercialization aspect in the innovation process and focuses on the effect of the relationships between the management level (parent firms) and operational level (projects) on the technological performance and commercialization of those technologies.

During the last two decades, given the increasing difficulty for any single firm to complete an innovation process [4], [8], opting for strategic alliances involving joint R&D has become an important innovation strategy [11], [19], [39]. Although even now such inter-organizational activities are expected to encourage innovations, some researchers have noted the high failure rate of such activities in the context of complex intellectual property regimes [28], [36].

In line with managerial trends, academic publications followed suit. Overall, studies on strategic alliances involving joint R&D have examined the motivations (why firms cooperate with each other), processes (how strategic alliances develop and terminate), and success factors (how and why a particular alliance accomplishes its goal). Among these studies, a significant number of articles exist on the success of alliances, and various factors have been ascribed as the cause of this success. Reference [24], which reviewed the stream of alliance researches, suggested that a large part of the success factors indicated by prior studies was that they were able to be combined into a "relational factor," which describes the nature of the relationships between firms (e.g., a trust relationship), leading to a decrease in opportunistic behavior.

However, in the context of innovations through joint R&D, prior studies have not adequately explained such success for two reasons. First, prior studies on alliances or joint R&D primarily focused on inventions or knowledge creation as shared goals, thus failing to capture the commercialization aspect of technologies or knowledge. The argument that the primary purpose of R&D is to generate ideas that can be commercialized [9], indicates the importance of revealing the factors that determine the success of innovations through joint R&D.

Second, in a related move, although innovation processes viewed parent firms as unitary actors having a single set of goals and making reasonable decisions, they had been thought to be a sociopolitical process shaped by different personal and contextual forces that could not necessarily be programmed [5], [42]. Thus, various actors in a single firm play different roles in an innovation process. Therefore, understanding the interactions of various actors within a particular organization in the context of joint R&D enables us to learn how to manage innovation through collaboration.

To fill this gap, this study explores two research questions: *(1) what are the processes and success/failure factors of innovation through joint R&D?* and *(2) what relationships between the operational and management levels encourage innovation through joint R&D?* In the next section, I define the innovation process through joint R&D and identify the context of this study. Following this section, I posit the conceptual framework and related hypotheses by drawing on innovation studies and the organizational literature. Then, I examine the hypotheses and discuss their implications. I conclude with this study's contributions, limitations, and directions for future research.

II. INNOVATION PROCESS IN ALLIANCES

Any innovation begins with creative ideas that can be commercialized or implemented to create economic value [2], and R&D is conducted to generate such ideas [9], [38]. However, firms cannot acquire economic value solely through activities of R&D because a significant amount of work remains, such as developing products, building plants, improving manufacturing technology, structuring selling systems, and consolidating intellectual property [25]. These activities, referred to as commercialization of ideas or technologies, are required steps to diffuse the innovation to society. In this way, the innovation process can be divided into two main steps: (1) the creation of ideas or technologies through R&D and (2) commercialization by linking them to in-house complementary resources. Notably, different actors play crucial roles within these two steps. This structure can be restated into a more consistent form in the context of joint R&D: (1') creating ideas or technologies through a joint R&D project and (2') commercializing them by any single firm (not jointly).

In the first step regarding R&D, major tasks are completed at the operational level or for a particular project consisting of R&D staff, whereas the second step is activated by a broader variety of actors, such as managers who have accountability and make a go/no-go decision or other departments holding the complementary resources necessary for commercialization. Innovation researchers have attempted to understand the dynamics of in-house innovation and examined managerial requirements or the conditions for successful innovation processes with respect to these two steps.

However, very few alliance studies on innovation included the commercialization aspect. In fact, as noted by [10], most alliance studies used patent-based measures for performance indices, despite the fact that patents are only intermediate products in a particular innovation process and provide no guarantee of commercialization. One of the few exceptions is [7], which considered the innovation processes occurring in a partnership through comparative case studies. They conducted five in-depth case studies on cross-industry technology alliances to check whether or not the following innovation requirements that are broadly accepted by the literature were achieved: (1) understanding of users' needs, (2) innovators having knowledge of marketing and distribution, (3) a champion, (4) a sponsor, (5) flexibility and appropriate control of projects, (6) easy and fast communication inside projects or between R&D and marketing and/or manufacturing, and (7) appropriability. As a result, they found that certain requirements, such as flexibility and appropriate controls, were met with hurdles in the context of alliances because of their logic emphasizing clarity and explicitness of the contract.

III. CONCEPTUAL FRAMEWORK AND HYPOTHESES

Regarding the management of innovations in alliances, managers must manage projects to allow for R&D to be efficiently conducted and to match R&D with its own strategies/objectives. In response to this control, R&D staff participating in projects must engage in joint activities with other project members from different organizations and must share diverse information with other departments in their own firms to prepare for commercialization. In summary, as described in Fig. 1, joint R&D projects or their members may have two roles, and they play an even larger role in setting forward an innovation process than managers who do not directly bring actual R&D outcomes.

Thus, because a joint R&D project at the operational level is central to innovation through collaboration, this paper draws on the "input-process-output" or IPO framework [32] and treats projects as a work team in an organizational setting.[1] As shown in Fig. 2, which describes the conceptual framework of this study, I focus on the following factors.

- "Project autonomy" as team inputs, which is related to team structures that depend on the degree of control of joint R&D projects;
- "Integration inside projects" and "integration between projects and firms" as processes, which describe the degree of joint activities including communication and/or knowledge sharing; and,
- "Technological performance" and "commercialization" as team outcomes.

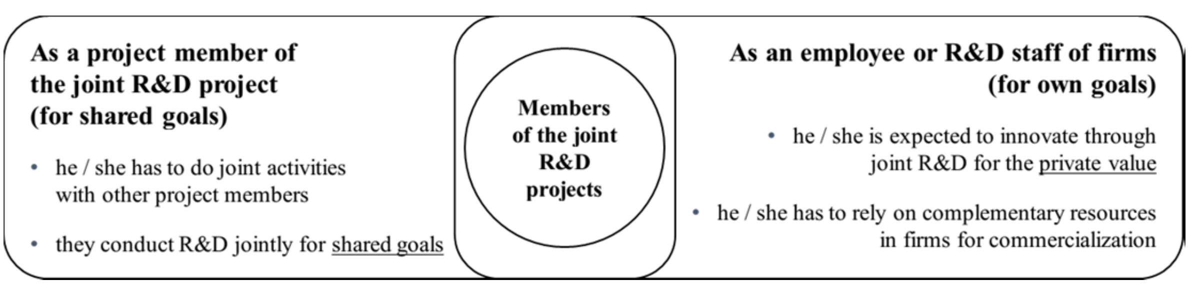


Fig. 1. Two roles of project members of joint R&D

[1] In the IPO model, inputs depict antecedent factors or structures that determine members' interactions, processes are actions that transform inputs into outcomes, and outcomes are the results of a team activity [31].

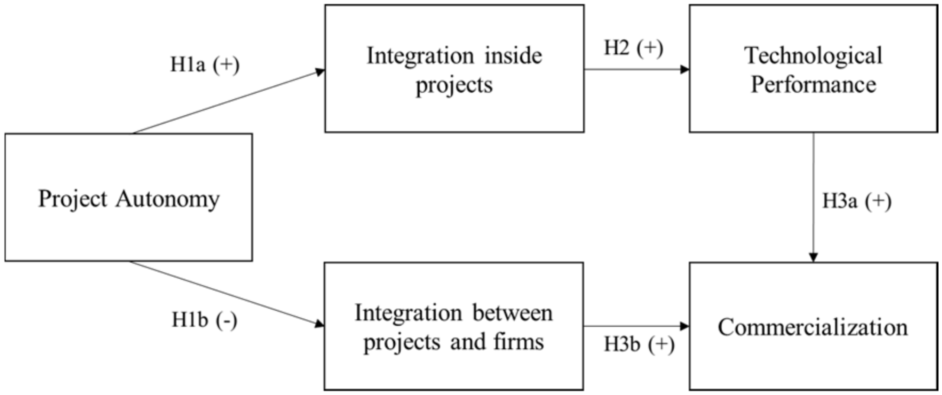


Fig. 2. Conceptual framework

A. Project Autonomy and Integration

In line with the organizational literature, I define project autonomy as the extent to which a project has the authority and freedom to make its own decisions to fulfill its mission [37], [21], [40]. In other words, an autonomous project can be defined as a project for which members have their own control. The literature on team structures shows the merits of an autonomous structure. For example, an autonomous structure provides flexibility for the task execution and allows for rich and frequent communication and decentralized decision making with few formal procedures [41]. That is to say, when placed in uncertain settings such as innovation projects, autonomous teams can be effective in terms of processing information and completing tasks.

Moreover, in the context of joint R&D, project members may have to effectively create and share new work routines because the project is constituted from members with quite different work methods or organizational routines. In such a case, autonomous projects are more able to create their own goals and procedures, such as shared processes, which may perform a binding function similar to that of glue. Then, project members with a shared understanding of goals and procedures are more likely to exchange information or knowledge and to synchronize their actions. This behavior occurs because it is easier to anticipate other members' behavior and trust them to not behave opportunistically when there is a shared understanding [29], [35].

In contrast, a less autonomous structure constrains the interaction between project members. In the case of joint R&D, members belong to different firms, with each firm aiming to maximize its return from the joint activity. Such firms may pull the direction of joint R&D in their favor in order to facilitate commercialization. Some aspects of these efforts are addressed in contract renegotiations, and other aspects may be presented in the form of controls over projects. Although the type of control that leads to a removal of project autonomy in a distorted manner is viewed as increasing the degree of integration between projects and firms by preparing communication channels and/or allocating more resources, other firms view this as opportunistic behavior and as restricting interactions between project members to address the risk that their proprietary knowledge is being used without compensation. Thus, we develop the following hypotheses:

HYPOTHESIS 1a (H1a): A more autonomous joint R&D project has a greater degree of integration within the project.

HYPOTHESIS 1b (H1b): A more autonomous joint R&D project has a lesser degree of integration between project members and their own firms.

B. Integration and Technological Performance

A major aspect of integration or joint activities is communication and coordination. Certain studies on innovation have examined the effects of communication and found that it allows the R&D staff to acquire the information necessary to solve problems efficiently, leading to greater R&D outcomes [1], [14], [34]. In addition, another stream of the literature indicates that communication can create an atmosphere of mutual support and respect among actors [33]. This atmosphere may be more likely to increase the predictability of a member's behavior and to reject deviant or opportunistic behavior by strengthening the group norm and its cohesiveness [15].

In the context of joint R&D, the project may have a broader range of knowledge as a whole than when R&D is conducted without inter-organizational collaboration because each member comes from different organizations that have accumulated unique knowledge. Then, joint R&D project members with high integration are more likely to achieve high technological performance because of their capability to utilize this broad range of knowledge to solve unforeseen problems. On the basis of these merits, I posit the following hypothesis:

HYPOTHESIS 2 (H2): A project with a higher degree of integration among its members is more likely to achieve high technological performance.

C. Conditions for Commercialization

Achieving high technological performance does not directly ensure commercialization; rather, it may depend on the potential benefits of that technology. In other words, innovation processes are never completed only by project members because mobilizing resources from other departments is required for commercialization [13]. For instance, it is necessary for each member to collaborate with production departments in order to develop a mass-production method. Moreover, the marketing department must develop products that satisfy customer needs and the intellectual property department must develop a scheme that results in higher appropriability. However, resource mobilization often faces the challenge of non-conformists given the cultural gap reflected in statements such as, "technical people find value in discovery and pushing the frontiers of knowledge, while commercialization people need a product to sell" [30]. In addition to these incongruent attitudes, holders of complementary resources are not likely to have sufficient information to consider the risks and benefits of providing their own limited resources.

In this situation, two conditions may allow project members to mobilize resources for commercialization: (1) higher technological performance and (2) a higher degree of integration between project members and managers or other departments. First, if the technological performance achieved for development through joint R&D is sufficiently high, other departments as stakeholders may be able to form clearer expectations of profits with acceptable risks. In contrast, if those technologies are rough around the edges and leave enough margin for elaborating, managers are not likely to invest in technologies that recall the demand for much larger costs to elaborate on ideas, as well as other departments. Thus, high technological performance may encourage commercialization if it results in other departments regarding the technologies in question as potentially profitable. Moreover, the integration between project members and other departments allows members to transfer technologies or knowledge into the firm [23]. This transferred information, which is used to evaluate its potential, may assist in the development of a common understanding or cooperation. On the basis of these effects, I posit the following hypothesis.

HYPOTHESIS 3a (H3a): A project with higher technological performance is more likely to achieve commercialization.

HYPOTHESIS 3b (H3b): A project with a higher degree of integration between project members and firms (managers or other departments) is more likely to achieve commercialization.

IV. RESEARCH CONTEXT, DATA, AND MEASURE

To examine the hypotheses, we used data from the follow-up survey conducted jointly by the New Energy and Industrial Technology Development Organization (NEDO) and Hitotsubashi University in August 2010. NEDO is a public organization that provides financial aid to encourage private firms to engage in R&D to develop and strengthen the technological capability of Japan's industries. NEDO has conducted surveys to understand adequate assistance and management methods. In particular, the survey is composed of questions on topics such as project management and performance, relationships between project members and their own firms. The survey was sent to a leader of the firm who had looked after the project in question and, in most cases, the leaders completed the questionnaires by themselves. Although the data are limited because of triangulation, the leaders were supposed to have relatively sufficient and unbiased information about the projects in which they were engaged.

Although joint R&D projects in this context were established and driven primarily by NEDO and participant firms during the initiation stage, most actual R&D processes are executed by project participants and consist of the firm's R&D staff and university researchers. The individuals with a central role in operations vary with each project. In one case, one particular member of a firm's R&D staff was able to get involved in designing the R&D process with other researchers. In another case, another staff member may conform to the plan outlined by the relevant players.

In this research, from the 301 responses to the survey (the survey response rate was 88%) using the item describing whether or not a project was collaborative, we extracted 128 samples of joint R&D being conducted. The resulting 128 samples were split into three categories from the standpoint of commercialization: 17 projects resulted in market launch ("commercialization"), 50 projects were continuing R&D within firms ("ongoing"), and 61 projects terminated R&D without commercialization ("termination"). As this categorization indicates, the rate of commercialization is relatively low (approximately 13%), although ongoing projects may subsequently have achieved commercialization. Other sample characteristics are as follows. The industries or technological themes of the sample projects include biotechnology, environmental technology, machine systems, material science or nanotechnology, energy conservation technology, new energy systems, and information and communications technology. The amount of aid from NEDO ranges from more than 11 billion yen to less than 450 million yen. Participant firms belong to a variety of industries such as the automobile, electronic devices, materials, and chemical industries.

A. Measure

Table 1 provides a list of variables.

Project autonomy. "Project autonomy," which is the extent to which a project has the authority and freedom to make its own decisions to fulfill its mission, [17], [37], [40], can be defined in terms of direct management involvement. This aspect, which highlights the degree of direct involvement by management to fit the R&D processes with the business strategy or other in-house activities of their own firm, is measured by "the extent of powers for resource allocation and goal setting." We measured the project side of this variable (the average of the power of project leaders and R&D leaders).

TABLE 1. VARIABLE DESCRIPTIONS

Name of variables	Consisting items
Project autonomy	The extent of powers for resource allocation and goal setting of project leaders and R&D leaders (five-point scale)
Integration inside projects$^{\sim}$	Exchange of information inside the project (five-point scale)
	Collaboration with researchers from other institutions (five-point scale)
	Technology acquisition from other institutions (five-point scale)
	Joint developments of technologies (five-point scale)
	Building networks with other firms (five-point scale)
	The leadership of project leader (five-point scale)
Integration between projects and firms$^{\sim}$	Exchange of information with other internal divisions (five-point scale)
	A cost analysis by other internal divisions (five-point scale)
	A market analysis by other internal divisions (five-point scale)
	A technology analysis by other internal divisions (five-point scale)
	A patent analysis by other internal divisions (five-point scale)
	The importance of key person bridging to other divisions (five-point scale)
Technological performance	Technological problems were resolved (five-point scale)
Commercialization	The outcome of the project resulted in a market launch (categorical variable: Commercialization = 1, Ongoing = 2, Termination = 3)
Basic research	The project started from the basic research phase (dummy variable: Yes = 1, No = 0)
Number of members	Total number of members participated in the project participating in project
Strategic importance	The project was important with regard to the business strategy (dummy variable: Yes = 1, No = 0)
The intention of commercialization	The participant firm intented commercialization at the outset of the project (dummy variable: Yes = 1, No = 0)
Time lag	The time span from the period of project ending to the period of answering to the survey

Note: $^{\sim}$ a composite variable (taking a mean value of consisting items)

Integration inside projects. "Integration inside projects," which implies the degree of communication and joint activity within a project, is a composite variable of the following items: (1) the extent to which information exchanges occur in the project, (2) the extent of collaborations with researchers from other institutions, (3) the extent of technology acquisitions, (4) the extent of joint technology developments, (5) the extent of networks built with other firms, and (6) the extent of the leadership of the project leader. All six items are rated using a five-point scale, and we use the mean value of these items as the variable.

Integration between projects and firms. "Integration between projects and firms" denotes the intensity of the relationship between project members and participant firms. Similar to integration within projects, this variable is a composite of three items, all rated on a five-point scale: (1) the extent that information is exchanged between the project and participant firm, (2) the average of the extent of the implementation of cost analysis, market analysis, technology analysis, and patent analysis by other internal divisions, and (3) the importance of a key person to act as a bridge between R&D and commercialization.

Technological performance. "Technological performance" is a variable measured from a five-point scale: "overcoming technological challenges."

Commercialization. In terms of whether or not joint R&D outcomes are commercialized, the samples were originally classified into three categories: "commercialization," "ongoing," and "termination." In this study, we use such a classification as a categorical variable in regression analyses, and as a dummy variable in the structural equation modeling.

TABLE 2. DESCRIPTIVE STATISTICS, CRONBACH'S ALPHAS, AND CORRELATIONS

Variables	Mean	s.d.	1	2	3	4	5	6	7	8	9
1. Project autonomy~	3.65	0.96	(0.66)								
2. Integration inside projects~	3.73	0.53	.38 ***	(0.65)							
3. Integration between projects and firms~	3.24	0.8	.22 **	.42 ***	(0.76)						
4. Technological performance	3.72	0.89	.06	.54 ***	.13						
5. Commercialization	2.34	0.7	-.03	-.21 **	-.33 ***	-.30 ***					
6. Basic research	0.81	0.39	-.10	-.04	-.21 **	.12	.01				
7. Number of members	10.64	10.58	.18 **	.18	.23 **	-.10	.03	-.26 ***			
8. Strategic importance	0.12	0.32	.05	.16	.29 ***	.07	-.28 ***	-.07	.16		
9. The intention of commercialization	0.23	0.5	.06	.24 ***	.37 ***	-.06	-.23 ***	-.17	.27 ***	.15	
10. Time lag	10.92	2.8	.11	.07	-.22 **	.13	.28 ***	.01	.02	-.13	-.33 ***

~ a composite variable (taking a mean value of consisting items)
** $p < .05$
*** $p < .01$
Cronbach's α are in parentheses.

Control variables. We also introduced control variables to address the alternative hypotheses. Regarding Hypotheses 1a, 1b, and 2, we controlled for "*number of members participating in project*" as a proxy for the difficulty of joint action, "*basic research*," "*strategic importance*" of the project, and "*the intention of commercialization*." Basic research is a dummy variable that indicates that a project started from the basic research phase, which may affect the firm's attitude to whether or not it will allow the project to conduct R&D autonomously. Strategic importance, which indicates that important projects may be controlled more rigorously to heighten appropriability, is a dummy variable showing that a project seems important in terms of the firm's business strategies. The intention of commercialization is measured along a five-point scale. In Hypotheses 3a and 3b, we added the variable "*time-lag*," which indicates the time span from the end of the project to the time at which the survey was filled out.

Table 2 summarizes the means, standard deviations, correlations of variables, and Cronbach's alphas of composite variables. Some relationships were significant at the 1% level, providing support for the hypotheses. Additionally, control variables such as the intention of commercialization were significantly related to certain variables.

V. RESULTS

A. Regression Analysis

The result of the regression analysis for Hypotheses 1a/1b is shown in Table 3. Hypothesis 1a states that more autonomous projects may be able to achieve a high degree of inside integration, and Hypothesis 1b postulates that the degree of integration between project members and participant firms may decline with the degree of project autonomy. From Table 3, we consistently see several significant effects of "project autonomy." Regarding Hypothesis 1a, project autonomy had a significant and positive effect on integration inside the project. However, regarding Hypothesis 1b, project autonomy has adverse effects on the integration between projects and participant firms. That is, the project autonomy was significant and positive for the integration between project members and participant firms. Thus, the result showed conformity to Hypothesis 1a, which means that project autonomy can enhance integration inside projects. Hypothesis 1b was not supported.

Table 3 also presents the result of the analysis for Hypothesis 2, which states that a high degree of integration may lead to better technological performance. The result revealed a significant and positive relationship between the hypothesized variables, which represent integration inside the project and technological performance. This result is coincident with research on the communication effects on R&D [1], [14], as well as Hypothesis 2. Thus, Hypothesis 2 was supported.

Table 4 shows the results for Hypotheses 3a and 3b with multinomial logit models. In the analysis, the baseline category of the model is set to "termination". Regarding model 4b with integration between projects and firms, the effect of integration on commercialization was significantly positive and stronger. In model 4c, which was added to technological performance, the relationship between technological performance and commercialization was strongly positive. However, in model 4d with all of the variables, the integration effect was least significant at the 10% level. Thus, Hypothesis 3b was only partially supported, whereas Hypothesis 3a was strongly supported even after controlling for several variables.

TABLE 3. REGRESSION ANALYSES RESULTS

	Integration inside projects				Integration between projects and firms				Technological performance			
Variables	Model 1a		Model 1b		Model 2a		Model 2b		Model 3a		Model 3b	
Control variables												
Basic research	.08		.00		-.12		-.12		.02		-.02	
	[.87]		[.01]		[-1.46]		[-1.30]		[.26]		[-.25]	
Number of members	.12		-.02		.08		.03		.04		-.02	
	[1.23]		[-.26]		[.96]		[.36]		[.45]		[-.26]	
Strategic importance	.13		.12		.23	***	.20	**	.18	*	.11	
	[1.43]		[1.40]		[2.80]		[2.23]		[1.98]		[1.41]	
The intention of commercialization	.22	**	.21	**	.27	***	.27	***	.17	*	.05	
	[2.45]		[2.35]		[3.18]		[2.90]		[1.83]		[.58]	
Main effects												
Project Autonomy			.30	***			.18	**				
			[3.42]				[2.12]					
Integration inside projects											.55	***
											[7.05]	
Adj_R^2	.069		.197		.184		.190		.044		.320	
N	125		113		125		113		125		125	

*** p < 0.01, ** p < 0.05, * p < 0.1; upper row is the β , lower row [ ] is the t value

TABLE 4. MULTINOMIAL LOGIT MODEL RESULTS

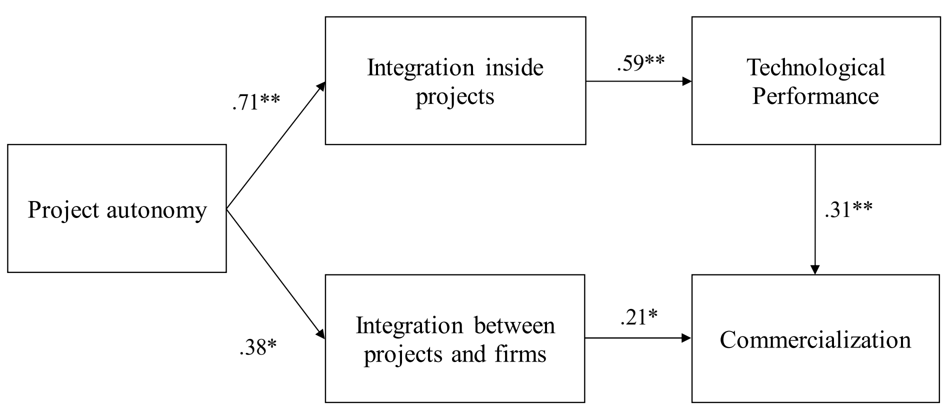
	Model 4a		Model 4b		Model 4c		Model 4d	
	Commercialization	Ongoing	Commercialization	Ongoing	Commercialization	Ongoing	Commercialization	Ongoing
Control variables								
Time lag	-.27 **	-.19 **	-.23 *	-.17 **	-.26 **	-.18 **	-.23 *	-.17 **
	[5.86]	[5.88]	[3.79]	[4.67]	[4.95]	[5.63]	[3.77]	[4.72]
Basic research	.19	-.01	.55	.18	.33	.01	.57	.18
	[.76]	[.01]	[.48]	[.11]	[.17]	[.01]	[.49]	[.11]
Strategic importance	2.85 **	2.56 **	2.31	2.33	2.58 **	2.47 **	2.26 *	2.30 **
	[5.70]	[5.48]	[3.57]	[4.42]	[4.53]	[5.05]	[3.34]	[4.24]
Main effects								
Integration between projects and firms			1.11 **	.44			.82 *	.33
			[6.43]	[2.40]			[2.71]	[1.98]
Technological performance					1.45 ***	.52 **	1.25 **	.46
					[8.85]	[.76]	[5.88]	[.29]
Pseudo R^2 (Cox - Snell)		.159		.208		.229		.251
-2 Log likelihood		101.359		211.894		164.213		213.152
N		128		128		128		128

*** p < 0.01, ** p < 0.05, * p < 0.1; upper row is the coefficient, lower row [ ] is the Wald value

B. Structural equation modeling

To examine the framework in Fig. 2, testing the entire causal path is necessary by addressing the possibility that many of the variables can be endogenous. To do so, I next conducted a structural equation modeling in order to test the validity of the conceptual framework. Structural equation modeling is a multivariate analysis technique which has been used to impute relationships between latent variables. In the analysis, samples of ongoing projects were dropped from the dataset and a dummy variable was created for commercialization (1 = commercialization, 0 = termination) because of the incapability of the structural equation modeling to incorporate categorical variables. Additionally, control variables used in the previous regression analyses were not introduced in the analytical model to minimize the complexity of the estimation. As a result, as is shown in Fig. 3, the structural equation modeling on 78 projects was executed using five hypothetical variables.

The results are mostly consistent with the results of the regression analyses. Similar to the results of the regression analyses, the relationship between "project autonomy" and "integration between projects and firms" was significant at the 5% level but inversely correlated to the hypothetical direction. That is, the results indicated that project autonomy does not decrease the degree of integration between projects and firms but, instead, may encourage such integration. These results suggest that an autonomous project may be able to organize for project members to exchange information with firms to which they belong in order to effectively conduct R&D. The significant correlation between "integration inside projects" and "integration between projects and firms" (shown in Table 2) may also provide partial support for this structure.



N = 78; ** p < .01, * p < .05.

χ^2	df	CFI	RMSEA	CD
151.98	101	0.84	0.08	0.71

Fig. 3. Structural Equation Modeling Results

Moreover, Hypotheses 2, 3a, and 3b were also supported by the structural equation modeling. First, the significant and positive effect of "integration inside projects" on "technological performance" provided support for Hypothesis 2. Second, Hypothesis 3a, which states that technological performance increases the probability of commercialization, was also supported. Third, "integration between projects and firms" had a significant effect on commercialization, indicating support for Hypothesis 3b. All of these results were approximately consistent with the results of the regression analyses, except for some differences in the coefficient values.

As described by the fit indices in Fig. 3, the analytical model executed showed modest fitness with the data. For example, RMSEA (root mean square error of approximation) which measures the size of the residuals was 0.08, which is the at least value recommended for an acceptable fit [22]. Also, CD (coefficient of determination) was 0.71, this means the whole analytical model explains 71% of variance within data. However, some shortfall in good fit due to dropping samples of ongoing projects and control variables, it requires us to be circumspect about interpreting the results of the analysis.

VI. DISCUSSION

A. Contributions and Implications of the Research

In a situation of increasing competition that requires firms to innovate in a continuous manner, strategic alliances or narrowly joint R&D have flourished globally. Given these trends, numerous scholars have discussed the success of alliances and have indicated the importance of relational factors. In contrast to studies that focused on attributes of relationships or the joint decisions of partner firms, this research has emphasized the perception needed to seize an innovation process that encompasses both R&D and commercialization in the context of joint R&D. In other words, this study focused on more concrete operational-level actors and their day-to-day management in the context of inter-organizational collaboration, rather than structuring the effort of parent firms as a unitary actor. This challenge, which bridges alliance and innovation research, is necessary to reflect the "value capture" aspect [38] or the commercialization that is the fundamental motivation for firms to participate in joint R&D.

Actually, innovation characterized as a "sociopolitical process" [16], [42] is never complete solely within joint R&D because additional processes exist for commercialization, such as mobilizing resources, organizing development projects, preparing mass production, and so on. Creativity research divided innovation into idea generation and its implementation [5]; similarly, this property of the innovation process requires us to expand the perspective to include the process that originates from champions aspiring to commercialize for broader social worlds. Thus, the main contribution of this study is that it demonstrates the importance of the joint R&D project as a unit of analysis for comprehending the process and success factors of innovation through collaboration.

In other words, the findings of this study revealed two roles of joint R&D projects or their members as the success factors of innovation through joint R&D: (1) as a member of a joint R&D project, cooperating in and conducting R&D with other project members from various organizations, and (2) as an employee or member of R&D staff of the organization to which they belong, championing commercialization by leveraging both the technologies they create and the complementary resources in their organizations. First, the results of the analysis showed that project members should integrate with each other to conduct R&D effectively and to achieve high technological performance, which can be a necessary condition for commercialization. This finding is mostly concordant with knowledge from communication studies in the innovation literature [1], [14] or knowledge management works [23], [34]. Second, this study confirmed that integration between project members and firms increases the chances of commercialization. This result also resembles the results in certain types of innovation literature, such as on the R&D–marketing interface [20], [26] and the effect of interpretative barriers [12]. Overall, both integration inside joint R&D projects and integration between projects and firms are possible success factors of innovation through joint R&D.

Considering the position of a particular project member, the two roles previously described are seemingly contradictory to each other as described in the hypotheses on project autonomy. As prior studies indicated, cooperation with other firms can be hampered by selfish championing that falls under the category of opportunistic behavior [7], although the absence of championing by project members may reduce the likelihood of commercialization. Moreover, the challenge of championing may be partly solved by firms' intervention to fit R&D with their own strategies or complementary resources—a step that may result in less cooperative attitudes—or early termination attributable to, at worst, a broken deal.

Against this prefiguration, the results of the analysis suggested another possibility: an autonomous project may be able to achieve integration without loss of autonomy. In contrast with the project's resource autonomy, which is shown to encourage integration inside a project but discourage it between projects and firms, project autonomy in terms of the power to determine resource allocation and goals may prompt both internal and external integration. In other words, participant firms may empower the project to decide on both "operational autonomy" and "strategic autonomy" [6], even in the context of joint R&D. In particular, in a situation that started with a basic research phase, the participant firm may have less information to design R&D processes than the R&D staff at the operational level, and the management level may have difficulty predicting possible outcomes and negotiating control rights [27]. In this way, it may be more efficient for firms to delegate the power for projects and maintain a loosely fitting contract than to make an effort to heighten appropriability by hampering cooperation. Although this deviation from tightly coupled contracts may have a profound effect, firms must control their projects to a limited extent to spoil the autonomy because extremely autonomous projects may get out of control, thus leading to an inability to commercialize [37].

B. Limitations and Directions for Further Study

This study contributes to the understanding of the dynamics of innovation through collaboration and its success factors. Nevertheless, limitations also exist.

First, because this study used data on samples funded by the government, special factors or noises existed in that situation. For example, government funding can affect a firm's attitude toward a particular R&D project, as indicated in prior research [18]. In addition, in government-funded projects, the government sometimes plays a central role in resource allocation and goal setting. However, this study cannot address these contextual problems, primarily because of limited data availability. In further studies, researchers must examine the R&D processes and the success/failure factors of joint R&D without government funding and compare the results from various contexts with those of this study.

Second, this study is restricted to the narrow perspective that focuses only on joint projects. A high rate of alliance failure was noted in alliance studies [28], [36]. To tackle this problem through an understanding of the nature of problems within joint R&D, it is necessary to compare joint projects with in-house projects while keeping other factors constant. Although only a few studies adopted an approach focusing on the project level in the context of the organizational boundary [3], future studies need to increase their range from in-house to broader contexts.

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