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Abstract

Innovation creating economic values has become a vital issue due to severe global competition. Given such a circumstance, government funding has flowed not only into pure research, but into applied research and product development linked directly with commercialization as well. Such a tendency has been accelerated since “Bayh-Dole Act” was enacted, which made it easier for firms to appropriate R&D outcomes.

Increased appropriablity that promotes commercialization, however, may prevent technological outcome produced by a government-funded R&D project from being widely utilized in a society. The project aimed at immediate commercialization may tend to create context-specific knowledge that can be applied only to the particular product category rather than generalized technological knowledge that can be widely available for other products or technological fields. Such a project may also have strong incentives to keep such technologies in-house. Therefore, the policy side confronts dilemma that the more government attempts to encourage private R&D activity with public support that are linked directly with market competition, the more the indirect spillover effects are sacrificed because of increased appropriability. To resolve this dilemma, we must identify the factors that influence the spillover effects of private R&D projects receiving public support.

In this paper, we first classified a spillover effect in accordance with three dimensions, spillover contents, scope of the spillover, and spillover recipient field. Furthermore, spillover contents can be divided into “technological spillover,” “cognitive spillover” and “social-relations spillover.” And then, we empirically investigate the factors that influence spillover effects by analyzing data obtained from 301 private R&D projects supported by NEDO (New Energy and Industrial Technology Development Organization), Japan’s public management organization promoting private R&D.

Our findings show that while the project starting at the exploratory phase had positive effects on technological spillover both within and outside the firm, and that spillover outside the firm is restricted when the project is of great strategic importance for a firm. We also found that information exchanges with other internal divisions had positive effects on not only technical spillover but on cognitive spillover and social-relations spillover.

Results imply that it is necessary for supporting institutions to confirm that projects are not isolated internally and that there is a system in place to receive assistance and cooperation from other divisions.

1. Introduction

For many countries, the creation of innovation has become a vital issue as industry maturation is accompanied by a leveling of technology and the global competition engulfing newly developing countries intensifies. On the other hand, for private firms exposed to daily profit pressure from capital markets, directing scarce management resources into highly uncertain innovation activities is no simple task. Consequently the voices at private firms anticipating public funds as a source of R&D funding are growing. For example, public support for R&D in the private sector in Japan has risen substantially over the past 20 years, climbing from roughly 2.3 trillion yen in 1991 to about 3.2 trillion yen in 2001 and approximately 3.5 trillion yen in 2011. In recent years in particular, there has been a tendency to invest public funds in not only pure research but in applied research and product development linked directly with businesses as well.

Based on the Bayh-Dole Act (Patent and Trademark Law Amendments Act) in the United States, or on similar legislation in other countries, private sector firms are able to retain ownership of the rights to technologies that have been created by projects with public supports. Ergo it has become easier to obtain public support for the development of differentiation technologies that are so critical for market competition. Furthermore, as governments' financial positions have become more constrained with each passing year, the demand that technology development based on public funds is not merely the simple promotion of science and technology and that it produce visible economic outcome also lies behind this tendency.

On the other hand, however, some express doubts that public funds should be spent to assist commercialization at specific companies. The reason is the danger that the appropriability enhanced by enforcement of laws such as the Bayh-Dole Act – i.e., the capacity of a firm to retain the added value it creates for its own benefit – will hinder the spillover of any technological outcomes achieved through the use of public funds. The more public support is directed toward the development of differentiation technologies linked directly with market competition, the greater the incentive as well of private firms to keep the outcome in-house. Furthermore, in the case of commercialization research aimed at specific application, the outcome can be sufficiently utilized only by a firm with the accumulated know-how or customer base related to the particular product.

Public support does not accomplish its original role merely by shouldering the costs of private R&D investment. Public support is justified when it is turned to technology development which, when left to the market, suffers from underinvestment, even though its social importance is high (Nelson, 1959; Arrow, 1962). Furthermore, the significance of public support for private R&D is recognized when public funds prime the pump and induce additional private investment (Leyden and Link, 1991; Busom, 2000; Guellec and Van Pottelsberghe, 2003; Almus and Czarnitzki, 2003;

Duguet, 2004; Gonzalez and Pazo, 2008; Ito and Nakano, 2009) or create demand by boosting social recognition of technological fields and industrial areas (David and Hall, 2000; David, Hall and Toole, 2000), and when the developed technologies are used broadly in society beyond the scope of the project– in other words, when these spillover effects can be anticipated.

There is a dilemma here that confronts the policy side, however. The dilemma is that the more government attempts to encourage private R&D activities with public support, the more the indirect spillover effects may be sacrificed. In order for public support to encourage technological development, there must be sufficient incentives for the private firms to accept the public support. And for that, appropriation of the outcome must to some extent be guaranteed. Here also lies the reason why laws such as the Bayh-Dole Act are enacted. Enhanced appropriability, however, may lead to restraining utilization of the outcome in the society. In particular, as the extent of public funds channeled to technological development directly linked to market increases, the tendency for diffusion of the outcome to be restrained may become stronger. And if that is the case, won't the spending of public funds for commercialization research that is likely to produce an economic outcome at an early stage tarnish the very justification for public support itself? What should be done to prevent such an outcome? How can encouragement of private R&D be achieved with public support without sacrificing social utilization of the outcome? To answer this question, we must identify the factors that influence the spillover effects derived from private R&D projects receiving public support. That is the objective of the present study. Specifically, it is to empirically clarify the factors that influence project spillover effects by analyzing data obtained from follow-up surveys for private R&D projects that NEDO (New Energy and Industrial Technology Development Organization), Japan's public management organization promoting private R&D, has supported (referred to below as "NEDO projects").

2. Classification of Spillover Effects

The spillover effects of public support for private sector R&D can have various meanings. Therefore we begin with a definition and classification of spillover effects.

In this paper, we define the spillover effects of public support as "the effects produced on a scope that goes beyond the purpose set by the project." This is a rather broad definition, which includes everything other than the outcome and effects aligned with the goals the project had set. Therefore we must further classify spillover effects in accordance with various dimensions.

The first dimension is the "spillover contents." These can be divided roughly into "technological spillover," "cognitive spillover" and "social-relation spillover." Technological spillover means use of the technological outcome outside the project. Included is direct exploitation of the technological outcome outside the project, such as technology licenses to other companies, and indirect uses as well, such as other companies developing successor technologies by referring to the technological outcome produced by a project.

"Cognitive spillover" means the heightening of recognition inside and outside companies of technologies or products that are the targets for development, or of project activities themselves, as an outcome of public support being pumped into the projects. The visible outcome of development that are produced with public support, as well as the kind of "endorsement or official go-ahead" that projects that receive public support represent, are believed to heighten the level of attention given to the developed technologies or project activities. This heightened recognition not only stimulates development investment by other firms, it is thought to also produce the effects of increasing the potential for commercializing project outcome in-house, and of elevating demand expectations in the market.

The third classification, "social-relation spillover," denotes the indirect effects, including the creation of relationships between firms and personnel training achieved through project activities. Publicly supported projects include many instances of joint R&D encompassing multiple firms or entities. Such joint research not only raises the efficiency of technology development through the exchange of technical knowledge, but may lead to the construction of long-term relationships between firms, and to personal relationships between individuals as well. While these are not necessarily effects that are evident in the short term, if contemplating public investment from a policy standpoint, they are outcomes that should be taken into consideration as effects that help reinforce a country's R&D capabilities over the long term. Public support may also possess a personnel training aspect in the long-term sense, such as the young researchers who are cultivated through a project's activities, for example.

The second dimension for spillover effects is the "scope of the spillover." Various scopes can be considered, such as geographical scope, legal scope, and political jurisdiction scope. Here, however, we will identify scope based on organizational boundaries (the internal and external classifications of a firm's organization). The reason is there may be significant differences in the intentions, processes and social effects pertaining to spillover within the entity that holds ownership to the outcome, and spillover outside that entity.

Much of the existing research refers to the influences beyond firms' boundaries. If we define spillover effects as "the effects produced on a scope that goes beyond the purpose set by the project," however, the effects need not always be limited to the influences outside the firm. In fact, the outcomes of projects sometimes are applied internally in forms different from the initial purpose. In addition, follow-up projects sometimes are established because unexpectedly strong outcomes were achieved. Such influences should be also understood separately as spillover effects.

The third dimension for classifying spillover effects (primarily those related to "technological spillover") is the "spillover recipient field." That refers to whether the project outcome influences other R&D activities in the same technological field, or in the different technological field. For example, when a project's outcomes elicit or are utilized for development in the same technological field at other companies, such outcomes can be classified as *external spillover in the same field*. In addition, when additional R&D investment is elicited within a company in the business field where use of the technology was envisaged, we can classify this as *internal spillover in the same field*.

On the other hand, the technology a project has developed sometimes might impact development in another technological field and different application areas. Normally there is fixed agreement between a project that receives supports and the public institution concerning details of the technology developed and the areas where that technology can be applied. For example, the "Expected outcomes" are described in the Research Plan, and the envisaged application field(s) identified there. Developed technologies, however, do not always flower and flourish in the field(s) initial considered. For example, the energy-absorbing nylon developed by T Industries, Inc. through a NEDO project initially was envisaged and developed for application in automotive parts, but ultimately found its market in sporting goods applications such as badminton rackets. There are cases of so-called "technology diversion" as well, where a developed technology blossoms inside the firm but in a different field, not in the business field assumed at the outset.

Figure 1 below positions the spillover effects of publicly supported private projects along the three dimensions described above.

- Figure 1: Classification of spillover effects -

3. Existing Research

Existing research dealing with R&D spillover effects has focused primarily on technological spillover to analyze the influence produced by spillover on productivity at the inter-firm level or inter-industry level (Griliches, 1992; Nadiri, 1993; van Pottelsberghe, 1997). Research at the inter-industry level identifies the impact produced by spillover on industry productivity by estimating the size of the spillover effect from the input-output relationship (IO flow) or investment relationship (investment flow) between industries (Terleckyj, 1974; 1980). This stream of research had generally found a positive influence of the spillover on productivity.

Research focusing on the spillover effect at the inter-firm level, on the other hand, identifies the size of the spillover effect by estimating the influence that an increase in R&D activity at other companies has on a firm's own productivity.

In pioneering research, Jaffe (1986) used panel data for U.S. firms to demonstrate that other companies' R&D investments have a positive influence on a firm's own patent productivity. Jaffe (1988), by analyzing difference panel data, also showed that other companies' R&D investments have a positive influence on a company's R&D intensity and sales growth. To estimate the spillover effects, he calculated the total amount of R&D investment by other companies that possibly influence firm's own R&D, by capturing the similarity of patent portfolios among firms as an indicator, weighting the amount of each other company's R&D investment by this indicator. Thus these outcomes suggest that similarity of technological field between firms may facilitate the spillover.

On the other hand, Adams (1990) measured the stock of industry technical knowledge by using the cumulative number of papers published in scientific periodicals, and showed this has a positive impact on the productivity growth of each firm. He took the correlation between the distribution of fields that the company's scientists belong to and the distribution of fields of scientific periodicals in the entire industry, and used this to weight the influence of the stock of industry technological knowledge. This suggests that a positive spillover effect is received to the extent the portfolio by field of the stock of industry technical knowledge is similar to the portfolio by field of scientists within a company.

Likewise, Anseline et al. (1997) measured the technical knowledge stock based on the cumulative value of the amount of university research expenditures, and weighted this value by the physical distance from the university to each firm, and estimated its influence on the number of commercialization of high-tech innovation outcome. As a result, the stock of technical knowledge at universities exerted a positive and significant influence on the innovation. This suggests that close physical distance promotes spillover.

There also is research verifying spillover effects that included investigations not at aggregated levels such as industries or firms but at the micro-level of research programs as well. For example, Henderson and Cockburn (1996) used patent data from leading pharmaceuticals manufacturers in Europe and the United States to demonstrate that patent production within a company in related research programs, patent production by other companies in the same research program and patent production by other companies in related research programs all have a positive and significant influence on a company's own patent production. In this regard, for patent production by the spillover source, the indicator used was not the simple number of patents but the number after subtracting, from the number of newly produced patents, the number of past patents that were eroded. Furthermore, Okada and Kawara (2004) conducted the research based on Henderson et al.

using data for Japanese firms, and similarly demonstrated that spillover effects from inside and outside the firm has a strong influence on productivity.

The principal objective of these researches was to identify the influence of spillovers on outcome such as productivity while having less intention to clarify the factors and mechanisms encouraging spillovers. Several factors that promote spillovers are, however, suggested in each research above. The research by Jaffe (1986, 1988), Adams (1990), and Henderson and Cockburn (1996) postulate the influence of technological field similarity and close proximity, while Anseline et.al. (1997) suggests that geographic proximity promotes spillover.

The influence of geographic proximity has often been identified in research concerning industrial cluster. There is ample research pointing out that an industrial cluster can lower the cost of technical knowledge transfer due to close geographic proximity and the social relationships, and that this leads to competitiveness (Marshall, 1890; Krugman, 1991; Saxenian, 1994). Jaffe et al. (1993) is an example of research that demonstrates the influence of such geographic proximity on spillover using the correlation to patent backward citations and forward citations. Jaffe et al. clarified that citations by universities and firms within the same state and especially within the same region accounted for a high proportion of all citations.

The complementary assets and absorptive capacity of firms have been pointed as another factors that promote spillover. Complementary assets are supplementary technologies or assets, such as production facilities and distribution chains needed to put a technology to practical use. The presence or absence of complementary assets may affect the size of technology spillovers since it affects the economic value of obtained technical knowledge. In general, the value of technology realized from other companies depends on absorptive capacity, the capacity that enables a firm to understand and use the technology. For example, Cohen and Levinthal (1990) have explained that firms make R&D investments even under low appropriability conditions because they expect it to improve absorptive capacity and facilitate the learning of external technical knowledge. Moreover, Cockburn and Henderson (1998) show that engaging in exchanges with outside groups, including collaborative or joint research with public institutions, is critical for increasing absorptive capacity.

Both complementary assets and absorptive capacity are factors residing in recipients of the spillover. On the other hand, there is almost no research that has focused on projects that become the source of spillovers and clarified the factors stimulating spillovers. The public institutions providing supports for private R&D, however, certainly want to understand, as much as possible beforehand, the size of the spillover effect a project will produce or the spillover capacity a project possesses. The reason is the value of investing public funds not only is created from the realization of the objectives the project has set, but is affected by the outcome being used broadly beyond the boundary of the project.

There is a possibility the extent of spillover will be influenced by factors such as the nature of the technical knowledge that a project generates, the project size, and the attributes of the firm administering the project. It may also be influenced by the project's activities, processes, and management. For example, the contents and values of developed technologies might become widely known and stimulate spillover if the project members engage in active communications with outside parties, in order to extensively utilize outside knowledge in the solution of technical problems. Identifying the factors that impact a project's spillover effects, including those related to the project management, becomes critical for achieving effective public support for private R&D.

One existing research that analyzed the factors affecting spillover effects of publicly supported project is Nagaoka and Tsukada (2011). They have found that the degree of R&D intensity, inclusion of both pure research and applied research, industry-academic cooperation, the intention to create technology seeds, and the presence of a PhD, are factors that tend to have a positive effect on spillovers. Because their concern was to comprehend the divergence of the deciding factors for public support and the deciding factors for spillover effects, however, they did not consider either the activities or processes of the project as factors stimulating spillover. One distinctiveness of this paper lies in the attention given to such activities and processes.

4. Factors and Mechanisms Promoting Spillover: Deriving Hypotheses

In Section 2, we classified spillover effects into three categories of "technological spillover," "cognitive spillover" and "social-relations spillover," and further positioned spillover effects as spillovers within a company and spillovers outside a company, and as spillovers in the same field and spillovers in different fields. In the following sections, we derive hypotheses concerning the factors and mechanisms that affect spillover in a form that is aligned with this classification.

4.1 Factors influencing the technological spillover

4.1.1 Nature of knowledge

The first factor thought to affect the technological spillover is the nature of the technology or knowledge developed by the project.

Much of the existing research has agreed that scientific knowledge tends to spill over (Cohen and Levinthal, 1990; Cockburn and Henderson, 1998; others as well). Scientific knowledge is knowledge related to principles and is not dependent on a specific application environment; it is highly generalized knowledge that potentially can be expected to be applied across broad fields. Relatively easily expressed by explicit means such as documents, symbols or others, it tends to spread widely in the form of scientific articles or patents. The reason much of public support for the private R&D is focused on basic research is that the externalities of basic research are substantial, and when left to the market will not elicit sufficient investment.

On the other hand, unique tacit know-how that is not easily expressed as explicit knowledge such as written documents, formulas or symbols is contained within the application specific or context-specific knowledge pertaining to practical application of products or other goods. While such tacit knowledge must be obtained in order to realize sufficient benefits from technology, it is not easily transmitted externally. Furthermore, commercializing technologies and introducing them to the market requires various complementary assets such as other related technology, production facilities and a sales network. The ability to enjoy the benefits of technological spillovers might be limited to firms possessing such complementary assets. The reason is that context-specific knowledge included in practical and applied technologies is something that is not easily used by outsiders. We can summarize the above discussion as the following hypothesis.

Hypothesis 1-1: Spillover beyond the project boundary increases as the extent to which project's outcome includes generalized and scientific knowledge increases.

However the above hypothesis might not hold in the case of spillover within the same firm. When the spillover occurs within the same firm, unique know-how required to take advantage of practical and applied research outcome can be shared, and any complementary assets necessary for practical use also can be used. In the case of internal spillover, there probably is little difference regardless of whether it is generalized knowledge or context-specific knowledge. Therefore Hypothesis 1 may hold notably for spillover outside a firm.

Hypothesis 1-2: Hypothesis 1 holds more notably for spillover outside a firm.

Furthermore, the greater the amount of highly generalized knowledge, the greater the influence exerted on various technological fields will be. This is because trial and error will be tested in various fields when future applications are uncertain. In the case of technologies related to practical application, on the other hand, the fields where a technology will be applied are often clearly recognized. Therefore the greater the extent to which knowledge is related to practical applications, the greater the tendency is that knowledge is utilized in the same technological or application field, and vice versa. We can show this argument as Hypothesis 1-3 below.

Hypothesis 1-3: Spillover to different technological fields increases as the extent to which project outcome includes generalized knowledge produced from basic research increases.

4.1.2 Information exchange

The second factor that, we conjecture, influences technological spillover is the level of information exchange with parties outside the project. For technology to spread out, information for its contents, details, and usefulness must be disseminated and understood by potential recipients.

As discussed in the previous section, existing research has clarified that geographic proximity exerts a positive influence on the spillover effect (Jaffe et al., 1993; Anseline et al., 1997). One thing geographic proximity implies is efficient information exchange that extends beyond the organization. Being geographically close not only facilitates frequent face-to-face communications, but also promote exchanges of tacit or implicit knowledge through the personal networks built in community. That existence of development outcomes are recognized through such information exchange is of primary importance for promoting spillover. Furthermore, as deep background information is exchanged, the expected benefits from a technology may expand, which is also a factor giving impetus to the spillover outside the firm.

Given this discussion, we conjecture that the technological spillover from the projects may depend on the diversity of the information channels to the outside, maintained by project members, and the volume of information exchanged through these information channels. We can summarize this argument as the following hypothesis.

Hypothesis 2-1: Technological spillover outside the project increases to the extent information exchange with outside parties by project members increases.

The exchange of information outside a project includes not only information exchange outside of the firm, but information exchange with other departments within the firm and with members of other projects. Both are likely to function as information channels broadening the points of contact for receiving spillover. It would be natural, however, to think the extent of their effects will differ.

Spillover to other companies outside the firm will be promoted by information exchanges outside the firm by project members. Nevertheless, given maintenance of confidentiality, it's difficult to imagine that information pertaining to critical know-how is included in informal communications with others outside the project. Although the existence of the technological development will become public as the result of such communications outside a project, the outlines of the developed technology tend to be well-known to begin with in the case of publicly supported projects. This is because projects are obligated to report the details of their development at the interim and final evaluations stages. Being considered in this way, the influence that communication with others outside of firm has on spillover might be limited.

If a development project is a joint research project across different firms, on the other hand, exchanges of information that exceed the boundary between the firms probably will occur provided it is within the range of the rules governing information exchange. Furthermore, spillover of project outcome within each firm can be expected once the collaborative project has been completed (or even during the period of the project). When considered in this way, compared with the case of research by a single firm, joint R&D can be envisaged to engender greater outside spillover. Because of the information management will be more strictly applied in joint R&D, however, this might hinder spillover. We summarize these arguments as the following hypothesis.

Hypothesis 2-2: Spillover of technological outcome outside the firm is higher (or lower) in a case of joint R&D projects across firms.

4.1.3 Strategic importance

The third factor that may affect technological spillover is the strategic position of the project within firms. Firms worry about leaks of information to other companies the most when applying for public support. Projects receiving public supports are usually required to report their outcomes periodically, or at a minimum, part of the outcomes normally will be publicly released. Although this is necessary to accomplish accountability for public funds use, it is also a drawback for firms receiving public support. Consequently firms tend to use their own capital to undertake developments that are of great strategic importance and to rely on public funds for projects with relatively low importance.

If a firm will accept public support for strategically important technological development as well for reasons such as financial or cash flow difficulties, however, it presumably will pay meticulous attention to leaks of information outside the firm. Accordingly, the outside spillover of project outcome with a high degree of strategic importance may be restrained.

On the other hand, if a technology development is strategically important for a firm, the project outcome will likely be readily recognized internally, and the firm probably will seek to use the outcome on a company-wide basis. Accordingly, contrary to the spillover outside the firm, spillover within the firm is predicted to become rather greater. We can summarize these arguments as the following two hypotheses.

Hypothesis 3-1: Spillover of technological outcome outside a firm decreases as the strategic importance of a project increases.

Hypothesis 3-2: Spillover of technological outcome within a firm increases as the strategic importance of a project increases.

4.2 Influences on cognitive spillover

4.2.1 External acknowledgement

If the technology in question is widely acknowledged and attracts attention externally as the outcome of public support, then through the process of inducing new investment by other private firms and stimulating potential demand economic value will be created for society, and the significance of public support will be recognized.

For a publicly supported project or a developed technology to be widely acknowledged, it is important whether those who report them, such as the press or news media, are interested. The scale of the capital invested in the project is one factor influencing such interest. If large amounts of public funds are invested in a project, the details must be properly reported and disclosed to the public to achieve accountability. Furthermore, for news media, a large project can be expected to have greater value as news than a small project.

Likewise, just as in the case of technological spillover, the exchange of information by project members with others outside the firm may also promote cognitive spillover. If project members actively bring attention to the project's outcome at academic societies and symposia, for example, or actively disclose details of the development through news media and magazines, this will raise external recognition and elicit development investment by other companies. We can summarize the above discussion as the following two hypotheses.

Hypothesis 4 -1: External recognition increases as the size of a project's budget increases.

Hypothesis 4-2: External recognition increases as the level of information exchange with parties outside the firm by project members increases.

4.2.2 Internal acknowledgement

The motivation for project advocates to apply for public support is sometimes found not only in their expectation of funding that is not accepted internally, but also in their hope of obtaining in-house recognition by having the "endorsement or official go-ahead" that comes from being selected as a public project. If the project can attract attention internally and additional investment by the firm can be elicited, the value of the public support can be vindicated. However obtaining public funds may hinder a company-wide commitment to commercialization because the project no more relies on internal resources. The project may also be organizational isolated for fear of becoming a window for information leakage to other companies.

Therefore, for a project that has received public support to be recognized internally as an important project, continuous interaction and information exchange with other internal divisions may become critical to ensure the project is not isolated from other internal activities. We can show this as the following hypothesis.

Hypothesis 4-3: Internal recognition increases as information exchange with other internal divisions by project members increases.

4.3 Influences on social-relations spillover

One cannot say that public support was of no significance whatsoever because a project was unable to surmount technological difficulties and failed to achieve the objectives. A project may provide project members with new activities and experiences that are otherwise not found in internal projects. Invaluable assets utilized over the long term, including the cultivation and training of human resources and the establishment of social relationships with other companies can sometimes be accumulated internally as by-products.

These by-products are more likely accumulated in the case of projects that undertake novel development jointly with other companies, rather than single-firm projects being conducted as extensions of existing development. Such projects offer numerous opportunities for direct new experiences through interaction with people at other companies. We can show this as the following hypothesis.

Hypothesis 5-1: Collaborative projects stimulate greater cultivation and training of personnel and the establishment of relationships with other companies than single-firm projects.

5. Research Method

5. 1 Outline of research and samples

To investigate the hypotheses discussed above, we use data from a follow-up questionnaire survey implemented jointly by NEDO and Hitotsubashi University in August 2010 and the data from the interview survey implemented afterwards. The follow-up questionnaire survey was a survey we conducted for private R&D projects for which NEDO provided financial support, here called the NEDO projects. In the questionnaire, we posed questions on topics such as the actual project management conditions, the social environment and market circumstances where the projects were implemented, and the project's technological outcome and social effects.

Typically, several private firms together with universities, public institutions, incorporated associations, and foundations will participate in a single NEDO project. The questionnaires were sent to representatives of each private firm among these that participated in the NEDO projects, and the representatives were the respondents[1]. Therefore, the unit of analysis in this paper is not the project per se but each firm that participated in the project.

The number of questionnaire responses totaled 301, and the response rate was 88%. Furthermore, following the questionnaire survey, we implemented interviews at 23 companies from February through October 2011 and from May through August 2013. The technological fields of the NEDO projects in which the respondent firms participated were classified into electronic information, new energy, energy conservation, mechanical systems, environment, biotechnology and medical technology, nanotech and materials, and other. The project budgets were distributed between 217 million yen and 11,716 million yen. The number of years in which each firm participated in its project ranged from less than one year to 14 years, while the industries were diverse and included automobiles, electronic devices, materials, and chemicals.

5.2 Variables and models

5.2.1 Dependent variable

The spillover effect was measured separately for "technological spillover," "cognitive spillover" and "social-relations spillover" as discussed below, in accordance with the classification shown in Section 2.

Technological spillover

For measurement of the technological spillover, we first used the number of citations of the patents the project had obtained (which we call NEDO patents). Although partial, "the total number of citations" that NEDO patents receive may show the level of use of the technological outcome by users outside the project. Next, to separate the spillover outside the firm from in-house spillover, we separated the total number of citations into citations by the company itself and citations by other companies, which we respectively labeled "number of internal citations" and "number of

[1] Respondents were the representatives within each firm that participated in the NEDO projects who were the most familiar with the projects in question, including not only their own company but the facts in terms of their relationships with the other organizations. While bias is unavoidable because the respondents were individuals, we believe that, as information obtained from individuals, the responses are highly reliable.

external citations.”

Furthermore, to distinguish the spillover recipient fields, the difference (distance) of the technological fields between a NEDO patent and patents citing a NEDO patent was captured by calculating the cosine similarity of the International Patent Classification (IPC) codes (considered to the subclass level) assigned to the two patents. Cosine similarity takes a value from 0 to 1. When the cosine similarity is one, this means the IPC codes assigned to the two patents are completely identical and indicates the patents are in the same field, while oppositely, when the cosine similarity is 0 (zero) the IPC codes assigned to the two patents are different and indicates the patents are in different fields. Next, we labeled the number of citations weighted using this cosine similarity the “influence in the same technological field.” As the number of times the NEDO patent(s) are cited in other patents classified in the same field technologically rises, this “influence in the same technological field” increases. Conversely, we labeled the number of citations weighted using the value “1 - similarity” the “influence on different technological fields.” As the number of times a NEDO patent is cited in patents affiliated with a different field increases, the value of the “influence on different technological fields” increases.

Both the “influence in the same technological field” and the “influence on different technological fields” have an influence within the firm and an influence outside the firm. The “influence in the same field within the firm” is the influence on the field limited to citations within the firm, while the “influence in the same field outside the firm” is the influence in the same technological field calculated using only citations outside the firm. Values were similarly calculated for “influence on different technological fields” as well.

For measurement of the technological spillover, in addition to the indicators using the number of citations of these patents, we made complementary use of the subjective evaluations by the respondents as well. Specifically, we asked respondents to indicate the extent to which the developed technology was diverted and used in applications different from the originally intended purpose, by using a five-point scale for the three categories “development and product technology,” “evaluation and testing technology” and “scientific knowledge.” We set the mean value of the responses for these three categories as the “technology diversion within the firm” ($\alpha = 0.83$). The patent citation cannot capture the actual status of technology use. Consequently we decided to request a subjective evaluation, at least concerning the internal spillovers the respondents understood.

Cognitive spillover

We measured cognitive spillover within firms and outside of firms, respectively. First, for cognitive spillover within firms, we received responses on a five-point scale on the level to which the legitimacy of the development activity is ensured within firms, which we set as the variable "development legitimacy within the firm." On the other hand, we captured cognitive spillover outside of firms based on two variables. One was responses on a five-point scale on the level of improvement of recognition for the project outside the firm, which we set as the variable "external recognition." The second was responses on a five-point scale for the 3 question items "stimulated technological development by other domestic organizations," "stimulated technological development by other overseas organizations" and "invigorated application markets," from which we prepared a synthetic variable named "impact on society" by using the values of the three answers as a mean value ($\alpha = 0.79$).

Social-relations spillover

We measured social-relations spillover based by two indicators. We first received responses on a five-point scale on the extent of creation of networks outside the firm through the project activity, which we used as the variable named "network." Second, we asked questions on the effect in stimulating human resources development within the firm, and used the responses for the variable named "human resource development (HRD)."

5.2.2 Explanatory variables

The explanatory variables are divided broadly, according to the presented hypothesis, into a variable that captures the nature of the generated knowledge, a variable that captures the exchange of information with others outside the project, and a variable that captures the strategic intent of the firm.

Nature of generated knowledge

We measures the nature (generalizability) of the generated knowledge by two variables. One is a "exploratory phase" variable; this is a dummy variable indicating the project being in the exploratory phase at the start. Some projects commenced from the exploratory phase and, through the development activity, proceeded to the practical application phase. Even so, those begun from the exploratory phase have a greater possibility of creating highly generalized knowledge than projects starting from the application phase. The second variable is a dummy variable to show whether commercialization was intended at outset of the project, named "intention for commercialization". Because NEDO projects are under the jurisdiction of the Ministry of Economy, Trade and Industry, their objective is to promote industrial technology, and in principle all projects are expected to ultimately seek a path to commercialization. But in reality, basic research with no expectation for immediate commercialization also is conducted. In such cases, the respondents answered “initially no intention for commercialization.” Of the sample for this survey, 63% of the responding firms answered that commercialization was intended, so for the remaining 37%, commercialization presumably was not the initial intent. Projects that don’t intend commercialization tend to pursue basic research, and that the technological knowledge produced by their efforts is more highly generalized in nature.

Information exchange

For the information exchange outside the project, we measured both the interaction with people outside the firm and interaction with other divisions within the firm. For interaction outside the firm, we received responses on a five-point scale for the five items “information exchanges with individuals in other firms,” “implementation of technology surveys by other firms and organizations,” “implementation of cost analysis by other firms and organizations,” “implementation of market research by other firms and organizations” and “implementation of patent survey by other firms and organizations,” respectively, and then set the mean of the five values as the variable “information exchange outside the firm” ($\alpha = 0.79$). The reason we included not only communication by project members but also the implementation of various surveys by outside organizations as a component of the variable is the belief that external organizations provide an information channel to the outside, through which information on the actual status and details of development are transmitted.

For interaction with other divisions within the firm, we similarly received responses on a five-point scale for five items, these being “information exchange with individuals in other divisions within the firm,” “implementation of technology surveys by other divisions within the firm,” “implementation of cost analysis by other divisions within the firm,” “implementation of market research by other divisions within the firm” and “implementation of patent survey by other divisions within the firm,” and then set the mean value as the variable “information exchange with other internal divisions”($\alpha = 0.80$).

In addition to these, we captured whether the projects were “joint research” by using a dummy variable. As shown by the hypothesis, the purpose is to examine whether joint research promotes spillovers through additional information channels, or instead hinders spillovers because of agreements governing strict information management.

Strategic intent

With regard to the strategic position of projects within a firm, we used the responses to the question “Is the technology development by this project indispensable for the long-term strategy of your firm” as a dummy variable (Yes = 1, No = 0).

5.2.3 Control variables

We included several control variables in the analysis. One is the project's technological performance. If a project produces excellent technological outcome, that fact alone is likely to attract attention, and will encourage both internal use and use outside the firm because the outcome will be useful for individuals outside the firm as well. We used a five-point scale to ask about "technological performance". The second control variable is the project size. The larger the size of a project, the higher the number of patents generated tends to be, which can be expected to increase the number of citations as well. We measured project size using two variables – "budget size" and "number of project members". The former variable "budget size" can also be construed as an explanatory variable that prods cognitive spillover, while the latter variable "number of project members" partially highlights information exchange outside the project because it indirectly shows the number of information channels to the outside. Finally, because the number of patent citations can be predicted to increase over the passage of time, as a control variable we introduced a "time lag" to show the length of time since the end of a project. Descriptive statistics for each variable, and the correlation matrix are shown in Table 1.

- Table 1: Descriptive statistics and correlation table-

5.2.4 Analytical model

We conducted a regression analysis based on the above variables. For the analysis using the patent citation data as the explained variable, we adopted the tobit model. The reason is there were numerous samples where the number of citations was zero (0), including cases where no patent was applied for. For cases where the dependent variable was on a five-point scale, we used the Ordered Logit model. In addition, when the dependent variable was a composite variable, we made an estimate based on OLS.

6. Results of Analyses

6.1 Influence on technological spillover

Table 2 shows summary of the results.

- Table 2: Multiple regression analysis results-

First, it indicates that more spillover occurs both internally and externally for projects starting at the exploratory phase. Significant relationships were found for all the dependent variables using the patent citation. Although Hypothesis 1-2 suggests the generality of knowledge did not overly influence internal spillover, according to the results, a project staring at the exploratory phase show both higher internal and external spillovers. Likewise, Hypothesis 1-3, stating that spillover to different fields increases as project outcome include more generalized knowledge, also is not supported. Whether in a different field or in the same field, outcome of the projects starting from exploratory phase spill over more than others. Whereas the hypotheses were partially rejected, our hypotheses stating positive relationships between the generalizability of knowledge produced and spillovers are supported overall.

One concrete example of a NEDO project showing this is development of hydrogen fuel cells. This was a project that covered from technology to improve the efficiency of hydrogen production, to product development and evaluation technology related to the practical application of hydrogen gas sensors and vessels for hydrogen gas transport. The objective of the project was narrowly defined from the outset, and application of the technology was clearly limited to hydrogen use. Because practical application was envisaged and development was limited to this use, the technologies developed did not spill over to others even within the firm.

On the other hand "intention for commercialization," another indicator showing the nature of knowledge created, is at odds with the hypothesis and does not have a significant influence on spillover. For technological diversion within the firm, there are rather positive influences. The "intention for commercialization" not only indicates the nature of the knowledge, but may also capture the size of the firm's commitment to commercialization. It may therefore promote internal use of the technological outcome. Likewise, because it is necessary for a product or technology to be completed to some degree for substantive redirection of the application of the technology within a firm, the more a project has made clear its "intention for commercialization," the more likely will be the redirection of the technology's application within the firm.

Next, the results in Table 2 show that the exchange of information by project members with others outside the project has a positive impact on technological spillover. However, only information exchanges with other internal divisions had an influence; the exchange of information outside the firm did not have a significant effect on technological spillover. Important confidential information tend to be controlled so that they are not leaked to outside, meaningful information might not be exchanged during ordinary communication with outside parties. Similarly, in the case of joint research, spillovers beyond project boundaries may not occur because strong controls will be exercised on confidential matters between the joint research parties.

On the other hand, "information exchange with other internal divisions" can be accomplished without being entangled in confidentiality problems.

The example of diversion of desulfurization catalyst technology for light oil to kerosene at “C” Oil Co., Ltd. is an example of a NEDO project where the exchange of information with another division within a firm promoted internal technological spillover. In this development, the developed technology was widely known internally and its commercialization was accelerated because the developers were frequently in communication with the headquarters R&D division from an early stage. Moreover, the project members eventually enjoyed frequent interaction with individuals in the Technology Division as well as the Mass Production Division at the refinery, and their being questioned directly about the possibility of the technology’s application to kerosene served as an opportunity, and the diversion of the desulfurization catalyst technology to desulfurization of kerosene was successful.

Furthermore, we can understand from Table 2 that the more strategically important a project is for a firm, the more spillover outside the firm will be restrained but, on the other hand, the more in-house spillover will be facilitated. On the point of internal spillover within a firm, “indispensable for the long-term strategy” had an significantly positive influence on “technology diversion”. For citations outside the firm, on the other hand, a significantly negative influence can be noted, whether in the same or a different field. This is consistent with Hypothesis 3-1 and Hypothesis 3-2.

6.2 Cognitive spillover and social-relations spillover

For cognitive spillover, the project size didn’t have significantly positive influence on both “impact on society” and “external recognition,” which is not consistent with Hypothesis 4-1. On the other hand, information exchanges with other divisions wihtin the project had a positive impact on both “impact on society” and “external recognition” though information exchanges outside the firm did not have any significant influence on either of the two. Moreover, “impact on society” was related to “technological performance” and “intention for commercialization.” This is understandable because a project has an impact on society to the extent it achieves superior technological outcome. Likewise, we can assent to the idea that the impact on society will grow as a project’s intention for commercialization increases. To the extent the developed technology is realized as a visible product or service, it will stimulate behaviors of other companies since it spread as a strong threat or opportunity.

For social-relations spillover, being joint research has a positive and significant effect on both personnel training and the building of relationships with other companies, consistent with Hypothesis 5-1. Moreover, results show that, while “information exchange outside the firm” have a positive impact on the establishment of relations with other companies, “information exchange with other internal divisions" stimulate personnel development.

7. Discussion

7.1 Two dilemmas faced by public support for private R&D

First, the results in this paper showed that, while spillover of technological outcome outside the firm becomes greater to the extent the project undertakes basic research activities, the spillover of outcome is restricted when a project is of great strategic importance for a firm. This result implies the public institutions providing supports will confront difficult decisions.

In recent years, as government fiscal conditions have become increasingly strained, there has been a tendency to demand visible outcome from public support for private R&D. This has consequently led to a push for innovations that will be linked to economic outcome, not the mere promotion of science and technology, being raised as a policy goal. Considered from this viewpoint, supporting project activities that are strategically important for firms with a significant commitment for commercialization would be the preferred approach. Conversely, support for projects that are in the exploratory phase should be limited. In fact, as our previous study indicated (Aoshima et.al.,2013), whereas there is a significant positive relationship between the level of strategic importance for a firm and commercialization of developed technology, there is a significant negative relationship between commercialization and the extent to which a project is in the exploratory phase when it commences[2]. If what is demanded is the generation of short-term economic value, then from this outcome as well, projects that are strategically important for firms and projects that have advanced to the commercialization phase should be the targets for public support. Under such an approach, however, spillover to society outside the firm boundary could not be expected; and the very justification for providing public support would be shaken. In other words, if considered from this aspect, the issue becomes the difficulty of compatibility between the pursuit of commercialization and the pursuit of spillover effects to society. Once this is understood, however, facilitating steps to make both goals as compatible as possible might be feasible. For example, when supporting projects with great strategic importance for firms, goals that would be considered might include the intention to announce and release the outcome widely to stimulate spillover of the outcome as much as possible, or putting together a well-balanced portfolio of projects in the exploratory phase and projects in the commercialization phase.

Second, the results showed that the exchange of information with outside parties that went

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[2] For the relationship to commercialization of the results, see Aoshima, Matsushima, and Eto (2013).

beyond the project, and information exchange with other divisions within the firm in particular, induced not only technical spillover but also cognitive spillover and social-relations spillover. Thus, management mechanisms for promoting information exchanges with outside parties become critical for stimulating the spillover. From this point of view, it may be necessary for public institutions supporting the project to confirm that the projects are not isolated internally receiving assistance and cooperation from other divisions.

Supporting institutions face one more dilemma, however. As indicated by our previous study, information exchanges with other internal divisions tend to decrease significantly as NEDO accounts for a larger share of the project budget. That is, information exchanges with outside parties decrease as the amount of public support increases, which weakens the spillover effect of the project outcome.

From a firm's viewpoint, projects that receive public support can become a window that leaks information to the outside. Publicly supported projects must regularly announce and disclose their outcomes. Of course, while this makes management of information disclosed outside the project prudent, it is understandable that other projects within a firm will tend to avoid interaction with a publicly supported project because disclosure at a level that will enable evaluators to understand the development details and their value is required. Moreover, the fact that a project is isolated from a firm's internal resource allocation process as a result of receiving public support also will work in the direction of curtailing information exchange with other divisions. R&D projects at firms regularly engage in activities to emphasize the significance and validity of their activities, in order to garner their budgets. Details of their research will be transmitted to others during this process. Projects being managed with 100% public support can dispense with such activity. Because they do not rely on internal resources, they have no need to be complained by anyone, and no need to persuade anyone. This may promote the informational isolation of such projects within a firm, however.

With their understanding of the existence of such a dilemma, what public institutions should consider is not only providing financial supports but also preparing, as much as possible, devices to ensure projects are not isolated internally.

7.2 Contributions and limitations of the study

One contribution of the present study is to empirically clarify the factors and mechanisms that stimulate spillover at the project level. Another contribution could be that we have empirically investigated the fact that, even with a tendency to demand greater economic outcome from public support to private R&D, there is a contradictory aspect to the pursuit of social value and promoting commercialization by private firms. Nevertheless, there are several limitations as well.

The first is the limitations concerning the measurement of spillover. In the present study, we adopted the method of quantitatively understanding spillover based on patent citations, and supplementing this with subjective responses by means of a questionnaire. Pion patent citation data, however, enables us to capture only a part of the spillover. Firms that were stimulated by development at other firms might attempt development using proprietary technology, without citing others' patents. Moreover, even when the commercialization of technologies developed with public supports significantly fosters complementary product markets or supplier industries, in which we can identify a clear spillover effect, we cannot sufficiently capture this from patents.

Furthermore, although distinctiveness of the present study is to distinguish technical spillover in the same field from that into a different field, we were unable to observe any difference in the factors arising from differences in the spillover fields. We believe this is because, while the number of patent citations have a large influence, the similarity of the citation source and citation recipient is not sufficiently reflected in the indicator.

In this paper we classified spillover effects systematically, and also referred to not only the technological spillover that has been noted in existing research but to cognitive spillover and social-relations spillover as well, and analyzed factors having an influence on these. However a measurement of cognitive and social-relations spillover relies on subjective ratings from the side that carried out the projects, an approach that must be deemed inadequate. Supplementing this with a survey of other companies and individuals that have been recipients of spillover is perhaps necessary.

A second limitation is insufficient compatibility with existing research. Our study, as factors stimulating spillover, mainly noted the internal factors residing in source projects such as the nature of the knowledge generated, the exchange of information with parties outside the project, and the strategic importance for the firm. On the other hand, we have not dealt with factors at the industry level or inter-firm level that have been clarified by existing research, including geographic proximity, complementary assets, absorptive capacity, the industry's stock of knowledge, or other factors on the side of spillover recipient firm. We need to undertake an analysis that encompasses both the factors that have been dealt with by existing research, and the factors at spillover source firms that are addressed by the present study.

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External	Spillover and diffusion of technological outcome outside a firm	Unexpected application and diffusion of technological outcome outside a firm	External recognition	Construction of relationships between firms
Internal	Pump-priming effect of R&D investment within a firm	Technology diversion within a firm	Internal recognition (Development legitimacy within a firm)	Personnel training effect within a firm
	Same field	Different field	Cognitive spillover	Social-relations spillover
	Technological spillover			

Figure 1: Classification of spillover effects

- Table 1: Descriptive statistics and correlation table-

		Mean	S. D.	N	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	Total number of citations	7.76	24.41	301																								
2	Influence in the same field	4.15	13.50	301	.960**																							
3	Influence on different fields	3.61	12.06	301	.950**	.824**																						
4	Number of internal citations	2.12	9.47	301	.851**	.740**	.894**																					
5	Influence in the same field (Internal)	0.99	4.58	301	.861**	.839**	.803**	.902**																				
6	Influence on different fields (Internal)	1.13	5.70	301	.722**	.555**	.840**	.938**	.695**																			
7	Technology diversion	3.25	1.22	269	.076	.070	.074	.091	.117	.062																		
8	Number of external citations	3.76	10.75	301	.891**	.925**	.768**	.629**	.701**	.481**	.088																	
9	Influence in the same field (External)	2.10	6.86	301	.771**	.873**	.583**	.499**	.588**	.357**	.066	.946**																
10	Influence on different fields (External)	1.67	4.80	301	.892**	.822**	.885**	.694**	.729**	.567**	.101	.887**	.689**															
11	Development legitimacy	3.52	0.83	269	.118	.102	.120*	.102	.128*	.072	.233**	.073	.025	.126*														
12	External recognition	3.57	0.81	269	.069	.076	.053	.035	.034	.031	.201**	.056	.058	.040	.609**													
13	Impact on society	2.83	0.91	269	.102	.107	.084	.118	.085	.125*	.289**	.109	.123*	.063	.268**	.295**												
14	HRD	3.83	0.66	269	.198**	.177**	.196**	.185**	.167**	.172**	.187**	.158**	.126*	.167**	.340**	.320**	.262**											
15	Network	3.87	0.73	268	.127*	.116	.124*	.119	.093	.120*	.171**	.127*	.107	.125*	.185**	.250**	.240**	.371**										
16	Joint research	0.47	0.50	270	-.034	-.069	.008	-.018	-.058	.011	-.070	-.059	-.078	-.018	-.105	-.081	-.064	.122*	.177**									
17	Indispensable for the long-term strategy	0.10	0.30	271	-.054	-.041	-.062	-.018	.009	-.034	.176**	-.077	-.054	-.091	.114	.112	.030	.027	-.044	.067								
18	Intention for commercialization	0.63	0.48	271	.057	.071	.035	.045	.073	.020	.277**	.076	.077	.056	.038	.132*	.175**	.022	-.100	-.193**	.145*							
19	Exploratory phase	0.81	0.40	273	.094	.077	.096	.068	.043	.073	-.053	.082	.052	.102	-.028	-.113	-.053	.053	.039	.023	-.155*	-.128*						
20	Information exchange with other internal divisions	3.17	0.88	270	.156*	.128*	.166**	.128*	.110	.123*	.250**	.111	.071	.144*	.231**	.152*	.276**	.253**	.128*	-.040	.093	.296**	-.134*					
21	Information exchange outside the firm	2.68	0.95	270	.123*	.090	.144*	.143*	.138*	.127*	.182**	.035	-.003	.082	.155*	.117	.247**	.161**	.179**	.033	-.024	.130*	-.200**	.423**				
22	Budget size (□ 1M)	3660.72	2987.53	245	.107	.146*	.056	.033	.032	.031	-.055	.162*	.178**	.083	.028	.040	.148*	.069	.036	-.121	-.015	.035	.056	.044	.115			
23	Number of members	23.29	182.33	270	-.021	-.021	-.019	-.015	-.016	-.013	.046	-.022	-.019	-.021	.044	-.035	.064	.023	.099	.060	-.009	.058	.021	.092	.071	-.051		
24	Time lag	10.75	2.72	272	.087	.109	.054	.027	.093	-.007	.006	.122*	.111	.100	.011	.012	-.012	.137*	.141*	.056	-.107	-.308**	.074	-.247**	-.131*	-.017	.051	
25	Technological performance	3.80	0.79	269	.113	.128*	.083	.127*	.146*	.097	.241**	.095	.097	.069	.335**	.381**	.289**	.206**	.254**	-.102	.162**	.159**	-.104	.146*	.155*	.138*	.026	-.061

Note: *p<0.05, **p<0.01.

- Table 2: Multiple regression analysis results-

	Technological spillover									
	Total			Internal				External		
	Total number of citations	Influence in the same field	Influence on different fields	Number of internal citations	Influence in the same field	Influence on different fields	Technology diversion	Number of external citations	Influence in the same field	Influence on different fields
	tobit	tobit	tobit	tobit	tobit	tobit	OLS	tobit	tobit	tobit
Constant	-112.015 ***	-57.618 ***	-73.065 ***	-124.393 ***	-45.500 ***	-126.363 ***	.201	-59.883 ***	-42.336 ***	-30.874 ***
	(21.806)	(11.400)	(14.172)	(29.338)	(10.640)	(31.399)	(.597)	(12.876)	(9.666)	(6.275)
Budget size (□ 1M)	.002 *	.001 **	.001	-.001	.000	.000	.000 *	.001 ***	.001 ***	.000 *
	(.001)	(.000)	(.000)	(.001)	(.000)	(.001)	(.000)	(.000)	(.000)	(.000)
Number of members	-.139	-.087	-.063	-.278	-.140	-.055	.000	-.013	-.009	-.007
	(.202)	(.107)	(.125)	(.248)	(.093)	(.208)	(.000)	(.026)	(.019)	(.012)
Time lag	3.657 ***	1.889 ***	2.311 ***	2.474 **	1.015 ***	1.960 **	.075 ***	2.023 ***	1.367 ***	1.015 ***
	(.935)	(.486)	(.599)	(1.065)	(.380)	(.945)	(.028)	(.536)	(.402)	(.257)
Technological Performance	2.775	1.967	.454	5.785	2.090	5.339	.191 **	1.332	.895	.250
	(2.955)	(1.551)	(1.885)	(3.569)	(1.275)	(3.291)	(.094)	(1.708)	(1.285)	(.813)
Joint research	4.071	.637	3.117	3.054	-.299	3.263	-.042	-.451	-1.167	.696
	(4.671)	(2.429)	(3.001)	(5.335)	(1.916)	(4.815)	(.149)	(2.710)	(2.035)	(1.298)
Indispensable for the long-term strategy	-14.043	-5.849	-7.937	7.505	4.502	.350	.652 **	-12.592 **	-7.634 *	-6.682 **
	(9.022)	(4.626)	(5.716)	(8.545)	(3.051)	(8.373)	(.253)	(6.204)	(4.501)	(3.050)
Intention for commercialization	7.103	4.579	2.806	4.640	2.092	-.987	.663 ***	2.458	2.777	1.059
	(5.271)	(2.774)	(3.367)	(6.213)	(2.218)	(5.432)	(.165)	(2.987)	(2.276)	(1.435)
Exploratory Phase	16.035 **	8.341 **	10.275 **	17.887 **	7.029 **	29.621 **	.150	11.410 ***	8.000 **	5.441 ***
	(6.426)	(3.368)	(4.169)	(8.130)	(3.042)	(11.676)	(.186)	(4.052)	(3.070)	(1.930)
Information exchange with other internal divisions	10.472 ***	4.823 ***	8.155 ***	8.579 **	2.753 **	8.759 **	.222 **	5.125 ***	3.289 **	3.121 ***
	(3.190)	(1.647)	(2.127)	(3.778)	(1.344)	(3.573)	(.093)	(1.828)	(1.369)	(.902)
Information exchange outside the firm	-1.832	-1.510	-.684	2.292	1.103	1.853	.147 *	-2.351	-1.798	-.696
	(2.823)	(1.469)	(1.784)	(3.190)	(1.161)	(2.878)	(.087)	(1.628)	(1.210)	(.773)
R-Squared (Pseudo)	.036	.043	.043	.043	.063	.063	.179	.053	.055	.064
Log Likelihood	-537.877	-459.903	-441.614	-219.716	-169.327	-173.049		-393.732	-338.696	-317.244
N	239	239	239	239	239	239	239	239	239	239

Note: *p<0.1, **p<0.05, ***p<0.01. Upper row is the unstandardized coefficient; lower row is the standard errors.

- Table 2: Multiple regression analysis results (continued)-

	Cognitive spillover			Socially-related spillover	
	Internal	External		Internal	External
	Development legitimacy	External recognition	Impact on Society	HRD	Network
	Orderd Logit	Orderd Logit	OLS	Orderd Logit	Orderd Logit
Constant			.327		
			(.462)		
Budget size (￥1M)	.000	.000	.000	.000	.000
	(.000)	(.000)	(.000)	(.000)	(.000)
Number of members	.000	-.001	.000	.000	.006
	(.001)	(.001)	(.000)	(.001)	(.011)
Time lag			.030		
			(.022)		
Technological Performance			.214 ***		
			(.073)		
Joint research	-.599 **	-.313	-.017	.597 **	.795 ***
	(.263)	(.259)	(.115)	(.287)	(.293)
Indispensable for the long-term strategy	.729 *	.461	-.123	.062	-.189
	(.436)	(.424)	(.196)	(.466)	(.451)
Intention for commercialization	-.379	.305	.250 *	-.082	-.268
	(.281)	(.273)	(.128)	(.296)	(.304)
Exploratory Phase	.166	-.321	.130	.325	.292
	(.327)	(.324)	(.144)	(.358)	(.353)
Information exchange with other internal divisions	.480 ***	.281 *	.215 ***	.578 ***	.162
	(.163)	(.158)	(.072)	(.178)	(.181)
Information exchange outside the firm	.212	.185	.111	.091	.346 **
	(.155)	(.154)	(.068)	(.167)	(.168)
R-Squared (Pseudo)	.041	.033	.141	.045	.049
Log Likelihood	-271.593	-278.624		-223.125	-230.272
N	240	240	239	240	239

Note: *p<0.1, **p<0.05, ***p<0.01. Upper row is the unstandardized coefficient; lower row is the standard errors.