Effects of government funding on R&D performance leading to commercialisation

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Abstract: This paper draws on data obtained from a questionnaire survey conducted for the 242 private R&D projects supported by NEDO (New Energy and Industrial Technology Development Organisation), Japan's public management organisation promoting R&D, to explore how dependence on government support affects processes of private R&D projects and, in turn, the performance and commercialisation of developed technologies.

Our analyses show that projects receiving more than a half of their entire R&D expenditures from NEDO tend to be isolated from in-house departments. Such isolation, derived mainly from the projects' unique positions in 'double dependence' structures, negatively affects project performance, especially those related to commercialisation, in two ways.

First, high dependence on government resources prevents project members from interacting with people outside the project within the company. This inhibits project members from effectively leveraging internal resources –both technological and human– to overcome technological problems. Secondly, such high dependence weakens internal controls over project activities. This causes delayed development of marketable technologies and makes it difficult for projects to achieve justification for further investment required for commercialisation.

Our findings suggest that for successful R&D leading to commercialisation, both companies and public funding agencies should encourage projects to maintain close relationships with other internal departments.

Keywords: government fundings; R&D performance; 'double dependence' structures; commercialisation; private R&D project.

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1 Performance of government funding for R&D activities in private sectors

Although government support for private R&D has exhibited a downward trend in countries around the world in recent years, including a reduction in the US military budget, for example, such support remains at a scale that cannot be ignored. In Japan, for example, nearly 20% of the 19 trillion yen in R&D expenditures by the private sector was supported with government funding in 2008 (Japan Ministry of Education, Culture, Sports, Science and Technology, National Institute of Science and Technology Policy, 2009).

For many countries, innovation that will create economic values has become a vital issue as the maturation of many industries accelerates in tandem with increasingly severe global competition. Given such circumstances, in recent years there has been no lack of instances in which government funding has flowed not only into basic research, but into applied research and product development that will lead to commercialisation as well.

In the USA, the Bayh-Dole Act that was enacted in 1980 and enables firms to retain ownership of the results from government funded R&D, is said to have accelerated R&D undertaken by private firms with government support and commercialisation of the R&D results. In response to this change, the so-called 'Japanese-version Bayh-Dole Act' (Act

on Special Measures for Industrial Revitalisation, Article 30) was enacted in Japan as well in 1989, making it easier for firms to receive government support for the development of technology that differentiates their products in the market.

On the other hand, as the fiscal condition in each country has become tight, the use of public funds is being subjected to sharp public scrutiny. The merits of such uses are especially easy to question when public funds are lavished on R&D in a way that encourages commercialisation at specific firms.

Under such conditions, it is no longer possible to steer around questions asking "Does government funding really promote private R&D activities?" and "Why should we spend our tax money on private sector activities?" when deciding appropriate government funding measures.

Among existing research there are many studies that have attempted to quantitatively clarify the effects of government funding at the industry and national levels (David and Hall, 2000; David et al., 2000; Hall and Van Reenen, 2000). On the other hand, there is little research that looks at R&D processes conducted by government-funded projects from a micro-economic viewpoint. To use public funds effectively, however, it is necessary to understand not only the results at the macro level, but to also supplement such understanding with an analysis of the specific processes by which projects achieve their results.

Particularly when government support extends even to applied research and product development, and the results from development belong to a specific firm, determining whether firms are able to create new businesses from R&D and create economic values becomes an important factor for measuring the effects of government funding. From this perspective as well, research on the project level management is needed.

Investigating the project management of government-funded R&D also raises several theoretical questions since it is distinct from those of ordinal private R&D projects.

Government funding is significant in promoting R&D that, despite its importance, tends to suffer from underinvestment if left to the private sector (Nelson, 1959; Arrow, 1962). By liberating R&D activities from the severe and short-term profit pressures at profit-seeking enterprises, government funding has an effect of promoting R&D with a long-term view.

For that very reason, however, the commercialisation incentives could be inhibited for R&D projects that are exempted from the severe selection process within private firms. With public institutions that support R&D as well, some doubt remains – despite project evaluations being conducted by teams of experts – as to whether such institutions are capable of making appropriate assessments concerning the possibility of commercialisation. Moreover, projects might be isolated organisationally or professionally from other internal departments, and the ability to exchange information within the firm obstructed, as a result of receiving government funding. There is also a possibility the use of human and technical resources within a company will be restricted due to such isolation. Differing from typical R&D projects at private firms, government-funded R&D projects need to consider these additional issues.

Based on such an awareness of the problem, this paper seeks to empirically identify the factors that determine a success or a failure of commercialising government-funded private R&D activities, by analysing data obtained from a follow-up questionnaire survey concerning projects supported by the New Energy and Industrial Technology Development Organisation (NEDO) ('NEDO projects') in Japan. NEDO, having over $2,700 million obligations under the direction of the Ministry of Economy, Trade and

Industry (METI), provides support for private sector R&D activities with a particular emphasis on economic results. The authors believe this will provide a suitable exploratory environment for measuring the effect of government funding from the point of whether commercialisation is or is not pursued.

2 Existing research

Much of the existing research has focused on the increase or decrease of R&D investment at private sectors after the receipt of public funds in order to identify the effects of public supports (Levy, 1990; Levy and Terleckyj, 1983; Busom, 2000; Almus and Czarnitzki, 2003; Guellec and Van Pottelsberghe, 2003; Duguet, 2004; González and Pazó, 2008). In this approach, if R&D expenditures in private sectors were reduced by the injection of government funding, public funds would be judged to be merely an alternative to private sector capital and to have no additional effect. If the private sector was found to boost its R&D outlays, on the other hand, such funding could be judged to have an additional accelerative effect.

There are, however, problems with the idea itself of understanding the effect of government funding from the increase or decrease in R&D spending at private sectors (Matsushima, 2011). For example, during an economic downturn, a firm that is experiencing a business slump and seen its spending capacity wither might have no alternative but to abandon some ongoing R&D projects even if the long-term importance of the projects is high. When government supports R&D activity that can no longer be carried out because of a business slump, even if such government funding is mere 'substitution' and is available only temporarily, this may be an effective alternative for encouraging private R&D activity.

Conversely, there might also be some instances where a private firm looks to government funding simply to play technological races with competitors, even though it has no strong intention of commercialising its R&D results. In other cases, public funds might be allocated to projects that have not been approved internally because of researchers' specific or narrow individual interests. In such instances, it is difficult to say the public funds were used effectively even if private firms' R&D expenditures were maintained or increased. This is all the more true if patents developed through a government-funded project belong to a specific firm but are merely hoarded and are not commercialised.

Therefore, it is necessary to ascertain, especially when providing government funding for R&D activities aimed at commercialisation, whether such funding is in fact linked to commercialisation and creating economic value. To do so, we must shift a unit of analysis down to the individual project level and investigate the details of the R&D management.

There are some existing studies, in this respect, that have looked at the relationship between government funding and performance of private R&D projects (Bérubé and Mohnen, 2009; Cockburn and Henderson, 1998; Czarnitzki and Hussinger; 2004; Czarnitzki and Licht, 2006; Czarnitzki et al., 2007).These studies tend to analyse the correlation between the government funding and R&D performance by taking the presence or lack of government funding as an independent variable, and the number of patents applied or received as a dependent variable[1]. These studies report that, on

average, the acceptance of public funding has a positive influence on performance, although it is conditional.

These researches are, however, insufficient for appropriately grasping the effects of government R&D support. First, the number of patents obtained cannot directly capture the contribution to commercialisation. The government funding might be judged to be ineffective from the standpoint of creating economic value if the patent is not commercialised and is held idly inside the firm. Secondly, the existing researches do not fully clarify the causal mechanisms that the government funding produces the economic results.

In such contexts, this study looks at government-funded projects with the goal of empirically clarifying the mechanisms that produce commercialisation results, while noting the unique management issues pertaining to government funded projects.

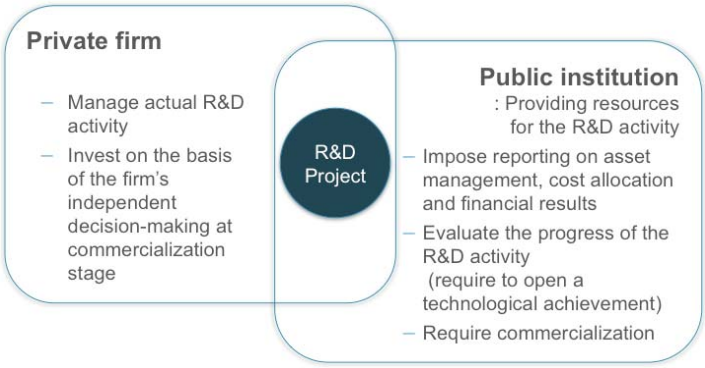
3 Issues on government funded project: deriving hypotheses

3.1 The problem of dual dependency

Government funding for private R&D activities is broadly divided between direct support and indirect support. The latter – indirect support – refers to tax exemption for R&D investments. The former – direct support – is further divided into 'contracts' and 'assistance.' A 'contract' is a provision of funds to procure the products and services that government agencies use. 'Assistance,' on the other hand, is the provision of funds for the R&D activities conducted at private firms, primarily in the form of grants or subsidies.

The present study looks at 'assistance,' and when government funding is discussed in the following sections it refers to 'assistance' in this sense[2]. The 'assistance' further ranges from providing support for basic research for broadly disseminating scientific knowledge to providing support for R&D activities aimed at commercialisation. The present study particularly concerns the latter.

Figure 1 Dual dependency of government funded R&D project (see online version for colours)



Government funded projects have distinctive characteristics that differ from those of ordinal private R&D projects, in that the R&D is placed under the dual control of both

the support entity (public institution) and the receiving entity (private firm) as indicated in Figure 1.

Because government funded projects depend on public funds, various obligations, including reporting on asset management, cost allocations, and financial results, are imposed along with the requirement to evaluate the progress of the R&D activity. The actual R&D activity, on the other hand, is placed under the management of private firms. Moreover, despite being dependent on public funds and subject to progress management during the R&D phase, investments are made on the basis of the firm's independent decision-making at the commercialisation stage.

Because of this dual nature, government funded projects possibly face the following two problems. One is the "disruption of exchanges of information with other in-house departments." The other is the "weakened controls concerning commercial feasibility."

3.2 Disruption of exchanges of information with other in-house departments

By isolating R&D activity from the resource allocation process at the private firms that demands strict profitability, government funding can ensure the continuation of development activity that is considered to be socially important. Because of this very isolation, however, there is a possibility that the exchange of information with other divisions within the firm will be hampered.

Normally a condition for government funding is that equipment purchased and technical knowledge developed with government funds will be used only for the project, and the leveraging facilities and knowledge to other internal activities (during the project period) is restricted. Consequently it is difficult for other in-house projects to benefit directly from the government-funded project in question.

Moreover, because of the obligation to publicly disclose the details of research results in the evaluation phase, government funded projects are likely to become an 'opening' through which internal information leaks outside the firm. Of course, in making the results public, a company will take sufficient care to ensure that the information does not work to its detriment in the competitive marketplace. Developed technologies also can be protected as patents[3]. In cases where patents will not be used effectively in the future, however, it is usual to establish the condition that the public institution will exercise the rights to the R&D results, and it is not always possible to fully ensure the avoidance of an information spillage in the future. Given such circumstances, there is certainly nothing odd if other divisions within a company have become nervous about sharing information with a government funded project. An especially cautious response to this problem is required when a government funded project will be undertaken jointly with another company.

Moreover, when a government funded project is conducted with collaborating firms at a geographically isolated lab (which called 'centralised lab system'), there is a possibility the free exchange of information or joint activity with other internal divisions will be limited. Such limits are likely to be especially prevalent when a project is supported entirely by public funds. This is summarised as the following hypothesis.

Hypothesis 1 The higher a project's dependence on government funding, the greater the restrictions on the exchange of information with other internal divisions.

3.3 Weakened controls concerning commercial feasibility

Government funding can provide a good reason for the continuity of R&D project on which for-profit firms, without it, would not invest due to high uncertainty or large risk. Precisely for that reason, however, there is a possibility that checks on the business profitability of projects that receive government funding will be weakened compared with other regular internal R&D projects. Of course, the public supporting institution is also likely to evaluate the status of the project's progress including commercial feasibility. In some cases, the support will be cut off when the progress reports are not encouraging. It is difficult to conceive of such an evaluation process accurately reflecting business profitability, however.

Because the size of the investment necessary for actual commercialisation will differ from the amount required in the R&D phase, a firm will make a prudent decision after considering its own strategy and available resources. It is impossible, however, for the support entity (or auditor chosen by the support entity) to fully understand the internal circumstances of the firm, such as its corporate strategy and the resources it possesses. Therefore, in many cases an evaluation by the support entity must be based on a progress report that focuses only on the technology development.

On the other hand, government funded projects that depend only minimally on internal resources will not be subjected to sharp scrutiny concerning business profitability. Such projects can also easily float above the internal 'horse trading' process through which the regular in-house developers struggle for their annual budget provision. This discussion can be recapitulated as the following hypothesis.

Hypothesis 2 The higher a project's dependence on government funding, the lower the internal participation pertaining to commercial feasibility.

3.4 Impact on development performance

Both of the two hypotheses discussed above – "disruption of exchanges of information with other in-house departments" and "weakened controls concerning commercial feasibility" – could have a negative influence on performance of government funded R&D projects.

First the disruption of information exchanges with other in-house departments may have the negative impact on the technical problem-solving activities. In the process of problem solving, other internal R&D activities and past experience are exploited in no small way. Limiting access to the ample technical, human, and information resources that have been accumulated internally will most likely work to the disadvantage of progress in resolving technical problems. Conversely, a project that has achieved an effective use of internal resources, despite of its high dependence on government funding, will be more likely to produce higher technological performance. This leads to the following hypothesis.

Hypothesis 3-1 The greater the exchange of information with individuals in other internal divisions, the greater the technological development performance of a project.

Frequent communications with other people within the company has another effect – it also increases the likelihood of commercialisation of the project results. Unlike in the

development phase, significant internal resources must be mobilised for commercialisation. For this purpose, it is necessary not only to plead the significance of the technological results but also to obtain broad agreement within the company from various viewpoints, including the profitability of the business, the future prospects for the technology and the contribution to the firm's long-term strategy (Takeishi et al., 2008). Frequent communication with other internal divisions during the R&D phase may be effective in obtaining such mutual consent. The reason is that helping the various internal people to understand the details and prospects of the technological development from an early stage can lead to acquiring legitimacy in the commercialisation phase. This is summarised as the following hypothesis.

Hypothesis 3-2 Acquiring legitimacy for commercialisation of a project is easier when there is frequent exchange of information with other internal divisions over the term of the project.

On the other hand "weakened controls concerning commercial feasibility" may first influence the problem solving activities related to cost issues. In order to commercialise the developed technology, it must clear the problems of mass production that influence product's cost and quality. If controls on feasibility grow lax, however, a project can focus purely on technical breakthroughs and problem solving (which is likely to enhance the technological performance), but there is a possibility the cost problems will be relatively downplayed. Conversely, project members are likely to proceed with development while conscious of mass production requirements, if the internal checks for feasibility are performed.

Furthermore, the continuous involvement of other internal divisions concerning feasibility will have a positive influence on the acquisition of legitimacy for commercialisation. This is because the checks on commercial feasibility that have been performed from the R&D phase are tied to obtaining internal consent concerning commercialisation of the developed technology. The above discussion can be summarised as the following two hypotheses.

Hypothesis 4-1 The greater the internal participation pertaining to commercial feasibility, the greater the progress in resolving cost problems.

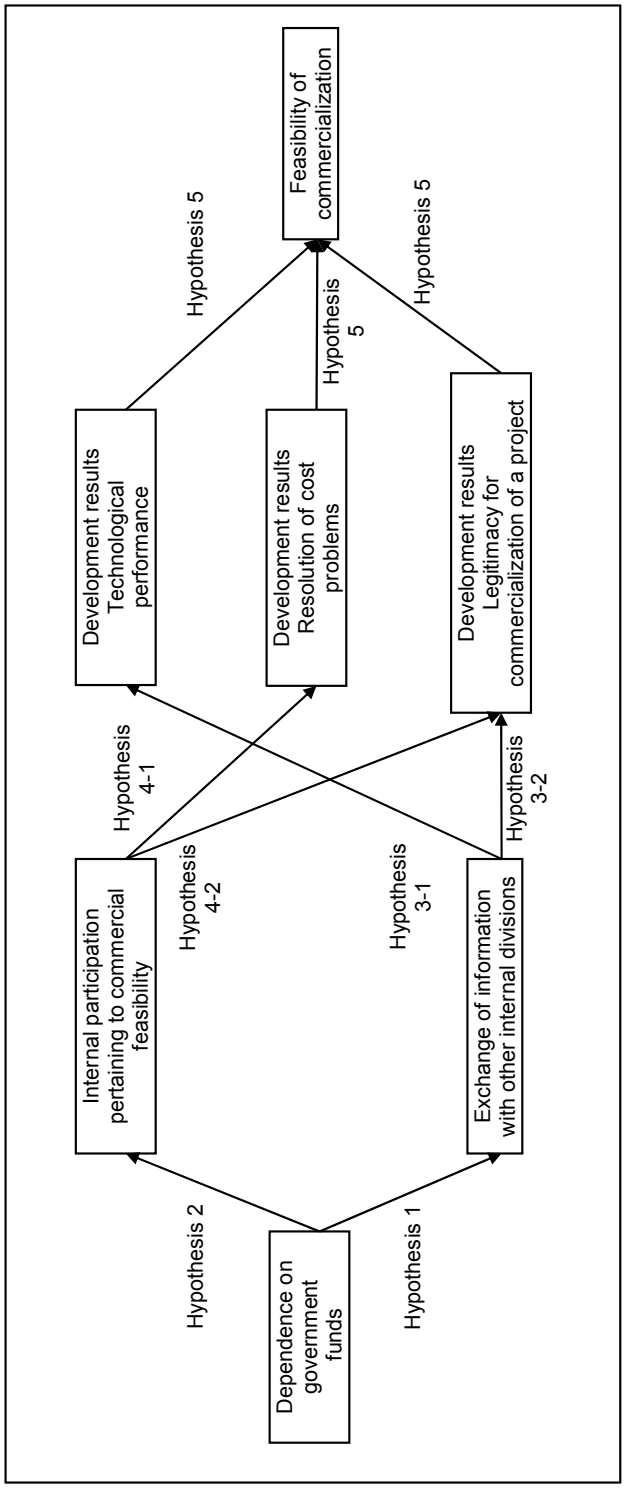
Hypothesis 4−2 The greater the internal participation pertaining to commercial feasibility, the easier it is for commercialisation of a project to acquire legitimacy.

Finally, we hypothesise hat each of the three performance indicators, 'technological performance,' 'acquisition of legitimacy,' and 'resolution of cost problems,' involved in the above hypotheses, improves the feasibility of commercialisation of a project's results. This can be summarised as follows.

Hypothesis 5 Each of technological performance, acquisition of legitimacy, and resolution of cost problems increases the possibility of commercialisation of the technology that a project has developed.

The analytical framework showing a synthesis of the above hypotheses is provided in Figure 2. Beginning from the following section we will proceed with a specific data analysis along lines that follow this framework.

Figure 2 Hypotheses and analytical framework



4 Research method

4.1 Summary of survey and samples

We will test the above hypotheses by using data from follow-up surveys implemented by NEDO in June 2009 (112 responses: a response rate was 100%) and by NEDO and Hitotsubashi University jointly in August 2010 (301 responses: a response rate was 88%). Both follow-up surveys, including the same questions, are questionnaire surveys for R&D projects conducted at private firms to which NEDO has provided financial assistance. Each questionnaire was sent to a leader of the company who had taken charged of the project in question, which had, in some cases, involved multiple companies. In most cases the leaders answered the questionnaires by themselves. We acknowledged the limitation of data obtained by one person for each questionnaire though the leaders were supposed to have relatively unbiased information for the sample projects that had included 6.6 members on average.

Twenty nine respondents answered both surveys, for which we excluded the 2009 survey responses from the analysis. The resulting 384 samples are divided into four categories: 83 projects that resulted in a product market launch (commercialisation) (referred to below as 'a product launch'), 159 projects that were implemented but terminated (referred to below as 'a project termination'), and 110 projects are continuing R&D within own companies following NEDO supported activities. We also have 32 unavailable responses. For the present study we used the total of 242 samples for either a product launch or a project termination.

Specifically the surveys ask questions, on a project basis, on topics such as the management and performance of the projects, the economic environment and market conditions in which the projects were implemented, and the broad effects on society and the economy as a result of project activities.

Sample characteristics are as follows. The industries that the sample project firms belong to range from automobiles, electronic devices, materials, and chemicals. The size of the firms is between more than 30,000 employees on a consolidated basis to less than 100 employees, with consolidated sales extending from over 2.0 trillion yen to less than 100 million yen. The number of years since establishment ranges between three years to 120 years. Although, in principle, all the NEDO supported projects need to envision commercialisation in the future, expectation for that differs from company to company. Firms that had clearly envisaged a product launch at the outset accounted for 64% of the total sample, and accounted for 74% of the entire sample when firms that succeeded in a product launch without clear initial plans for commercialisation are also included.

4.2 Operationalisation

In the following paragraphs we discuss the regression analysis divided into three phases and the structural equation model integrating them in accordance with the analytical framework in Figure 2. First, with regard to Hypothesis 1 and Hypothesis 2, we performed a regression analysis for the influence the extent of dependency on public funds exerts on "the exchange of information with other internal divisions" and "internal participation pertaining to commercial feasibility." Next, for Hypothesis 3 (3-1 and 3-2) and Hypothesis 4 (4-1 and 4-2), we analysed the influence "the exchange of information

with other internal divisions" and "internal participation pertaining to commercial feasibility" exert on the three types of project performance, namely 'technological performance,' 'resolution of cost problems' and 'acquisition of legitimacy.' For Hypothesis 5, we analysed the influence these three types of performance exert on 'commercialisation,' after controlling other factors that affect commercialisation. Finally, by analysing a series of structural equation models, we verified the causal paths.

The variables used for the analysis are described in Table 1. "Dependence on public funds" highlights the extent of dependency on public funds as illustrated by the ratio of funds from NEDO as a share of all R&D expenditures for the project. We defined dependency on NEDO for 50% or more of a project's funding as 'high,' which we measured as a binary (dummy) variable showing whether it corresponds to 'high.'

"The exchange of information with other internal divisions" uses a variable to measure the extent of "communications with other internal divisions" along a five-point scale. "Internal participation pertaining to commercial feasibility" is a composite variable (mean value) to measure the extent of implementation of both a "cost analysis by other internal divisions" and a "market analysis by other internal divisions," according to a five-point scale (α is 0.68).

Project performance was captured from the three aspects: 'technological performance,' 'resolution of cost problems,' and 'acquisition of legitimacy.' 'Technological performance' is a composite variable (mean value) used to measure the extent to which technological issues are overcome and development accelerated, and 'acquisition of legitimacy' is a composite variable (mean value) used to measure both the extent to which development legitimacy is secured internally and increased external awareness, according a five-point scale (α are 0.67 and 0.75, respectively)[4]. 'Resolution of cost problems' is a variable to measure the extent to which cost issues are overcome, using a five-point scale.

With regard to whether a project is commercialised, the sample projects were originally classified into 'a product launch' and 'a project termination'[5].

We also added several control variables. As an alternative hypothesis to Hypothesis 1 and Hypothesis 2, communications with individuals in other internal divisions can be anticipated to grow, and in-house participation concerning commercial feasibility expected to increase, when a project is already near the commercialisation phase at the outset. Therefore, we added "number of members responsible for commercialisation at the start of the project" and "basic research (a dummy variable to show a project is at the basic research phase at the time of start-up)," to control for proximity to the commercialisation phase at the time of project initiation. Furthermore, because the exchange of information with other internal projects can be restricted in order to maintain confidentiality when a project is a collaborative one with other companies, we introduced a dummy variable to show a project is a "collaborative project with other companies."

We also introduced 'number of members participating in project' as a control variable, for Hypotheses 3 and 4, because it might directly influence project performance.

Finally, we considered the following control variables as affecting commercialisation. First, we captured changes in a project's external environment through two questions: "Did the economy deteriorate more than expected? (Unexpected deterioration of the economy)" and "Did the business strategy within the organisation change and the project diverge from the original orientation after the project had been completed? (Divergence because of change in business strategy)" Both are dummy variables to show whether the above questions apply.

In addition, we looked at the degree to which the technology developed by the project attracted attention, which also indirectly indicates the competitive environment, by asking, "Has this technology already broadly attracted attention in society and are many firms developing the technology? (Extent of external awareness and competition) " That the technology in question had attracted society's attention meant that market growth could be anticipated, but also that appropriating profits might be difficult because the market would be competitive. Therefore, it is possible this variable could influence commercialisation positively or negatively.

Table 1 Description of variables

Name of variables	*Consisting items*
Dependence on public funds	The ratio of NEDO funds as a share of all R&D expenditures for the project is more than 50% (dummy variable: yes = 1, No = 0)
Communications with other internal divisions	Exchange of information with other internal divisions (five-point scale)
Internal participation pertaining to commercial feasibility* ($\alpha = 0.68$)	A cost analysis by other internal divisions was implemented (five-point scale)
	A market analysis by other internal divisions was implemented (five-point scale)
Technological performance* ($\alpha = 0.67$)	Technological problems were resolved (five-point scale)
	A development process was accelerated (five-point scale)
Resolution of cost problems	Cost problems were resolved (five-point scale)
Acquisition of legitimacy* ($\alpha = 0.75$)	Development legitimacy was internally secured (five-point scale)
	Importance of the technology developed by the project became aware externally (five-point scale)
Commercialisation	The project resulted in a product market launch (dummy variable: Yes = 1, No = 0)
Basic research	The project was at the basic research phase at the outset (dummy variable: Yes = 1, No = 0)
Number of members responsible for commercialisation	The number of initial project members responsible for commercialisation
Number of members participating in project	Total number of members that participated in the project
Collaborative project with other companies	The project is a collaborative project with other companies (dummy variable: Yes = 1, No = 0)
Unexpected deterioration of the economy	The economy deteriorated more than expected (dummy variable: Yes = 1, No = 0)
Divergence because of change in business strategy	Because of change in business strategy of the firm, the project diverged from the original orientation (dummy variable: Yes = 1, No = 0)
Indispensable for long-term strategy	Technological development of the project was recognised as indispensable for the long-term strategy of the firm (dummy variable: Yes = 1, No = 0)
Extent of external awareness and competition	Technology developed by the project had already attracted broad attention in society and many firms had started to develop it (dummy variable: Yes = 1, No = 0)

Note: *a composite variable (taking a mean value of consisting items)

Table 2 Descriptive statistics and correlation table

		Mean value	*Standard deviation*	*N*	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*	*10*	*11*	*12*	*13*	*14*
1	Commercialisation ~	0.34	0.48	242														
2	Basic research ~	0.38	0.49	242	–.088													
3	Number of members responsible for commercialisation	2.93	3.73	174	.011	–.175*												
4	Number of members participating in project	6.61	6.92	242	.145*	–.152*	.390**											
5	Collaborative project with other companies ~	0.49	0.50	242	–.113	–.057	–.002	–.088										
6	Dependence on public funds ~	0.55	0.50	230	–.151*	–.038	.046	.002	.030									
7	Communications with other internal divisions	3.33	1.04	242	.198**	–.088	.195*	.199**	.000	–.143*								
8	Internal participation pertaining to commercial feasibility	2.77	1.06	242	.197**	–.075	.214**	.172**	.012	–.117	.334**							
9	Unexpected deterioration of the economy ~	0.10	0.30	225	.073	–.183**	–.051	–.035	.078	–.025	–.043	–.032						
10	Divergence because of change in business strategy~	0.11	0.31	225	–.130	.032	–.002	–.014	.160*	.122	–.131*	–.105	.161*					
11	Indispensable for long-term strategy ~	0.13	0.33	242	.322**	–.176**	.135	.174**	–.052	–.105	.140*	.179**	.062	–.084				
12	Extent of external awareness and competition ~	0.14	0.35	242	–.092	.047	.143	.055	.058	.026	–.072	.044	–.046	.111	.059			
13	Technological performance	3.60	0.73	242	.387**	.035	.151*	.159*	–.056	–.006	.236**	.173**	.098	–.181**	.144*	–.005		
14	Resolution of cost problems	2.89	0.71	242	.310**	–.019	.102	.168**	–.045	–.045	.196**	.128*	.082	–.195**	.147*	.114	.479**	
15	Acquisition of legitimacy	3.47	0.78	241	.364**	–.055	.124	.159*	–.109	.080	.264**	.214**	.033	–.262**	.153*	–.022	.489**	.412**

Notes: *p < 0.05, **p < 0.01; dummy variables indicated with a tilde (~)

Furthermore, we measured the level of managements' commitment to the projects with the question, "Was this technological development recognised as indispensable for the long-term strategy of the firm? (Indispensable for long-term strategy)" A firm's final decision-making regarding commercialisation can be affected substantially depending on how important the development and the commercialisation of the technology are to the firm's long-term strategy.

Descriptive statistics for each of the variables used for the analysis and a correlation matrix are shown in Table 2.

5 Results of the analyses

5.1 Results of the regression analysis

The results of a multiple regression analysis (OLS) concerning Hypothesis 1 and Hypothesis 2 are shown in Table 3.

From the table we can see that 'dependence on public funds' has a significant negative effect both on "communications with other internal divisions" and "internal participation pertaining to commercial feasibility." "Number of members responsible for commercialisation" has a significant positive effect both on communications with other internal divisions and internal participation pertaining to commercial feasibility, as expected. Even after controlling for this effect the negative effects produced by high dependence on public funds remain significant. From these results we can say that both Hypothesis 1 and Hypothesis 2 were supported.

Table 3 Multiple regression analysis results: Hypothesis 1 and Hypothesis 2

Independent variable	*Dependent variable*							
	Communication with other internal divisions				*Internal participation pertaining to commercial feasibility*			
	1		*2*		*3*		*4*	
Constant	(25.638)		(24.612)		(18.598)		(17.671)	
Basic research	–.113 (–1.457)		–.094 (–1.223)		–.079 (–1.008)		–.065 (–.834)	
Number of members responsible for commercialisation	.174 (2.234)	**	.186 (2.425)	**	.203 (2.609)	***	.212 (2.733)	***
Collaborative project with other companies	–.092 (–1.207)		–.086 (–1.144)		.014 (.187)		.019 (.246)	
Dependence on public funds			–.188 (–2.485)	**			–.134 (–1.751)	*
R^2	.059		.094		.054		.071	
Adjusted R^2	.041		.071		.036		.048	
F	3.359	**	4.144	***	3.041	**	3.077	**

Notes: *p < 0.1, **p < 0.05, ***p < 0.01; upper row is the coefficient; lower row ( ) is the t value

Table 4 Results of multiple regression analysis: Hypothesis 3 and Hypothesis 4

Independent variable	*Dependent variable*					
	Technological performance		*Resolution of cost problems*		*Acquisition of legitimacy*	
	1	*2*	*3*	*4*	*5*	*6*
Constant	(35.584)	(14.110)	(29.194)	(11.687)	(32.092)	(11.726)
Basic research	.045	.063	–.009	.004	–.053	–.029
	(.672)	(.957)	(–.130)	(.065)	(–.793)	(–.456)
Dependence on public funds	–.005	.033	–.046	–.018	.077	.126 **
	(–.075)	(.511)	(–.702)	(–.272)	(1.169)	(1.976)
Number of members participating in project	.160 **	.111 *	.163 **	.127 *	.146 **	.082
	(2.407)	(1.661)	(2.455)	(1.882)	(2.201)	(1.250)
Communications with other internal divisions		.189 ***		.148 **		.224 ***
		(2.740)		(2.118)		(3.318)
Internal participation pertaining to commercial feasibility		.088		.055		.142 **
		(1.292)		(.796)		(2.113)
R^2	.025	.075	.029	.057	.033	.116
Adjusted R^2	.012	.054	.016	.036	.020	.096
F	1.961	3.631 ***	2.267 *	2.693 **	2.558 *	5.838 ***

Notes: $^*p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$; upper row is the coefficient; lower row ( ) is the t value

The results of a multiple regression analysis (OLS) concerning Hypothesis 3 (3-1, 3-2) and Hypothesis 4 (4-1, 4-2) are shown in Table 4. From the table we can see that "communications with other internal divisions" has significant positive effects on all three performance-indicators, 'technological performance,' 'resolution of cost problems,' and 'acquisition of legitimacy.' Hypothesis 3-1 was thus supported. Beyond our expectation, communications with other internal divisions is effective not only for technical problem solving but also for resolving cost problems.

On the other hand, "internal participation pertaining to commercial feasibility" has a significant effect only on 'acquisition of legitimacy.' Contrary to the hypothesis there is no significant effect on 'resolutions of cost problems' though a sign for the coefficient is as expected. Thus, we can say that Hypothesis 4-1 and Hypothesis 4-2 were only partially supported.

Table 5 Logistic regression analysis results: Hypothesis 5

Independent variable	*Dependent variable*			
	Commercialisation			
Unexpected deterioration of the economy	.185 (.119)	.284 (.302)	.464 (.766)	.071 (.017)
Divergence because of change in business strategy	–.546 (.729)	–.520 (.695)	–.466 (.531)	–.077 (.013)
Indispensable for long-term strategy	1.815*** (12.132)	1.742*** (12.373)	1.727*** (12.073)	1.825*** (11.834)
Extent of external awareness and competition	–1.199** (4.108)	–1.305** (5.149)	–1.052* (3.293)	–1.235** (4.110)
Basic research	–.111 (.105)	–.016 (.002)	.083 (.061)	–.073 (.043)
Technological performance	1.449*** (23.546)			1.071*** (10.275)
Resolution of cost problems		.955*** (14.289)		.449 (2.537)
Acquisition of legitimacy			1.219*** (20.113)	.810*** (7.833)
–2logL	229.10	244.365	236.051	216.175

Notes: *p < 0.1, **p < 0.05, ***p < 0.01; upper row is the coefficient; lower row ( ) is the Wald value

Continuing on, Table 5 shows the results of a binomial logistic regression analysis concerning the effect on 'commercialisation.' Two control variables, 'divergence because of change in business strategy' and 'unexpected deterioration of the economy,' do not have significant effects on commercialisation. On the other hand, 'indispensable for long-term strategy' has a significant positive effect on commercialisation. This implies that high expectations and commitments by management increase the probability of commercialisation.

The results also show that "extent of external awareness and competition," which highlights the market opportunity and competitive environment, has a negative effect on commercialisation. There is a possibility that, when a technology had already attracted intense interest with substantial competition, firms judged it unable to appropriate the profits even if they commercialised the results.

With regard to the relationship between the three project performance variables and 'commercialisation,' all of the performance variables had a significant positive relationship with 'commercialisation' when being introduced into the model separately. In this respect, we can say that Hypothesis 5 is supported. However, since 'technological performance,' 'resolution of cost problems' and 'acquisition of legitimacy' are highly correlated, they might be endogenous. In fact, when all three performance variables are introduced into the model simultaneously, the only 'technological performance' and 'acquisition of legitimacy' positively affect 'commercialisation.' It remains unclear whether this is a statistical bias caused by the high correlation itself or an actual interrelationship. We will take up this point again in the path analysis explored in the following section.

5.2 Examining causal paths: structural equation model

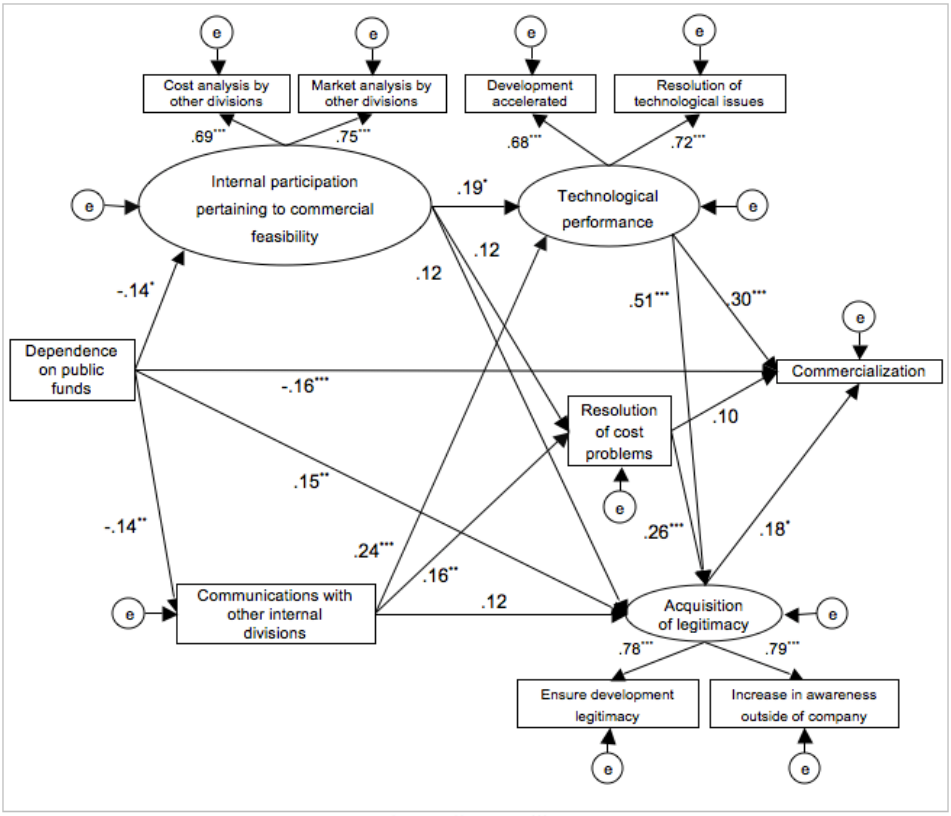
As shown in the analytical framework in Figure 2, many of the variables used in the regression analysis discussed above can be endogenous. To test the entire causal paths by taking this point into consideration, we next ran a structural equation models. For the analysis we used the AMOS from SPSS Inc. To keep the model from becoming complex, the control variables introduced into the regression analysis were not incorporated.

The results shown in Figure 3 are consistent with the results of the regression analysis in the preceding section. As the entire model, communications with other internal divisions were obstructed when dependence on public funds increases, and the technological performance diminished and commercialisation hindered as a result. This suggests the possibility that receiving government funding itself becomes a factor hindering commercialisation.

The dependency on public funds also negatively affects "internal participation pertaining to commercial feasibility" that, in turn, contributes to the 'technological performance'. This implies that high dependence on public funds may lead to low technological performance, which lowers probability of commercialisation, through its negative impact on internal participation on a feasibility study. On the other hand, effects of 'internal participation pertaining to commercial feasibility' on 'resolution of cost problems' and 'acquisition of legitimacy' are not statistically significant through its signs for the coefficients are as hypothesised.

As for the relationship between performance variables and commercialisation, the diagram indicates that there are direct effects of 'technological performance' and 'acquisition of legitimacy' on commercialisation, but no direct influence from 'resolution of cost problems.' It also shows that both 'technological performance' and 'resolution of cost problems' indirectly encourage commercialisation through their impacts on 'acquisition of legitimacy.' Because the three performance variables have a high correlation, however, it seems that one should exercise prudence concerning an interpretation in the direction of the cause and effect shown by the model.

Figure 3 Structural equation model



Note: *p < 0.1, **p < 0.05, ***p < 0.01

χ^2	χ^2/df	*GFI*	*AGFI*	*CFI*	*RMSEA*
94.443*	3.935	.931	.843	.855	.113

Note: *p < 0.05

6 Discussions

6.1 Contribution and implications of the study

With each country struggling under stringent fiscal conditions, the impact of government funding on private sector R&D also continues to be subjected to greater scrutiny than ever. Given such circumstances, significant effort has been made to strictly measure the effects government funding has on changes in private sector R&D mainly at an industry, national or similar macro level. The accumulated research at a micro-level, on the other hand, remains thin. Based on this awareness, the present study was aimed at supplementing existing research by undertaking an analysis focused on the

micro-level process in which government funding affects project performance and commercialisation.

One important finding of this study is that, when viewed at the project level, the act of receiving government funding itself entails some danger of hindering the commercialisation of a project's results.

The significance of government funding for private sector R&D lies in the fact it achieves a socially appropriate allocation of R&D resources, by providing support for technologies that are not profitable but which have social value, or by providing support for the development of technologies which, although they are expected to generate considerable economic value in the future, engender risks that private firms cannot accept because of the high degree of uncertainty. Viewed from the firm side, because the profitability of the R&D investment is enhanced by the receipt of public funds, government funding enables an enterprise to undertake, from a long-term perspective, R&D activity it had rejected in the past.

The present study showed that, in contrast to this positive aspect of government funding, there is also a negative aspect from a project management standpoint. When public funds are tilted toward private sector R&D activity aimed at commercialisation, there is a tendency for project activity to be shut off from the exchange of information with other internal departments. Therefore, compared with the ordinal R&D projects within the firm, the use of internal resources is limited, which has a negative effect on commercialisation. We also find that high dependency on government funds tend to prevent a project to receive less involvement of other internal departments pertaining commercial feasibility, which also hinders technological performance.

Because it is an intrinsic problem that originates from the inevitable structure of government funded projects, in which the side providing resources for the R&D activity and the side managing the project toward commercialisation are separate, eliminating this problem at its source might be impossible. By recognising the existence of this problem, however, the supporting side and a firm may be able to adopt various mechanisms to mitigate the problem. From the supporting side it is possible to make an informal appeal, together with an institutional guarantee, which enables a government funded project to receive support from other internal departments. This might include easing restrictions on the sharing of facilities being used by the supported project with other internal divisions. If it earnestly obtains results from a project that receives government funding, and works to tie its results to commercialisation, a firm should also be able to appeal formally or informally in a manner that encourages support from in-house.

Our results suggested that participation by internal departments in commercial feasibility promotes the project performance and commercialisation. If this result is accepted at face value, it means it is important for the supporting side and the firm to encourage other internal divisions to get involved in the commercial feasibility. The danger that excessive involvement concerning commercial feasibility might destroy the autonomy of a project must also be considered, however. The problem of balance with respect to this point will be the focus of future research.

Furthermore, although not a central theme of the present study, it became clear from the analysis in Table 5 that the strategic intent of the firm, or the societal expectations for the development technology and competitive conditions, are critical as factors influencing the success of commercialisation. For example, the analysis in the present study showed there is a high probability of commercialisation of technological

developments that were judged to be essential for the long-term strategy of a firm, and that commercialisation is dropped as the result of changes in the orientation of corporate strategy. It also showed that, to the extent society is already broadly aware of a technological development and there is tremendous competition from the very start, results will not be commercialised.

In other words, the success or failure of commercialisation appears to be greatly related not only to the process of technological development but also to the position of the project in-house and its competitive position in the market. If such position is determined to a certain extent at the start of the project, we can also say that the selection of support project will greatly affect the success or failure of commercialisation. In other words, the present study suggests that the two considerations necessary for leading the commercialisation of government funded projects to success are

1 selecting appropriate support projects

2 taking actions to ensure support projects are not isolated from other internal departments.

6.2 Limitation and direction for the future study

We believe that by putting the focus on government funded projects and clarifying the mechanism connected with the results at the project level, this study has made a certain contribution to understanding. Nevertheless, there are also limitations as discussed below.

First, if we are to discuss the influence of government funding, a comparison between projects that receive government funding from the start and projects that develop the same kind of technology without receiving any government funding is needed. And in fact, among the existing researches that measure the effect of government funding there does exist some research that prudently performed such matching at the firm level(Almus and Czarnitzki, 2003; Duguet, 2004; González and Pazó, 2008; Bérubé and Mohnen, 2009). For the present study focusing on individual projects as the unit of analysis, however, it was extremely difficult to obtain such a match sample. Therefore, although the samples were limited to NEDO projects, we decided to comprehend the effect of government funding by classifying the samples according to dependency on public funds. Using this research methodology, however, meant we could not understand the effect from 'receiving or not receiving' government funding. If obtaining a large number of matching samples at the project level is difficult, then we believe that, at a minimum, it will be necessary in the future to supplement the knowledge obtained from the present study by focusing on specific projects and performing a comparative case study with similar private sector R&D projects that have not received government funding.

Finally, although the present study regarded success in the commercialisation of the supported project as the final result, given the nature of government funding, the broad spill over effects to society as a whole, including other companies, should also be considered as an important result. Therefore, one future direction will be to conduct research that looks at a variety of performance indicators.

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Notes

1 Bérubé and Mohnen (2009) examine the results of product development by looking not only at the technology but also encompassing economic indicators. Moreover, Cockburn and Henderson (1998) indirectly demonstrated the relationship between research results and the presence or absence of public funding or its amount, and also briefly discussed the mechanism leading to this result. They showed that R&D activities performed by private sector firms in cooperation with public institutions has an effect on the R&D resource allocation process and on the incentives to conduct science-level research and pure research, and that as a result it also has a positive influence on the R&D results, as shown by the number of important patents. Finally, they assumed this joint development through cooperation between private corporations and public institutions is carried out mainly under public funding.

2 In the case of Japan, there has existed the 'commissioned research' system as an intermediate position between 'contract' and 'assistance.' Under this system, private firms conduct R&D on themes determined by government agencies. This system had expanded under the global trend toward abolishing industrial subsidies. However it led to enactment of the Japanese-version Bayh-Dole Act once it had become clear the system was hindering commercialisation incentives at commissioned firms because all of the study results belonged to the government. Because it has been possible since 1989 for firms implementing the R&D to keep the results, thanks to the Japanese-version Bayh-Dole Act, the current commissioned research system can be positioned as 'assistance' that is closer to being grants.

3 In Japan, the so-called Japanese-version Bayh-Dole Act is normally applied to government funded projects.

4 We included 'increased external awareness' in constructing the 'acquisition of legitimacy' variable because the existing research indicated the importance of project's acceptance outside the company has for the acquisition of legitimacy within organisations (Takeishi et al., 2008).

5 For these composite variables we adopted the mean values for each given variable, but as discussed below the results differ little when the factor scores are used.