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# R&D Subsidy and Self-Financed R&D: The Case of Japanese High-Technology Start-Ups

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ABSTRACT. This paper examines whether public R&D subsidies constitute a substitute or complement for private-financed R&D. The empirical analysis is based on a panel data of 223 Japanese high-technology start-ups. Our evidence is consistent with the complement hypothesis, i.e., that publicly-funded R&D does promote private R&D. The complement effects are stronger for more mature firms. This is because such firms, in the growth phase, might have greater demands for R&D funds.

## 1. Introduction

It is said that industrial R&D, particularly, basic research, tends to be less developed than the socially optimal level. Since new technologies resulting from R&D have the characteristics of public goods, inventors cannot monopolize economic benefits from these technologies. In addition, imperfection of the capital market discourages risky but socially beneficial R&D investment, causing industrial R&D to be in a state of undersupply. Some empirical studies have been conducted on measuring the private and social rate of returns in industrial R&D in order to test the above theory. These studies have yielded evidence that the social rate of return exceeds the private rate of return in industrial R&D, i.e., industrial R&D is underdeveloped.[1]

Public R&D is expected to correct these market failures and to augment the supply of socially useful technologies. If public R&D can accomplish this goal, these new technologies will have the potential to induce additional private R&D. In this case, public R&D is assumed to be a complement for private R&D.

However, according to David et al. (1999), there may be at least two instances where public R&D may become a substitute for private R&D, i.e., public R&D may crowd out private R&D. The first instance is related to the funding process. In the funding process, public funds tend to be awarded to projects with a high probability of success or projects whose performance is easy to assess ex post facto. In this case, government simply supports R&D projects that can be conducted without public funds. The second instance concerns the inelastic supply of R&D input, particularly R&D personnel. As David et al. (1999) point out, firms faced with difficulties in hiring additional scientists or engineers because of an inelastic supply may decide to discontinue previously profitable projects in order to carry out publicly funded projects.[2] As a result, R&D subsidies may crowd out beneficial private R&D.

The relationship between publicly funded R&D and private R&D might differ among industries. Demand for R&D subsidies might also differ for R&D-intensive industries and less R&D-intensive industries. In addition, firm size might influence the relationship between government-subsidized R&D and private R&D. Furthermore, demand for R&D subsidies is perhaps stronger in small firms than it is in large firms. The above discussions suggest that in theory, any publicly funded R&D and private R&D can be either complementary or substitutive. Hence, it is necessary to examine these relationships empirically.

Numerous authors, using data from western countries, have examined the relationship between

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R&D subsidies and company funded R&D.[3] Some studies focus on the case of high-technology start-ups. For example, Wallsten (2000) tests whether SBIR (Small Business Innovation Research) grants actually stimulate private R&D, using data on American high-technology start-ups.[4] He concludes that SBIR grants in fact may decrease private R&D because of selection bias in the funding process. On the other hand, Lach (2000) used data on Israeli high-technology start-ups to examine whether or not R&D subsidy stimulates private R&D. He finds evidence suggesting that R&D subsidy increases long-run private R&D expenditures. The author reports that long-run elasticity with respect to the R&D subsidy is 0.22.

In Japan, high-technology start-ups are expected to play a key role in revitalizing Japanese economy. People expect these firms to spur innovation, create new markets, and augment national income. Indeed, Japanese government has introduced a variety of policies to foster activities of these firms, parts of which are discussed later. However, thus far, very few empirical studies on activities, particularly, innovative activities of small firms have been conducted despite the fact that Japanese government has supported their innovative activities. Therefore, in this paper, we aim to empirically examine the relationship between R&D subsidies and company-financed R&D, focusing on Japanese high-technology start-ups.

This paper is organized as follows. The next section gives a brief explanation of the technology policies that have been introduced for small and medium firms. In Section three, we will discuss the characteristics of the data and the strategy of our econometric analysis. Section four is devoted to the interpretation of the estimated results. Here we reconsider the relationship between the two types of funds, taking into account firm characteristics. Finally, some conclusions are presented in Section five.

## 2. Technology policies for small and medium enterprises in Japan

According to the *White Paper on Small and Medium Enterprises in Japan* (2001), 21 different technology policies for Small and Medium Enterprises (hereafter SMEs) are currently in force. These polices are classified into three groups.

The first group consists of ten policies, all of which are intended to promote technological innovation of SMEs. They are (1) small and medium enterprise technology innovation system (Japanese SBIR), (2) promotion of business innovation to meet specific needs, (3) subsidization of R&D on creative technology and creative technology contributing to regional revitalization, (4) system of taxation to strengthen the technological base of SMEs, (5) subsidization of development work to commercialize industrial technologies, (6) subsidization of joint international R&D by ventures, (7) R&D on SMEs industrial technology, (8) creation of standards to help strengthen the technological base of SMEs, (9) development of SME knowledge base, and (10) expansion of Support for the Introduction of Technology by SMEs.

The second group consists of four policies aimed at facilitating cooperation between industry, universities and government: (1) promotion of cooperation between industry, universities and government to develop SME technology, (2) subsidization of research on industrial technology, (3) R&D benefiting SMEs conducted by National Institute of Advanced Industrial Science and Technology, (4) matching fund system of subsidization of industry-university cooperation to develop commercial technologies.

The third group is intended to strengthen the manufacturing base of SMEs through local government cooperation, and includes (1) development of manufacturing human resource support structure, (2) local manufacturing association support activities, (3) technical training by JASMEC (Japan Small and Medium Enterprise Corporation), (4) regional revitalization adviser program and other support programs, (5) promotion of the uptake and joint use of new advanced technology, (6) R&D to facilitate access to SME related information, and (7) revitalization of basic technology industrial agglomerations.

This paper will focus on "subsidization of R&D on creative technology and creative technology contributing to regional revitalization (hereafter, SRDCT)."[5] Any firm that has fulfilled the following two requirements will become eligible for

SRDCT. The first requirement is that the firm be either a "small or medium enterprise" within the definition of Article 2 of the Small and Medium Enterprise Basic Law, or "a group of corporations" as defined in Article 34 of the Civil Code. The second requirement is that the firm develops new technologies or new products by itself. SRDCT will cover a part of the firm's R&D expenditures,[6] the upper limit being 50% of its R&D expenditures or 45 million yen, whichever is lower. In the next section, we will consider the relationship between SRDCT and private R&D.

## 3. Methodology and data

### 3.1. *The model*

Here we will discuss the methodology of the empirical analysis and the characteristics of the data. The econometric analysis is based on the following simple R&D equation.

$$R_{it} = a_i + \alpha SUB_{it} + \beta PR_{it} + \lambda RS_{it-1} + \delta SIZE_{it} + t + u_{it} \quad (1)$$

In equation one, index $i$ represents firms and index $t$ represents years. The dependent variable $R_{it}$ is the natural logarithm of corporate R&D expenditure. In addition, there are four explanatory variables in equation one.

The variable $SUB_{it}$ is a dummy variable that equals one if a firm received SRDCT in a given year, and zero otherwise. As previous studies show, simultaneity between subsidies and private R&D might occur. The fact that a firm received subsides might affect the level of its R&D. On the other hand, whether a firm can receive subsidies or not might depend on the firm's R&D expenditures. Some empirical studies on subsidy-R&D relationships have emphasized the importance of such a bilateral causality.

We treat such a simultaneity problem in the following manner. First, we estimate equation one, by both the OLS and the Instrumental variable method. Then we examine whether or not there is any systematic difference between the two estimated results, applying the Hausman test. The result of the Hausman test shows that there is no significant simultaneity between the dependent variable $R_{it}$ and the independent variable $SUB_{it}$. Hence, we ignore the simultaneity problem in our empirical analysis.

The variable $PR_{it}$ is the ratio of operating income to sales. As McWilliams and Siegel (2000) point out, there may be a highly positive correlation between the level of R&D and profitability. In this case, if we ignore these relationships, empirical results might be overestimated. Furthermore, profitability of the firm might have some effects on the probability of the firm receiving R&D subsidy. For example, firms that earn low profits might be more likely to be awarded the subsidy. Therefore, if we omit profitability, we will underestimate the effects of the subsidy on subsequent R&D. For these reasons, we introduce the variable $PR_t$ to avoid these misspecifications.

On the other hand, as Himmerberg and Petersen (1994) show, R&D investment tends to rely on internal funds because of asymmetric information and imperfection of the capital market. From this point of view, we could interpret the variable $PR_{it}$ as a proxy for the availability of internal funds.

The level of R&D will be greatly influenced by the firm's technological capability. We express the technological capability of the firm with the variable $RS_{it-1}$. The variable $RS_{it-1}$ is defined as the natural logarithm of the total number of researchers in year $t - 1$. The technological capability could also be expressed by other indicators such as knowledge capital, total number of patents applied for, or total number of new products. However, all these indicators include the following problems. We do not have sufficient R&D data for the past years to construct knowledge capital, because our available data is only for four years; four years is too short a period for creating data on knowledge capital. It is also questionable to adopt the lagged R&D (flow data) as a proxy for technological capability. Indeed, we have no rational reasons for interpreting the lagged R&D in a completely different manner from current R&D. On the other hand, a problem occurs when we adopt patents and new products as a proxy for technological capability. The distributions of both patents and new products are severely skewed to the left. In other words, the total number of patents or new products take the value zero for most of our sample firms. For these reasons, we chose the number of total researchers as an indicator of technological capability.

The variable $SIZE_{it}$ denotes the natural logarithm of the total number of employees in year *t*. This is introduced to our equation to control the effects of firm size on R&D. Firm size has been considered as one of the most important determinants of R&D thus far. Thus we will test whether or not a Shumpeterian hypothesis is supported in the case of our sample firms.[7]

The level of R&D might also be governed by a variety of firm-specific characteristics other than those discussed above. These "unobservable" firm characteristics will include, for example, geographical adjacency to universities and research institutes, a human network with consumers and other firms. Furthermore, parts of firm-specific characteristics will be overlapped with such managerial characteristics as educational background and occupational experience. We consider these firm and managerial characteristics together and treat them as unobservable characteristics "$\alpha_i$". In empirical studies, we will try to estimate our equations by both the fixed effects and the random effects model.

Empirical results may be affected by a factor influencing the data for the mid-1990s, during which banks refrained from granting loans to small firms. In that period, small firms may have demanded more government funds than in other periods. Hence we will introduce time dummies *t* to eliminate such annual macro-economic shocks. Finally, $u_{it}$ represents a disturbance term.

### 3.2. *Data*

Panel data on 223 Japanese high-technology start-ups over four years (from 1995 to 1998) are used for our empirical study.

The data were collected from the original database constructed based on a questionnaire survey conducted by the NISTEP in 1999 (hereinafter, the 1999 NISTEP survey). The sampled firms in the 1999 NISTEP survey were (1) Japanese firms founded after January 1989, which (2) were classified into "high-technology industries". It is not easy for us to define "high-technology industry" clearly. We selected these industries in the following manner. We first used the *Report on the Survey of Research and Development* (1999), to identify the most R&D-intensive industries in Japan. From these R&D-intensive industries, we selected the following six industries about which Tokyo Shoko Research (TSR) possesses a large amount of information (most importantly, information on firms).[8] Our "high-technology industries" include chemicals, metalworking machinery, special industrial machinery, electrical machinery, motor vehicles, and precision instruments. Besides firms in these six industries, several information-technology (IT)-related firms were added to the samples.

Based on the above definition of high-technology start-ups, we selected 4,958 firms from a database provided by the TSR, and sent questionnaires to these firms. Consequently, we received responses from 1,384 firms.[9] Since many of the 1,384 respondent firms did not answer the questions about R&D expenditures, sales, and profits, we were forced to reduce our sample size from 1,384 to 223. We are fully aware that it is certainly questionable to regard these 223 sample firms as representative of Japanese high-technology start-ups. Under the present circumstances, however, there is no other available data on high-technology start-ups. For this reason, these 223 firms are the sample firms used in our empirical analysis in the following sections. Table I lists the definitions of the variables, Table II reports summary statistics of the sample firms, and Table III shows the correlation matrix.

TABLE I
Definition of the variables

| Variable | Definition |
|---|---|
| $R_t$ | The natural logarithm of company-funded R&D in year *t* |
| $SUB_t$ | A dummy variable which equals one if a firm received a subsidy in year *t* |
| $SUB_{t-1}$ | The first lag of the variable $SUB_t$ defined above |
| $PR_t$ | The ratio of operating income to sales in year *t* |
| $RS_{t-1}$ | The first lag of the variable $RS_t$. $RS_t$ is defined as the natural logarithm of total number of researchers in year *t* |
| $SIZE_t$ | The natural logarithm of total number of employees in year *t* |

TABLE II
Summary statistics

| Variable | No. of OBS | Mean | Std. Div. | Minimum | Maximum |
|---|---|---|---|---|---|
| All firms | | | | | |
| $R_t$ | 642 | 2.194 | 1.598 | 0 | 9.047 |
| $SUB_t$ | 642 | 0.0218 | 0.1461 | 0 | 1 |
| $SUB_{t-1}$ | 642 | 0.0186 | 0.1355 | 0 | 1 |
| $PR_t$ | 642 | 0.0001 | 1.425 | –34 | 8.889 |
| $RS_{t-1}$ | 642 | 0.6417 | 0.8386 | 0 | 5.669 |
| $SIZE_t$ | 642 | 2.675 | 0.9622 | 0.6931 | 7.013 |
| Newborn firms | | | | | |
| $R_t$ | 196 | 2.048 | 1.643 | 0 | 9.047 |
| $SUB_t$ | 196 | 0.0408 | 0.1983 | 0 | 1 |
| $SUB_{t-1}$ | 196 | 0.0357 | 0.1860 | 0 | 1 |
| $PR_t$ | 196 | –0.0281 | 0.4949 | –3.257 | 1.027 |
| $RS_{t-1}$ | 196 | 0.6068 | 0.7905 | 0 | 4.094 |
| $SIZE_t$ | 196 | 2.574 | 0.9023 | 0.6931 | 5.609 |
| Young firms | | | | | |
| $R_t$ | 446 | 2.258 | 1.581 | 0 | 8.280 |
| $SUB_t$ | 446 | 0.0134 | 0.1153 | 0 | 1 |
| $SUB_{t-1}$ | 446 | 0.0112 | 0.1054 | 0 | 1 |
| $PR_t$ | 446 | 0.0125 | 1.679 | –34 | 8.889 |
| $RS_{t-1}$ | 446 | 0.6570 | 0.8593 | 0 | 5.669 |
| $SIZE_t$ | 446 | 2.720 | 0.9851 | 1.098 | 7.013 |

TABLE III
Correlation matrix

| Variable | $R_t$ | $SUB_t$ | $SUB_{t-1}$ | $PR_t$ | $RS_{t-1}$ | $SIZE_t$ |
|---|---|---|---|---|---|---|
| All firms | | | | | | |
| $R_t$ | 1.000 | | | | | |
| $SUB_t$ | 0.0740 | 1.000 | | | | |
| $SUB_{t-1}$ | 0.0535 | 0.2944 | 1.000 | | | |
| $PR_t$ | 0.0115 | –0.0500 | –0.0257 | 1.000 | | |
| $RS_{t-1}$ | 0.6559 | 0.0337 | 0.0475 | –0.0178 | 1.000 | |
| $SIZE_t$ | 0.4887 | –0.0014 | 0.0053 | 0.0235 | 0.5854 | 1.000 |
| Newborn firms | | | | | | |
| $R_t$ | 1.000 | | | | | |
| $SUB_t$ | 0.1439 | 1.000 | | | | |
| $SUB_{t-1}$ | 0.1241 | 0.3771 | 1.000 | | | |
| $PR_t$ | –0.1356 | –0.3513 | –0.1353 | 1.000 | | |
| $RS_{t-1}$ | 0.6817 | 0.0498 | 0.0742 | –0.0426 | 1.000 | |
| $SIZE_t$ | 0.4120 | –0.0464 | –0.0155 | 0.0342 | 0.4671 | 1.000 |
| Young firms | | | | | | |
| $R_t$ | 1.000 | | | | | |
| $SUB_t$ | 0.0341 | 1.000 | | | | |
| $SUB_{t-1}$ | 0.0101 | 0.1724 | 1.000 | | | |
| $PR_t$ | 0.0313 | 0.0023 | –0.0079 | 1.000 | | |
| $RS_{t-1}$ | 0.6461 | 0.0298 | 0.0373 | –0.0166 | 1.000 | |
| $SIZE_t$ | 0.5180 | 0.0403 | 0.0311 | 0.0230 | 0.6286 | 1.000 |

## 4. Empirical results

### 4.1. *Basic results*

First, we confirm the existence of any individual effects among the sample firms. For this purpose, we test the null hypothesis that all $\alpha_i$ equal zero in our sample firms. The $F$ statistic shows $F(222, 412) = 17.23$, meaning that there are unobservable firm-specific differences among the sample firms. Next, we test the null hypothesis that the coefficients of the variables estimated by the fixed effects model are the same as those obtained by the random effects model. If this hypothesis is rejected, there are systematic differences between two estimators. In such a case, we could not adopt the assumption that the individual effects are uncorrelated with the dependent variable. The statistic of the Hausman test in column (1) shows the value 58.24. This suggests that the individual effects are correlated with the dependent variable. Therefore we should treat such firm-specific characteristics as fixed effects, or employ the fixed effects model in estimating equation one. The same procedure is performed for the remaining models. In each column, the statistic of the Hausman test implies that we might have to estimate our equations using fixed effects models.

The first and second columns of Table IV list the estimated results for all firms. In column (1), the coefficient of the variable $SUB_t$ is significantly positive. The $t$ value indicates that the coefficient is significantly different from zero at the 1 percent level. This means that R&D subsidy is an important determinant of company-funded R&D. Furthermore, the positive sign of the coefficient implies that R&D subsidy does promote company-funded R&D; in other words, R&D subsidy is a complement for private R&D. As discussed in the

TABLE IV
Estimated results

| | All Firms | | Newborn Firms | | Young Firms | |
|---|---|---|---|---|---|---|
| | (1) | (2) | (3) | (4) | (5) | (6) |
| $SUB_t$ | 0.5844*** | 0.7041*** | 0.3385 | 0.0108 | 0.6522*** | 0.7317*** |
| | (0.1938) | (0.2057) | (0.2791) | (0.4398) | (0.2457) | (0.2469) |
| $SUB_{t-1}$ | – | 0.3682* | – | –0.3929 | – | 0.8276** |
| | | (0.2158) | | (0.4076) | | (0.2864) |
| $PR_t$ | 0.0246** | 0.0240** | 0.0176 | 0.0780 | 0.0257* | 0.0260* |
| | (0.0137) | (0.0167) | (0.0895) | (0.1093) | (0.0417) | (0.0146) |
| $RS_{t-1}$ | 0.0490 | 0.0400 | 0.2735* | 0.2788* | –0.0300 | –0.0488 |
| | (0.0913) | (0.0913) | (0.1467) | (0.1469) | (0.1106) | (0.1102) |
| $SIZE_t$ | 0.6312*** | 0.6277*** | 0.1250 | 0.1211 | 0.8852*** | 0.8886*** |
| | (0.1244) | (0.1241) | (0.1597) | (0.1598) | (0.1647) | (0.1636) |
| Year dummies | YES | YES | YES | YES | YES | YES |
| No of OBS | 642 | 642 | 196 | 196 | 446 | 446 |
| No of firms | 223 | 223 | 85 | 85 | 138 | 138 |
| Within $R$-square | 0.157 | 0.163 | 0.101 | 0.109 | 0.194 | 0.206 |
| $F$-statistic | 10.98 | 10.02 | 1.68 | 1.59 | 10.36 | 9.78 |
| Hausman statistic | 58.24 | 58.25 | 28.04 | 25.02 | 35.83 | 28.94 |

*Notes:* The dependent variable is the natural logarithm of company-funded R&D. The independent variables include $SUB_t$, $SUB_{t-1}$, $PR_t$, $RS_{t-1}$, $SIZE_t$, and year dummies. $SUB_t$ denotes a dummy variable that equals one if a firm received a subsidy in year $t$. $SUB_{t-1}$ is the first lag of the variable $SUB_t$. $PR_t$ is the ratio of operating income to sales in year $t$. $RS_{t-1}$ is the first lag of the variable $RS_t$ that is defined as the natural logarithm of total number of researchers in year $t$. Finally, $SIZE_t$ is the natural logarithm of total number of employees in year $t$. Standard errors are in parentheses.
*, ** and *** indicate statistical significance at the 10 percent, 5 percent and 1 percent levels, respectively. In columns (3)–(6), sample firms are divided into two groups based on the mean firm age in 1998. The first group is defined as newborn firms whose firm age is under six years. The remainder is called young firms.

introduction of this paper, R&D subsidy could either substitute (Wallsten, 2000) or complement (Lach, 2000, 2002) company-funded R&D. Estimated results obtained in this study are classified into the later group, supporting the complement hypothesis. Regarding our estimated results, we could not find evidence that public R&D crowds out company financed R&D.

In column (1), we mainly presented the relationship between R&D subsidy and company-funded R&D in the current year. Then, in column (2), we add the lagged subsidy to our equations to elucidate the subsequent effects of R&D subsidy on company financed R&D.

Column (2) shows that the coefficient of the variable $SUB_{t-1}$ is as significantly positive as that of $SUB_t$. This result is different from that obtained by Lach (2000, 2002), who finds evidence that the coefficient of R&D subsidy shows a negative sign in the current year, but a positive sign in the subsequent year. However, our results show that the coefficient of the R&D subsidy has a positive sign both in the current and in the next year.

Lach (2002) interprets his results in the following manner. Small firms scale down their existing R&D projects immediately after they receive an R&D subsidy. This is because they must concentrate their resources on publicly funded R&D projects. However, in the next year, their R&D expenditures increase so much that the subsequent stimulus effects exceed the immediate displacement effects.

On the other hand, our results imply that firms initially face serious liquidity constraints although they have many investment opportunities. After receiving an R&D subsidy, firms will increase their R&D to complete both their existing R&D and publicly funded R&D. However, this R&D promoting effect will decrease in the next year. This is inferred from the fact that the absolute value of the coefficient of $SUB_t$ is smaller that that of $SUB_{t-1}$.

Another interpretation is possible for our results. Although firms initially have sufficient in-house R&D resources, they do not have enough investment opportunities. One of the reasons why they lack investment opportunities is that technological opportunities for start-ups are relatively limited. Receiving subsidy provides start-ups with the chance to develop close ties with universities. This enhances the investment opportunities of start-ups, and induces their idle R&D resources to be used to the full employment. Consequently, firms can conduct their self-financed projects and publicly funded projects at the same time.

As far as the relationship between the two kinds of R&D is concerned based on our sample firms, we can conclude that R&D subsidy is an effective tool for promoting company-financed R&D.

We will refer to the estimated results of variables other than R&D subsidy. The variable of profitability $PR_{it}$ indicates significantly positive signs in both columns (1) and (2). This result indicates that firms with high profits tend to invest much money in research and development activities than firms with low profits. In addition, we could also interpret these results to mean that firms with plentiful internal funds are keener in R&D activities than firms with sparse internal funds. In either case, profitability is one of the most important determinants of R&D in a firm.

The variable $RS_{t-1}$, which denotes the technological capability of the firm, does not show significant coefficients in either column (1) or (2). We could not support the hypothesis that firms with higher technological capabilities have the tendency to conduct R&D more intensively than those with lower ones. One of the reasons might be that the number of researchers is not a suitable proxy for technological capability. In the case of start-ups that have not accumulated sufficient technological capability, it might be difficult for us to express their capability by such firm specific variables as the number researchers or R&D expenditure. Rather, managerial characteristics such as educational background or occupational experience might be more suitable proxies of their technological capability.[10]

In both columns (1) and (2), the positive coefficients of the variable indicate that the level of R&D is proportional to firm size. However, the absolute value of the coefficient is at most 0.6 in both columns. This means that there is only a monotonic relationship between them.

### 4.2. *An extension*

The demand for R&D funds depends on the availability of a firm's internal funds and investment opportunity. Some firms face serious liquidity constraints, while other firms do not need additional funds to conduct their own R&D. Consequently, there are expected to be some differences in the demand for public funds among firms. In this section, we examine whether the relationship between R&D subsidy and private R&D differs among firms, taking firm age into account.[11]

In order to consider the above problem, we divide our sample firms into the following two groups, based on the firm's average age in 1998. The first group is defined as newborn firms whose firm age is under six years. The remainder is called young firms. Summary statistics for both groups are also reported in Table I.

The third and fourth columns of Table IV list the estimated results for newborn firms, and the fifth and sixth columns those for young firms. All equations are estimated using the fixed effects model. Columns (3) and (4) indicate that R&D subsidy does not have positive effects on R&D investment by newborn firms. On the other hand, columns (5) and (6) reveal that R&D subsidy promotes R&D investment by young firms.

We interpreted these results as follows. R&D activities of newborn firms might be confined by their initial funds. In addition, newborn firms are not as likely to receive R&D subsidy as young firms are. Consequently, even if these firms have successfully obtained funds from outside sources, they probably do not have a strong incentive to conduct additional R&D. Rather, they might have incentives to use such funds for other purposes. On the other hand, young firms, which are in the growth stage, will have stronger demands for R&D funds than do newborn firms. This is because R&D investment is recognized as the source of growth for young firms. Therefore, once these young firms receive subsidies, they might allocate those funds to additional R&D. This inference is also related to the fact that profitability $PR_{it}$ is significantly positive only in young firms. As we mentioned earlier, $PR_{it}$ is considered to be a proxy for the availability of internal funds. Therefore, our estimated results imply that the liquidity constraint is binding in young firms.

## 5. Conclusions

Public R&D is expected to correct the undersupply of private R&D in the market and to augment the supply of socially useful technologies. However, according to David et al. (1999), there may be at least two cases where public R&D may become a substitute for private R&D. The first instance is related to the endogeneity of the funding process. The second instance concerns the inelastic supply of R&D input, particularly R&D personnel. Theoretically, any publicly funded R&D and private R&D can be either complementary or substitutive. Thus we tried to clarify the relationship between them, using panel data on 223 Japanese high-technology start-ups. In the empirical studies, we examined the relationship between two types of R&D, first for all sample firms, and then considered it, taking into account the age of the firms.

From regression results, we found evidence that R&D subsidy becomes a complement for private R&D, which means that R&D subsidy does promote company-funded R&D. The complement effect was observed not only in the current year, but also in the subsequent year. When considering firm ages, we found that subsidy becomes a complement for private R&D in relatively mature firms. These firms, which are in the growth phase, might have stronger demands for outside R&D funds than do immature firms. As far as the relationship between them is concerned based on our sample firms, we could conclude that R&D subsidy is an effective tool for promoting company financed R&D, particularly in mature firms.

In closing our discussions, we should point out the limitations and the future subjects of our study. First, R&D subsidy was defined as a dummy variable. This limited the evaluation of the relationship between subsidy and private R&D to a qualitative one. Second, empirical results may be affected by a factor influencing the data that covers the second half of the 1990s. During this period, banks refrained from lending funds to small firms, and small firms faced serious liquidity constraints. These effects may have produced negative biases in the estimated results.

Third, the viewpoints of our analysis are limited to the short term. As David et al. (1999) show, public R&D has two long-run effects on private

R&D. The first effect is that public R&D will provide industries with new information via spillover. New knowledge resulting from public R&D is expected to enhance the technological opportunity of industries. Then, industries will have incentives to conduct additional R&D based on the new technological opportunity. The second effect stems from the training of new scientists and engineers. The qualified research personnel that are provided by universities or research institutes will shift the researchers' supply curve to the right and stimulate industrial R&D. From these discussions, we predict that the complement effects will become stronger in the long run.[12]

Finally, we should make an attempt to increase the amount of data available for econometric analysis, in order to obtain more robust results. These problems will be revisited when more accurate data on public and private R&D is made available to us.

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## Notes

1 For example, see Griliches (1998).
2 Goolsbee (1998).
3 For example, Leyden and Link (1991) suggest complementarity between public R&D and private R&D. On the other hand, Lichtenberg (1984, 1987, 1988), Mamuneas and Nadiri (1996), and Buson (2000) observe substitutability between them. David and Hall (2000) provide theoretical frameworks to examine the relationship between them.
4 On the other hand, Audrestch et al. (2002) evaluate the SBIR program from various viewpoints, and conclude that this program does stimulate R&D as well as efforts to commercialize that would not otherwise have taken place.
5 Firm level data other than this subsidy are unavailable to us.
6 R&D-related costs that are covered by this subsidy include costs of materials, costs of equipment, and other expenditures.
7 For example, see Cohen (1995).
8 Tokyo Shoko Research is one of the largest research firms that mainly investigates business failures in Japanese companies.
9 For more details, see Sakakibara et al. (2000).
10 Romijn and Albaladejo (2002) explore the determinants of innovation capability in small U.K. electronics and software firms. They classify the determinants into internal factors and external factors. They argue that educational background and prior work experience are positively related with the innovation capability of the firm.
11 Firm age is defined as the number of years passed since the foundation of the firm. The ages of the firms in 1998 are used. The average sample firm age is 6.15.
12 In the presence of a lagged dependent variable, there is a distinction between the short-run and the long-run effects of a change in subsidy. However we could not obtain significant results from such a specification.

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