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Abstract:
Tax incentives have been implemented in several countries, including Japan, to promote research and development (R&D). Several previous studies evaluate the effects of R&D tax incentives on R&D expenditures, but few address the changes in its conditions. This study fills this gap by focusing on the tax incentive reform in Japan in 2009 and using a comprehensive panel data set of Japanese corporations (TDB COSMOS1). Using DID and fixed-effect panel analyses, we found a positive and significant effect of enhancing the deduction ratio ceiling but not extending the carryover period on R&D expenditures.

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1. Introduction

Research and development (R&D) activities are increasingly regarded as an important business strategy for private firms in a global economy. R&D is an important source of innovation, competitive advantage, economic growth, and job creation and contributes to solutions to social problems. Therefore, R&D expenditures, both public and private, have been increasing, both in the developed and developing or emerging countries.

However, owing to market failures such as uncertainty, positive externalities, and public goods problem, private firms' R&D investment may be suboptimal from a social point of view. Moreover, owing to information asymmetry and capital market imperfections, R&D investment is often seriously constrained, especially for small and young firms (Honjo et al. 2014). Hence, in several countries, governments have implemented various support policies to promote private R&D, including subsidies and special loans, networking with other firms and universities, technological advice from public research institutes, and intellectual property rights (IPR) policy. This study focuses on tax incentives (tax deductions and tax credits), a major policy instrument for promoting R&D and innovation in several countries.

Tax incentives aim to increase private R&D investment and promote innovation by partially deducting R&D expenditures from corporate tax payments. This policy is expected to provide direct incentives to private firms with positive corporate income (profit) to increase R&D investment, through which they can save tax payments. Therefore, tax incentives are popular R&D support measures in several countries. According to the Organization for Economic Cooperation and Development (OECD) (2017), "in 2017, 30 OECD countries gave preferential tax treatment to business R&D expenditures, up from 16 OECD countries in 2000" (p. 156). Moreover, "in 2015, R&D tax incentives accounted for nearly half of the total government support for business R&D in the OECD area, up from one-third in 2006" (p. 156). Especially in Japan, the share of tax incentives in government support for R&D was 81% in 2015 and thus among the highest in OECD countries (OECD 2017, p. 156).

After 2000, tax incentives in Japan experienced frequent changes owing to macroeconomic shocks. In the 2003 reform, tax incentives schemes according to the *level* of R&D expenditures were introduced as an alternative to the traditional scheme according to the *increase* in R&D expenditures. In 2006, both options were integrated so that applicants may use the new in addition to the old scheme. Further changes followed in 2008, 2009, 2012, 2013, 2015, 2017, and 2019.

In this way, tax incentives in Japan are subject to complicated design and frequent changes, which makes empirical evaluations challenging. Hence, previous empirical studies on Japanese tax incentives have been relatively scarce. Relying on Kasahara et al. (2014), who analyzed the 2003 tax incentive reform, we focus on the 2009 reform in Japan with two different program changes (the increase in the upper limit of the tax deduction ratio from 20% to 30% and the extension of the carry-forward period until 2012) and estimate the causal effects of this reform on corporate R&D expenditures, distinguishing between these two program changes. We employ Difference- in-Differences (DID) estimation and fixed-effect panel estimation for these empirical evaluations and use the company micro data of Teikoku Databank (TDB). Moreover, we compare the effects of these policy changes between large and small firms and R&D-intensive and other industries.

The remainder of this paper is organized as follows: The following section explains the development of the Japanese tax incentive policy. Section 3 provides a brief review of previous studies on the effects of tax incentives on private R&D. Section 4 describes the data and samples used for the empirical analyses. Section 5 presents the empirical models and estimation results. In Section 6, we discuss the obtained results and provide additional tests. Finally, we conclude the paper in Section 7.

2. Overview of the Japanese Tax Incentive System

2.1. R&D tax incentive as a public R&D support

The R&D tax incentive is a special measure of tax deductions for corporate R&D, which is implemented in several countries to promote R&D and innovation. Private business corporations can deduct a part of R&D expenditures (including material costs, personnel costs, and research outsourcing) up to a certain amount from the corporation tax to be paid in the current year.

Public R&D support includes both subsidy and tax incentive policies (Busom et al. 2014). Using public subsidies, the government can select target R&D projects to provide direct financial support. Public subsidies for private R&D may distort resource allocation through market mechanisms through public intervention, which may be justified if it solves or mitigates market failures and thus contributes to enhancing social welfare. Specifically, if the private R&D level is suboptimal owing to market failures and the government can increase private R&D to a socially optimal level, the public subsidy is a favorable policy. With appropriate information and foresight, the government may promote R&D and innovation in specific industries and technological fields through targeted R&D subsidies. However, it has been argued that direct subsidy may incur moral hazard and thus a crowding-out effect in R&D when private investment is replaced by public subsidies (Czarnitzki and Lopes-Bento 2013)[1].

In contrast to public subsidies, under R&D tax incentives, the government does not directly intervene in selecting target firms and projects, but private firms decide to apply for tax deductions. Therefore, in general, tax incentives are preferable to subsidies from an economic point of view. Moreover, regarding tax incentives, the crowding-out issue of R&D investment is, by definition, less serious than support with subsidy. Yang et al. (2012) provide empirical evidence for this argument by showing that firms that applied for R&D tax incentives expend significantly more for R&D than those that did not. However, R&D tax incentives have been considered to be favorable for large firms because of the larger amount of profit and tax deduction and more active R&D than small firms.

2.2. Development of R&D Tax Incentive System in Japan[2]

In Japan, R&D tax incentives were first implemented in 1967 as a deduction of the *increased* amount of R&D expenditures from corporate income tax payments. As a preparation for the capital investment liberalization in 1970, the Japanese government developed private business R&D capabilities with a new public support measure. However, since this measure is applicable only for firms that continuously increase R&D expenditures, relatively few firms could benefit from tax incentives. Thus, in the 2003 reform, tax deductions of the *total* amount of R&D expenditures were introduced, and the firms could choose between both options of tax incentives (deduction of the increased or the total amount of R&D expenditures). Both options were integrated in 2006 so that firms may apply for both. In 2003, additionally, the upper limit of a tax deduction was raised to 20% of corporate tax payment, and the carryover of tax deduction to the following year was introduced so that R&D expenditures of the current year can be carried forward to the following year and deducted from the corporate tax of the following year.

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[1] Specifically, in Japan, the public subsidy is usually provided to reimburse actual costs after the project was finished. Hence, the problem of crowding out may be partially mitigated.

[2] The description in this subsection is mainly derived from the website information of Japanese Ministry of Finance and National Tax Agency.

In 2008, a new option was introduced so that the firm can add to the basic tax deduction according to the total amount of R&D expenditures, another deduction based on either the part of total R&D expenditures that exceed 10% of total sales, or the increase in total R&D expenditures (an average of the preceding three years) (Figure 1). The tax deduction ceiling was 20% of corporate tax in the baseline, but with the option of additional incentives for 10%, the maximum ceiling reached 30%.

Owing to the Lehman shock in September 2008, corporate income, corporate income tax and tax deduction significantly decreased in numerous firms. To promote R&D and innovation, in 2009, the Japanese government raised the upper limit of tax deductions from 20% to 30% of corporate tax as the baseline (the maximum ceiling with the optional deduction reached 40%) and extended the carryover period of tax deductions from one year until 2012 (for three years in maximum). The upper limit of tax deduction as the baseline was again decreased to 20% (optional maximum 30%) of corporate tax in 2012 but increased again to 30% (optional maximum 40%) in 2013 until 2015.

In 2015, the R&D tax incentive system experienced a considerable change: the carryover of R&D tax deductions to the following year was abolished, and tax incentives were extended in favor of R&D expenditures for open innovation. In 2017, new service innovation was added to the eligible target of R&D expenditures while considering the change in R&D expenditures from the average of the preceding three years (baseline ceiling 30%, optional maximum 40%). Finally, in 2019, open innovation (collaborative R&D with universities and other firms) and research outsourcing were considered new targets of tax incentives, with a special scheme for R&D ventures. The optional maximum ceiling was raised to 45% of corporate tax and 60% for R&D ventures.

It is noteworthy that a specific, advantageous scheme of tax incentives for small and medium enterprises (SMEs), "Tax Incentive Scheme to Strengthen the Technological Base of SMEs," was first introduced in 1985 and strengthened in 2003, 2006, and 2015. This scheme is eligible for firms with less than 100-million-yen capital and cannot be applied with the general scheme explained above. However, as Figure 3 shows, the share of this special scheme for SMEs has been almost negligible in total R&D tax credits.

2.3. Trend and International Comparison of R&D Tax Incentives

Figure 2 shows an international comparison of public financial support for private R&D to Gross Domestic Products (GDP) among OECD countries as of 2015 (OECD 2017). The share of public R&D support to the GDP in Japan is not among the highest, but the share of indirect support (tax incentives) to total R&D support in Japan is the fourth highest among the OECD countries with 80%. This suggests the importance of R&D tax incentives in Japan's public R&D support policies, while it may be ascribed to the highest ratio of R&D expenditures by large firms in Japan among the OECD countries (95%) (OECD 2017, p. 147).

Figure 3 shows the amount of R&D tax deductions in Japan since 2000. Tax deduction drastically increased in 2003 with the new tax incentive scheme, based on the total amount of R&D expenditures. After the Lehman shock in 2008, tax deductions significantly decreased with taxable income and corporate income tax. Since then, tax deductions have increased constantly. It is also shown that firms use tax incentives regarding the total amount rather than the increase in R&D expenditures in most cases. Moreover, the tax incentive scheme specific for SMEs has been used at a relatively low level.

Table 1 demonstrates the trend of R&D tax deductions based on capital size classes. The larger the capital size, the larger is the amount of applied tax deductions. This suggests that large firms have large R&D expenditures and are thus more likely to receive the benefits of R&D tax incentives.

The above data indicates that in Japan, indirect financial support via R&D tax incentives has a large share in the public support for private R&D and that the amount of R&D tax deductions has increased in recent years. However, large firms receive more benefits from R&D tax incentives than small firms due to many R&D expenditures.

Table 2 presents an international comparison of R&D tax incentives in some major countries as of 2008, just before the 2009 tax incentive reform in Japan, based on a Japanese material from the Ministry of Economy, Trade and Industry (METI). In China, South Korea, Australia, the U.K., France, and Canada, there is no ceiling of tax deduction ratio for R&D expenditures, whereas, in Japan, the ceiling is 30% of corporate income tax (20% for the baseline). Therefore, private incentives for R&D, especially in innovative firms, maybe hindered in Japan owing to the low ceiling of tax deductions.

Moreover, although the carryover of R&D tax deductions for the following year was introduced in 2003 in Japan, it can only be applied to firms with a positive taxable income and increased R&D expenditures in the following year. Considering that approximately 70% of Japanese firms (especially SMEs) have deficits, a large proportion of Japanese firms may not enjoy the favorable carryover of tax incentives.

In an international comparison (Table 2), Japan shows the shortest carryover period with only one year: all countries except for the Netherlands allow the firms to carry forward tax deduction to the following years, so that even firms with deficits in the current year may use tax incentives for R&D within some years. However, while tax deduction can be carried forward only to the following year in Japan, the carryover is allowed for a longer term (the following five to 20 years) or infinitely in other countries. As mentioned before, this carryover for one year was abolished in Japan in 2015.

Overall, the Japanese R&D tax incentive system is characterized by a low ceiling of tax deductions and a short and limited carryover, and thus quite different from the other major countries. Therefore, in the empirical part of this study, we target the 2009 tax incentive reform in Japan that addresses both the ceiling and carryover of tax deductions and separately estimate the effects of these changes.

3. Literature Review

Empirical studies on the effects of R&D tax incentives on private R&D have been conducted since the 1980s. Early studies targeting North America (Mansfield 1986; Cordes 1989; Hall 1993; Hall and van Reenen 2000) find positive but modest effects on R&D expenditures by estimating tax price elasticity. Paff (2005) compares state-level R&D tax credits between California and Massachusetts and finds a positive effect of tax credit rate increase (which occurred only in California) on R&D expenditures, using a DID approach and a firm-level panel dataset.

Some studies analyze panel data of OECD countries and obtain similar findings (Bloom et al. 2002; Thomson 2017). Elschner et al. (2011) analyze and argue the effectiveness of R&D tax incentives in the European Union (EU) countries, considering the differences in their design, especially tax credit conditions. They suggest that the design of tax incentives must be by the framing tax system to be effective.

Previous studies compared the effects of R&D tax incentives on small and large firms (Baghana and Mohnen 2009; Lokshin and Mohnen 2012; Labeaga et al. 2014; Romero-Jordán et al. 2014; Rao 2016). Lokshin and Mohnen (2012) analyze the effectiveness of level-based R&D tax credit in the Netherlands and find positive effects on private R&D investment but cannot reject crowding-out for large firms. Using panel data of Spanish manufacturing firms, Labeaga et al. (2014) find that large firms use R&D tax credit more than small firms do, whereas its impact is smaller for large firms than for SMEs.

Romero-Jordan et al. (2014) are also one of the first to compare the effects of R&D tax credit and subsidies on R&D expenditures. Using the panel data of Spanish manufacturing firms and the fixed-effect two-step generalized method of moment (GMM) model, they show that tax credits have positive effects only for large and established firms, whereas public grants have adverse effects, but only for small and young firms. Another recent study (Neicu et al. 2016) analyzes how the policy mix of

R&D tax credit and R&D subsidy affects the behavioral additionality of recipients, using the Belgian firm data. They find that R&D subsidies induce tax credit users to focus more strongly on studies relative to development and to accelerate the execution of R&D projects. Moreover, the policy mix induces firms to scale up current R&D or initiate additional projects.

While most empirical studies on R&D tax incentives address the effects on R&D input, some studies examine their effects on innovation and patents (Czarnitzki et al. 2011; Cappelen et al. 2012; Dechezlepretre et al. 2016; Altstadsaeter et al. 2018). Czarnitzki et al. (2011) evaluate the impact of R&D tax credits on innovation using the Canadian innovation survey data. Employing the propensity score matching (PSM) method, they find that recipients of tax credits show significantly better scores on most innovation performance indicators. Cappelen et al. (2012) estimate the effect of R&D tax credit introduction in Norway in 2002 on innovation using the innovation survey data. They find that projects receiving tax credits tend to develop new production processes but not new-to-the-market products. Dechezlepretre et al. (2016) employ a Regression Discontinuity Design (RDD) to evaluate the impact of tax incentives on private R&D and innovation. With the size threshold change of SMEs in the U.K. in 2008, firms above the old SME threshold became eligible for a special SME rate, they estimate a significant impact on both R&D and patenting.

While most previous studies target R&D tax incentives in North American and European (especially EU) countries, only a few policies focus on Japanese policy (Koga 2003; Kasahara et al. 2014; Kobayashi 2014), although the share of R&D tax incentives in public R&D support in Japan is among the highest among OECD countries[3]. Koga (2003) estimates tax price elasticity on R&D expenditures using panel data of manufacturing firms from an official survey from 1989 to 1998 and finds that R&D tax incentives have positive and significant effects only on large firms (but not on medium firms). Kasahara et al. (2014) focus on the R&D tax credit reform in Japan in 2003 and find a significant effect of the increased tax deduction limit, larger for firms with higher debt ratios. Kobayashi (2014) targets Japanese SMEs and, using PSM and official survey data, finds a positive effect of R&D tax credits on SMEs' R&D expenditures, especially for liquidity-constrained firms.

To sum up the previous literature, most empirical studies on the effects of R&D tax incentives focus on the effects of this policy as such, while relatively few studies

[3] There are some other empirical studies on Japanese R&D tax incentives written in Japanese. Moreover, Yang et al. (2012) provide firm-level evidence from Taiwan using PSM and panel GMM and report a positive and significant impact on R&D expenditures.

explicitly consider the effects of policy design (Elschner et al. 2011) or policy changes (Cappelen et al. 2012; Kasahara et al. 2014; Dechezlepretre et al. 2016) in the tax incentives. Moreover, to the best of our knowledge, no empirical studies have addressed the effects of the possibility of carrying forward tax credits in later years, although this condition differs significantly across countries (see Section 2 and Elschner et al. 2011). This study fills this research gap and provides empirical evidence by targeting the 2009 tax incentive reform in Japan as a social experiment. Specifically, we estimate the effects of enhancing the tax deduction ceiling and extending the carryover period separately. Moreover, we compare these effects between small and large firms and between industries with relatively high and low R&D intensity.

4. Data and Sample

We used the company financial information database COSMOS1 of Teikoku Databank (TDB) for the period 2008-2014, which was provided to the authors through the Teikoku Databank Center for Advanced Empirical Research on Enterprise and Economy (TDB-CAREE) at Hitotsubashi University, Graduate School of Economics. TDB is the largest incentive information company in Japan. This database covers financial statements (balance sheet data and profit-loss statement) of more than one million companies in Japan for several years, so that we can construct a large-scale panel data set for empirical estimations.

From all firms in this database, we excluded firms with no data for R&D expenditures (missing values) and those with no R&D expenditures (zero values). Thus, our sample comprises only firms for which we could obtain R&D expenditure data from 2008 to 2014. We use an unbalanced panel dataset owing to missing data for some years so that the number of firms differs across years. The sample size for each year is approximately 22,000 (see Table 4).

This study distinguishes sample firms into large and small firms according to the amount of capital to compare the policy effects between large and small firms; we classified firms with a capital of more than 100 million yen into large firms and those with smaller capital into small firms[4]. Moreover, we classify the firms into various one-digit industries (sectors), such as construction and wholesale, whereas firms in the manufacturing sector are classified into two-digit industries such as food/beverage,

[4] This classification is based on the corporation tax law rather than the Basic Law of Small and Medium Enterprises (SMEs).

chemical, and electric machinery industries, based on the TDB Industry Classification Codes. This is because R&D expenditures and R&D intensity may differ significantly across industries within the manufacturing sector.

Then, according to industry classification, we divide the sample into R&D-intensive and other industries. We define R&D intensity as the ratio of R&D expenditures to total assets and regard the industries with above-median R&D intensity as "R&D intensive industries." Table 3 shows the median R&D intensity of sample firms in each industry.

We have more challenges in obtaining the real tax deduction ratio for each firm since the tax payment data of each firm is not available. Therefore, based on the method used in previous studies, we calculate the tax deduction ratio of sample firms indirectly from financial data in the following way.

First, we calculate the amount of corporation tax for each firm in each year. For this purpose, we need to estimate the taxable income levels. According to Kasahara et al. (2014), we calculate taxable income (or loss) from operational profit. By defining taxable income as the difference between operating profit and forwarded loss, and the amount of corporation tax as the product of corporation tax ratio and operating income, we can calculate the amount of corporation tax as the product of the corporation tax ratio and the difference in operational profit and forwarded loss. The corporation tax ratio was 30% from 2008 to 2012 and reduced to 25.5% in 2013 and 2014 for large firms. A special (low) rate was applied to SMEs (smaller firms); for the taxable income of up to eight million yen per year, the ratio was 22% in 2008, 18% from 2009 to 2012, and 15% in 2013 and 2014. For the other part of taxable income above eight million yen, the tax ratio is the same as large firms.

Next, we calculate tax deductions for each year from taxable income or loss. This calculation is complicated since the rules of R&D tax incentives are often revised during the sample period. Thus, the calculation of corporate tax deductions varies every year. We explain the details of this calculation in 2008, 2009-2011, 2012, and 2013-2014 in a supplement, which will be available from the authors upon request.

Finally, by dividing the estimated tax deduction by R&D expenditures, we can obtain the tax deduction ratio, the ratio of tax deductions to R&D expenditures. The larger this ratio, the higher the incentive of firms to invest in R&D to save corporate tax payments. We show the descriptive statistics of the variables in Table 4, including the estimated amount and ratio of tax deductions for each year and for large and small firms.

5. Empirical Models and Results

5.1. Baseline Estimation Model

In September 2008, the Lehman Shock incurred a deficit in numerous firms, which considerably reduced R&D expenditures. Thus, the tax deductions of R&D expenditures decreased dramatically. However, after the tax incentive amendment in 2009, private R&D expenditures and R&D tax deductions increased again. Therefore, we empirically investigate whether the tax incentive reform in 2009 significantly contributed to the promotion of private R&D investment by solving the inherent problems of R&D tax incentives in Japan mentioned in Section 2, identifying the causal effects of this policy change.

Referring to Kasahara et al. (2014), we employ the following estimation model as the baseline:

$$ln\,RD_{it} = \beta_1 + \beta_2\tau_{it} + \beta_3 lnSIZE_{it-1} + \beta_4\frac{b_{it-1}}{A_{it-1}} + \beta_5(\tau_{it}\frac{b_{it-1}}{A_{it-1}}) + \beta_6\frac{CF_{it-1}}{A_{it-1}} +$$

$$\beta_7(\tau_{it}\frac{CF_{it-1}}{A_{it-1}}) + Z'_{it}\alpha + \eta_t + \mu_i + \varepsilon_{it} \quad \ldots\ldots (1).$$

The dependent variable $ln\,RD_{it}$ is the R&D expenditures of firm *i* in year *t* in the natural logarithm. τ_{it} denotes the ratio of R&D tax deductions applied to firm *i* in year *t*, calculated using the method explained in the previous section. We expect this variable to have a positive effect.

Considering the endogeneity of the independent variables, all variables except for the amount and ratio of R&D tax deductions take a time lag of one year. $lnSIZE_{it-1}$ is the number of employees in the natural logarithm of firm *i* in year *t-1*, and a proxy for firm size. We expect this variable to have a positive effect. b_{it-1}/A_{it-1}, the ratio of debt to assets of firm *i* in year *t-1*, is expected to have a negative effect on the firm's R&D expenditures, which is mitigated by the R&D tax incentive. Thus, we expect $\tau_{it} \times b_{it-1}/A_{it-1}$, the interaction term of the debt ratio with the R&D tax deduction ratio, to have a positive effect. CF_{it-1}/A_{it-1}, the ratio of cash flow to assets, proxies for the availability of internal funding are expected to have a positive effect. Its interaction with the tax deduction ratio, $\tau_{it} * CF_{it-1}/A_{it-1}$ is expected to also have a positive effect. Z_{it} covers other control variables (year, industry, and settlement month dummies). η_t and μ_i denote year- and firm-fixed effects, respectively. ε_{it} is the error term and denotes unobservable and heterogeneous effects on a firm's R&D expenditures.

In the following Section, we estimate the effects of the tax incentive reform in 2009 regarding 1) the increased upper limit of tax deduction ratio and 2) the extension of the carryover period of tax incentives on private R&D expenditures using this baseline model.

5.2. Effects of Increasing the Upper Limit of Deduction Ratio

First, we examine the effect of increasing the upper limit of the R&D tax deduction ratio from 20% to 30% of corporate tax. We present the hypothesis that an increase in the upper limit of tax deductions promotes private R&D expenditures. Moreover, as previous studies show that R&D tax incentives have a positive effect, especially for firms with larger size (capital) (Koga 2003) and in high-tech industries (Yang et al. 2012, we expect that the increase in the upper limit of the tax deduction ratio may have similar effects, thus larger positive effects for large firms and in R&D-intensive industries.

We employ DID estimations before and after 2009. The treatment group comprises firms whose estimated ratio of R&D tax incentive was positive (τ_{it}>0) both in 2008 and 2009, whereas the firms in the control group have no R&D tax incentive (τ_{it}=0) both in 2008 and 2009. Thus, we exclude firms from the sample that applied R&D tax incentives either in 2008 or 2009. This is because we would overestimate the effect of tax incentive reform by including firms that used tax incentives only in 2008 and underestimate it by including firms that used tax incentives only in 2009.

For this estimation, we extend the baseline model (1) as follows:

$$lnRD_{it} = \beta_1 + \beta_2(\tau_{it} * AFTER_{i,2009}) + \beta_3\tau_{it} + \beta_4 AFTER_{i,2009} + \beta_5 lnSIZE_{it-1} + \beta_6\frac{b_{it-1}}{A_{it-1}} + \beta_7(\tau_{it}\frac{b_{it-1}}{A_{it-1}}) + \beta_8\frac{CF_{it-1}}{A_{it-1}} + \beta_9(\tau_{it}\frac{CF_{it-1}}{A_{it-1}}) + Z'_{it}\alpha + \varepsilon_{it} \quad \ldots\ldots (2).$$

If we estimate a positive and significant value for β_2, which is the coefficient of $\tau_{it} * AFTER_{i,2009}$ and indicates the average treatment effect on the treated (ATT), we can identify a causal effect of enhancing the upper limit of tax deductions on private R&D expenditures. β_3 is the coefficient of the treatment variable τ_{it} (the ratio of R&D tax deduction ratio) of firm *i* in year *t*. $AFTER_{i,2009}$ is a dummy variable that takes the value one for 2009 (the year of the focal tax incentive reform) or later, and zero otherwise (for and before 2008). The estimation period is limited to 2008 and 2009, excluding the data for the years 2010-2012, in which tax incentive reform in 2009 was applied. In this way, we will exclude the effect of another reform, the extension of the effective carryover period from 2010 to 2012. The other variables in this model are the same as those in the baseline model.

We confirm that the median of firms' R&D expenditures in the treatment and control groups before the observation period (from 2005 to 2007) are quite similar (Figure 4), suggesting that the precondition of parallel trends for DID is satisfied.

Table 5 presents the estimation results. In this table, Models 1 and 2 show the results for large firms (more than 100-million-yen capital), whereas Models 3 and 4 show results for small firms. Models 1 and 3 target R&D-intensive industries (with a median of R&D intensity above average), whereas Models 2 and 4 target other industries. In this way, we compare the effects of tax incentive reform between large and small firms on the one hand and between R&D-intensive and other industries.

We find that ATT (the coefficient of tax deduction ratio and AFTER dummy) is positive and significant at the 1% level for large firms in R&D-intensive industries (Model 1). As expected, regarding control variables, firm size, the interaction term of tax deduction ratio and debt ratio, and the interaction term of tax deduction ratio and cash flow ratio have all positive and significant coefficients. The AFTER dummy has a strongly negative coefficient, suggesting a significant overall decline in R&D expenditures after the Lehman Shock. The results are quite similar in Model 2 for large firms in less R&D-intensive industries, except for the negative effect of firm size and no effect of the interaction of tax deduction ratio and debt ratio. These results suggest that the increase in the upper limit of the tax deduction ratio as a part of the tax incentive reform in 2009 encouraged large firms' R&D expenditures in both R&D-intensive and other industries.

Regarding small firms, we again confirm positive and significant ATT (at the 1% level) for those in R&D-intensive industries (Model 3) but not in other industries (Model 4). The AFTER dummy has strongly negative coefficients in both models, suggesting a significant overall decline in R&D expenditures after the Lehman Shock. The tax deduction ratio (single term) has a positive and significant coefficient only in Model 4. The interaction term of tax deduction ratio and cash flow ratio shows a negative and significant effect for R&D-intensive small firms in Model 3.

Overall, we find that the increase in the upper limit of the tax deduction ratio significantly promoted R&D expenditures in 2009 for large firms in all industries and small firms in R&D-intensive industries. These results are consistent with those of Koga (2003) and Yang et al. (2012).

5.3. Effects of Extending the Carryover Period

Next, we examine the effect of the extension of the carryover period until 2012 (maximum three years). By 2008, carryover of R&D tax deductions for the following years was not allowed in Japan, in contrast to other countries. The Japanese government changed the rule in 2009, as a response to the Lehman Shock, to allow temporary carryover of R&D tax deduction until 2012 (again, since 2013, carryover was not allowed). When the carryover of tax deductions for the following years is allowed, it may significantly encourage R&D expenditures, especially for small firms, since the firms now have the opportunity to select a better year (with more corporate tax payments). Thus, we hypothesize that extending the carryover period of tax deductions until 2012 promoted R&D expenditures. Moreover, we expect this effect to be larger for small firms whose operating income and corporate tax payments may differ significantly across years.

For this estimation, we employ the DID panel fixed-effect estimation under the following two conditions:

1) Each firm can recognize their maximum tax deductions from year t to 2012, based on corporation tax payments in the previous year.

2) Each firm determines its optimal R&D expenditures in each year based on the difference between the sum of maximum tax deductions from year t to 2012 and the carryover tax deductions from the previous year.

Let us provide an illustrative example: Firm i determines R&D expenditures in 2010. If it paid a corporate tax of 100 in the previous year (2009), its maximum R&D tax deduction is 40 in 2010, 40 in 2011, and 30 in 2012. The sum of the maximum R&D tax deductions in each year (100) equals the sum of the maximum tax deductions until 2012. Firm i determines R&D expenditures in 2010, based on this consideration. The sample period is from 2009 to 2012, which covers the carryover extension period.

We extend the baseline model as follows:

$$ln\, RD_{it} = \beta_1 + \beta_2 CFRD_{it} + \beta_3 lnSIZE_{it-1} + \beta_4 \frac{b_{it-1}}{A_{it-1}} + \beta_5 \frac{CF_{it-1}}{A_{it-1}} + \eta_t + \mu_i + \varepsilon_{it} \quad \text{…. (3).}$$

The independent focal variable $CFRD_{it}$ is defined as the ratio of the sum of maximum R&D tax deductions before and after the application of tax deduction carryover (sum of maximum R&D tax deductions including deduction carryover/sum of maximum R&D tax deductions minus deduction carryover) of firm *i* in year *t*, which should be larger than 1. The larger the tax deduction carryover, the smaller the denominator, and thus the larger the $CFRD_{it}$. If the estimated β_2 is positive and significant, it suggests that firms with larger $CFRD_{it}$, namely those with larger tax deductions carryover, may expend more in R&D. As in the baseline estimation model, we control firm size, debt-to-asset ratio, and cash-flow-to-asset ratio. We also include year dummies, industry dummies, and settlement month dummies to control for time- and industry-specific factors. Moreover, we employ firm fixed-effect estimations to control for the effects of any unobservable, firm-specific, and time-invariant factors.

However, applying tax incentive carryover should fulfill the condition that the current R&D expenditures should be larger than those in the previous period. Therefore, the application of tax deduction carryover is an endogenous factor, suggesting that numerous firms did not use carryover owing to this condition. We check the robustness of our estimation results with an additional sub-sample estimation of the top 25% $CFRD_{it}$ firms. Moreover, with another estimation covering the period 2013 and 2014 (extended sample period from 2009 to 2014), in which carryover was restricted only to the following year, we may distinguish the effect of the carryover period from the effect of carryover itself.

Table 6 presents the estimation results on the extension of the carryover period, distinguishing between large and small firms, between R&D intensive and other industries, and between the entire sample and the sub-sample of the top 25% CFRD. First, it is common to all specifications (sub-samples) that the CFRD has no significant coefficients. These results suggest that the extension of the carryover period of tax deduction in the 2009 reform may have no effect on R&D expenditures for both large and small firms, in R&D-intensive and other industries, and also for firms with the top 25% CFRD.

Table 7 presents the results of another robustness check by extending the observation period until 2014, the last year of the tax deduction carryover, similar to those in Table 6. For both large and small firms, in R&D-intensive and other industries, and for firms with the top 25% CFRD, we find no significant effects of CFRD on R&D expenditures.

6. Discussion

The previous section examined the causal effects of the extension of the carryover period of tax deduction until 2012 (CFRD) using fixed-effect panel estimation to control for unobservable, time-invariant firm characteristics and found no significant effects on R&D expenditures in any sub-sample. Alternatively, we estimated the same model using pooled OLS and found positive and significant effects of CFRD in all sub-samples. These contrasting results suggest that there may be significant firm-level heterogeneity, which could increase R&D expenditure through this policy change.

Owing to the Lehman Shock in September 2008, numerous firms got deficits and reduced R&D expenditures, and thus R&D tax incentives significantly. However, both private R&D expenditures and tax deductions increased again after the tax incentive reform in 2009. The empirical test is described in Section 5.2. targets the years 2008 and 2009 and employs DID, but we will alternatively test whether the increase in the tax deduction ratio resulted in an absolute increase in R&D expenditures in the longer term. Thus, we employ the first-difference panel fixed-effect model instead of the DID and target the years 2009-2012. The estimation model is formulated as follows:

$$\Delta lnRD_{it} = \beta_1 + \beta_2 \Delta\tau_{it} + \beta_3 \Delta lnSIZE_{it-1} + \beta_4 \Delta \frac{b_{it-1}}{A_{it-1}} + \beta_5 \Delta(\tau_{it} \frac{b_{it-1}}{A_{it-1}}) + \beta_6 \Delta \frac{CF_{it-1}}{A_{it-1}} + \beta_7 \Delta(\tau_{it} \frac{CF_{it-1}}{A_{it-1}}) + Z'_{it}\alpha + \Delta\epsilon_{it} \;\ldots\ldots(4).$$

Equation (4) is a first-difference fixed-effects model, in which β_2 denotes the effect of an increase in the tax deduction ratio on the increase in R&D expenditures. The estimation period was from 2009 to 2012.

Table 8 presents the estimation results of the first-difference model. β_2 is positive and significant in all sub-samples. These results suggest that an increase in the tax deduction ratio incurred an increase in R&D expenditures after 2009 for both large and small firms and in R&D-intensive and other industries.

We also check the mechanism of increasing the upper limit of R&D tax deductions on R&D expenditures by focusing on the mediating role of cash flow. Through tax incentives, the corporate tax to be paid is partially retained and increases the firm's cash flow. In addition, the estimation results in Table 8 indicate that the cash flow to asset ratio in the preceding year increases R&D expenditures in the current year. Thus, R&D tax deductions may indirectly affect R&D expenditures in terms of an increase in cash flow. To check this indirect effect, we employ structural equation modeling (SEM) instead of DID to distinguish the indirect effect (in the following year) from the direct effect (in the current year) of the R&D tax deduction ratio.

Table 9 summarizes the estimation results of SEM, comparing the direct and indirect effects of the increase in the tax deduction ratio on the increase in R&D expenditures in the following period. For firms in R&D-intensive industries, both large and small firms, we find significant indirect effects, though much smaller than direct effects. These results suggest that R&D tax incentives may affect R&D expenditures via increased cash flows in such industries. Moreover, we find an adverse and significant direct effect for small firms in R&D-intensive industries. A major reason for this adverse direct effect may be that, since most small firms have deficits, numerous small firms with R&D activities cannot apply for R&D tax incentives.

7. Conclusion

This study targets the R&D tax incentive reform in 2009 in Japan and investigates the effects on private R&D expenditures by increasing the upper limit of the tax deduction ratio from 20% to 30% and the extension of the carryover period until 2012. Based on the estimation model of Kasahara et al. (2014) and using DID and panel fixed-effect estimation, we find positive and significant effects of the former on R&D expenditures, except for small firms in less R&D-intensive industries, but no significant effects of the latter on R&D expenditures in any slab sample.

We can point out some shortcomings of this study. First, we could not access administrative data, so we could not obtain actual tax deductions. Instead, relying on Kasahara et al. (2014), we estimate tax deductions indirectly from operating income in financial statements. However, using tax account data, which was not available to us, we could estimate R&D tax deductions more accurately.

Second, we may underestimate the impact of tax incentive reform. In employing DID, we have to distinguish between the treatment and control groups. More specifically, we exclude the endogenous move of firms between these groups. Thus, we limit the treatment group to firms that applied for tax incentives in 2008 and 2009 and the control group to firms that applied for tax incentives in 2008 or 2009. However, numerous firms may use tax deductions in 2009, but not in 2008, since they had a deficit (and so no tax payment) in 2008 owing to the Lehman Shock. Since we exclude these firms from our sample, the effect of tax incentive reform may thus far be underestimated.

We derive some policy implications for our study. First, we obtain direct evidence of an increase in the upper limit of the tax deduction ratio but no empirical evidence on the positive impact of tax deduction carryover. Thus, we cannot support tax deduction carryover. A Japanese study (Kato and Saito 2013) argues for further extension of the carryover tax deduction period as a relief measure for deficit firms, but our study does not support this argument. Tax deduction carryover in Japan, though only to the following year thus far, was abolished in 2015; instead, a new type of R&D tax deduction about open innovation was introduced. Under this new scheme, a firm that collaborates in R&D with external organizations (other firms, universities, etc.) is eligible for application to R&D tax incentives. Based on the estimation results of this study, we may support this new policy scheme.

Moreover, tax incentives have been criticized as being favorable for large firms because large firms have a larger profit and thus pay more corporate tax. In contrast, most small firms in Japan have a deficit, and even small profitable firms earn relatively small profits. Thus, on average, large firms can benefit more from tax incentives. Our estimation results that the increase in the upper limit of tax deduction has no significant effect on small firms' R&D expenditures in less R&D-intensive industries are consistent with this argument and previous empirical evidence. Therefore, the government should consider a policy scheme of tax deduction that is more "friendly" to small firms.

Finally, although evidence-based policymaking (EBPM) has been attracting attention from policymakers and academia in recent years, especially in Japan, recent empirical studies on R&D tax incentives are relatively few, perhaps owing to the limited availability of administrative data and the complicated policy design with frequent changes. However, R&D tax incentives are undoubtedly an important policy measure to promote R&D and innovation. Therefore, in several countries, including Japan, R&D tax incentives play a major role. Public policy should consider previous empirical evaluations when designing policy schemes.

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Table 1: The trend of R&D tax deduction by capital size classes (¥)

Capital size class	2011	2012	2013	2014	2015	2016	2017	2018
Less than 10 million	2,131	2,153	2,271	2,411	3,268	3,348	3,538	3,827
Less than 20 million	3,608	4,198	3,551	4,027	4,501	4,290	5,176	5,674
Less than 50 million	5,324	4,756	5,258	6,390	7,313	6,108	5,604	6,482
Less than 1 billion	17,365	16,788	17,099	20,014	19,987	20,789	23,247	23,271
Less than 3 billion	6,485	6,226	6,536	6,731	7,850	8,051	6,509	6,369
Less than 5 billion	10,827	9,460	10,966	12,142	11,961	11,850	14,253	12,942
Less than 10 billion	5,579	5,475	5,464	6,464	6,674	6,514	6245	6,986
Less than 100 billion	46,268	48,020	53,371	60,929	55,770	53,614	56204	57,056
Over 100 billion	167,496	175,007	231,055	220,870	180,581	155,151	165,771	155,898
Consolidat. corporation	265,084	123,073	288,401	334,635	317,875	322,868	379,461	343,067

Source: Ministry of Finance, survey report about the application of Act on Special Measures Concerning Taxation, each year (Jap).

Table 2: International comparison of R&D tax credits, 2008

Country	Upper limit of deduction	carryover period
Australia	Unlimited	Infinite
China	Unlimited	5 years
France	Up to 16 million euros	3 years
Japan	Up to 20% of CIT	1 year
Korea	Unlimited	5 years
Netherlands	Unlimited	Not available
Spain	Up to 35% of CIT	15 years
UK	Unlimited	Infinite
US	Up to 25% of (CIT - $ 25,000)	20 years

Source: METI (2008).

Note: “CIT” denotes corporate income tax.

Table 3: The median R&D intensity of the sample firms in each industry

Industry		2008	2009	2010	2011	2012	2013	2014
1. Agriculture, forestry	Median	0.001169	0.001842	0.002339	0.001209	0.001294	0.001136	0.001438
	Observations	44	53	59	61	60	58	67
2. Fishery	Median	0.000466	0.001064	0.000996	0.001555	0.00023	0.00114	0.0001
	Observations	1	1	2	3	3	5	3
3. Mining and quarrying of stone	Median	0.001591	0.001233	0.001168	0.00094	0.001112	0.00079	0.000466
	Observations	54	44	37	36	37	31	30
4. Construction	Median	0.001728	0.001735	0.001723	0.001504	0.001495	0.001447	0.001457
	Observations	10120	9514	9360	8760	8705	8484	8513
5. Miscellaneous services	Median					0.005625	0.001456	
	Observations	0	0	0	0	1	1	0
6. Miscellaneous manufacturing	Median	0.002278	0.00316	0.002108	0.002474	0.002808	0.002601	0.001813
	Observations	151	145	141	139	138	136	142
7. Manufacture of leather tanning,	Median	0.00137	0.000599	0.000715	0.000955	0.00103	0.000511	0.000389
	Observations	27	26	25	25	24	24	22
8. Manufacture of general-purpose	Median	0.003321	0.003559	0.002933	0.003455	0.002396	0.003171	0.0028
	Observations	230	225	256	238	239	260	238
9. Manufacture of rubber products	Median	0.002778	0.0034	0.003372	0.003455	0.002047	0.002295	0.002782
	Observations	51	48	48	53	60	60	52
10. Manufacture of pulp, paper, and	Median	0.000745	0.000663	0.00064	0.000694	0.000636	0.000552	0.000705
	Observations	84	87	98	86	77	94	82
11. Manufacture of plastic products,	Median	0.001611	0.001996	0.001876	0.001639	0.001324	0.001374	0.00118
	Observations	233	236	241	239	252	276	257
12. Manufacture of chemical and allied	Median	0.015182	0.013429	0.011591	0.013846	0.013307	0.011509	0.011958
	Observations	391	419	432	422	443	468	435
13. Printing and allied industries	Median	0.000588	0.000726	0.000692	0.000781	0.000554	0.000617	0.000499
	Observations	90	86	93	80	89	94	96
14. Manufacture of furniture and	Median	0.001424	0.001316	0.001197	0.001178	0.001306	0.001349	0.00143
	Observations	102	97	94	90	86	77	95
15. Manufacture of information and	Median	0.026882	0.02693	0.023845	0.02274	0.024856	0.023476	0.025056
	Observations	103	95	88	92	95	88	89
16. Video picture, sound information,	Median					0.000734		
	Observations	0	0	0	0	1	0	0
17. Manufacture of lumber and wood	Median	0.001317	0.000914	0.001097	0.001119	0.000653	0.001089	0.000585
	Observations	62	63	65	62	58	66	66
18. Manufacture of business-oriented	Median	0.016946	0.014036	0.013314	0.012129	0.011612	0.014175	0.013568
	Observations	181	187	189	176	178	185	196

Table 3: The median R&D intensity of the sample firms in each industry (cont.)

19. Manufacture of production	Median	0.003888	0.003944	0.003505	0.003535	0.002991	0.002804	0.002187
	Observations	450	438	457	487	479	510	524
20. Manufacture of petroleum and coal	Median	0.002697	0.002561	0.001059	0.001167	0.001333	0.0014	0.000802
	Observations	22	24	25	27	21	25	19
21. Manufacture of ceramic, stone, and	Median	0.001668	0.001576	0.001571	0.00187	0.001734	0.001846	0.001332
	Observations	245	227	236	230	225	226	225
22. Manufacture of textile mill products	Median	0.001943	0.001749	0.001932	0.001619	0.001756	0.002549	0.002273
	Observations	155	172	167	169	168	161	172
23. Manufacture of transportation	Median	0.00397	0.004173	0.003116	0.003451	0.003771	0.003634	0.00264
	Observations	151	146	163	164	177	175	170
24. Manufacture of fabricated metal	Median	0.001203	0.001295	0.001435	0.001385	0.001509	0.001429	0.001358
	Observations	388	422	428	419	422	447	432
25. Manufacture of iron and steel	Median	0.002193	0.002627	0.002352	0.002209	0.001845	0.00211	0.001049
	Observations	71	78	79	81	76	80	80
26. Electronic parts, devices, and	Median	0.009689	0.007766	0.008993	0.008027	0.008279	0.007846	0.008738
	Observations	145	157	146	150	148	149	147
27. Manufacture of electrical	Median	0.007459	0.007287	0.007673	0.008302	0.007919	0.007788	0.007446
	Observations	341	347	355	360	365	364	372
28. Manufacture of non-ferrous metals	Median	0.003386	0.002151	0.004041	0.003542	0.003541	0.002953	0.002347
	Observations	68	68	71	71	66	71	63
29. Manufacture of food	Median	0.001044	0.000879	0.000947	0.000887	0.000997	0.000876	0.000794
	Observations	440	458	470	469	480	500	493
30. Manufacture of beverages, tobacco,	Median	0.001177	0.001119	0.001436	0.000804	0.001163	0.001408	0.00106
	Observations	71	83	72	75	71	89	91
31. Electricity, Gas, Heat supply, and	Median	0.007493	0.00649	0.006225	0.006139	0.005332	0.004808	0.004658
	Observations	44	40	50	58	59	59	55
32. Information and communications	Median	0.005314	0.004123	0.003906	0.003168	0.003364	0.003692	0.003418
	Observations	786	766	756	774	834	839	893
33. Transport and postal activities	Median	0.000644	0.000655	0.000567	0.000671	0.000565	0.000517	0.000611
	Observations	136	149	175	170	172	179	187
34. Wholesale and Retail trade	Median	0.001169	0.001173	0.001138	0.001046	0.001108	0.001065	0.001038
	Observations	3892	3866	3913	3993	4167	4364	4426
35. Finance and Insurance	Median	0.05102	0.013048	0.012186	0.009457	0.008984	0.005793	0.023592
	Observations	35	12	6	5	5	5	4
36. Real estate and goods rental and	Median	0.000601	0.000578	0.000682	0.000588	0.000508	0.000506	0.000574
	Observations	596	587	565	559	563	529	525

Table 3: The median R&D intensity of the sample firms in each industry (cont.)

37. Scientific research,	Median	0.003256	0.00305	0.003717	0.003138	0.002935	0.002993	0.003147
	Observations	600	568	583	605	609	608	676
38. Accommodations,	Median	0.001244	0.001036	0.000932	0.0009	0.00105	0.001052	0.001049
	Observations	387	396	396	430	445	484	541
39. Living-related and personal	Median	0.000847	0.000992	0.00094	0.000734	0.000786	0.000753	0.000888
	Observations	133	145	144	137	145	154	155
40. Education, learning support	Median	0.001345	0.002065	0.001471	0.001385	0.001924	0.00175	0.005943
	Observations	20	22	26	25	24	23	22
41. Medical, health care, and welfare	Median	0.001365	0.001399	0.001085	0.001243	0.001389	0.001481	0.001561
	Observations	187	172	173	197	235	229	236
42. Compound services	Median	0.000743	0.000761	0.000536	0.00063	0.000454	0.000525	0.00038
	Observations	40	43	54	62	60	60	67
43. Services, N.E.C	Median	0.001781	0.001657	0.001504	0.001263	0.00149	0.001538	0.001561
	Observations	657	685	716	691	690	721	751

Table 4: Descriptive statistics of the 2007–2012 regression sample (mean and variance)

	Large firms					
	2007	2008	2009	2010	2011	2012
R&D expenditure	2,172,139	2,285,101	2,306,615	2,216,145	2,281,039	2,294,593
	(15800000)	(16900000)	(16900000)	(15200000)	(15600000)	(15600000
Number of employees	856	871	917	939	938	936
	(2427.101)	(2448.608)	(2529.089)	(2554.4)	(2575.509)	(2601.513)
Asset	101,000,000	99500000	99000000	104000000	105000000	106000000
	(4.52E+08)	(4.5E+08)	(4.47E+08)	(4.57E+08)	(4.81E+08)	(4.91E+08)
Debt	56,900,000	56600000	58400000	59600000	60900000	62900000
	(3.01E+08)	(3.07E+08)	(3.18E+08)	(3.16E+08)	(3.53E+08)	(3.85E+08)
Cashflow	4,603,994	4091213	1317949	2298524	3455977	2136433
	(23100000)	(19400000)	(19700000)	(17300000)	(17800000)	(22600000
Ratio of debt to asset	0.0058	0.5935	0.6229	0.5805	0.5728	0.5795
	(0.312456)	(0.455948)	(0.935941)	(0.560251)	(0.520723)	(0.567126)
Ratio of cashflow to asset	0.0002	0.0115	-0.0048	0.0086	0.0182	0.0147
	(0.194356)	(0.237091)	(0.221904)	(0.171345)	(0.244706)	(0.232874)
Taxable income		4,608,699	2,695,945	3,111,734	3,912,783	3,562,968
		(20500000)	(14300000)	(17000000)	(18200000)	(23500000
Corporate income tax		1,382,610	808,784	933,520	1,173,835	1,068,890
		(6151024)	(4278756)	(5099472)	(5455258)	(7054541)
R&D tax credit amount		136,330	117,944	125,081	139,567	96,121
		(941554.8)	(858892.8)	(932225.3)	(905332.1)	(593484.9)
R&D tax credit rate		0.061	0.0854	0.0859	0.0634	0.0612
		(0.03937)	(0.122254)	(0.129296)	(0.042564)	(0.069788)
Carryover of R&D tax credit		33,222	45,837	33,302	103,867	130,452
		(585040.5)	(639320)	(397751.3)	(827952)	(1250864)
CFRD			1.035963	1.097355	1.14538	1.316126
			(0.470029)	(1.673193)	(1.219125)	(3.134351)
observations	2983	2967	2878	2781	2732	2660

Table 4: Descriptive statistics of the 2007–2012 regression sample (cont.)

	SMEs					
	2007	2008	2009	2010	2011	2012
R&D expenditure	3,410 (29803.64)	3,577 (26674.5)	3,332 (22296.19)	3,303 (20497.47)	3,372 (19802.71)	3,654 (30595.31)
Number of employees	33 (82.24609)	33 (84.73957)	34 (79.00551)	38 (348.1398)	36 (92.86293)	37 (95.01411)
Asset	1003867 (2627459)	996063 (2729777)	962530 (2334521)	1020768 (3425480)	1059246 (4839170)	1076514 (2676766)
Debt	685116.8 (1838510)	667211.4 (1899017)	631317.1 (1575829)	654390.4 (2047694)	668698.1 (2628560)	678731.8 (1610023)
Cashflow	34383.21 (160397.7)	32733.74 (183054.9)	21543.06 (145005)	29775.31 (175370.8)	36746.29 (345018.4)	41424.53 (257084.3)
Ratio of debt to asset	0.0081 (1.44467)	0.8189 (1.62121)	0.8429 (1.283205)	0.8384 (0.94142)	0.8383 (1.169628)	0.8385 (1.26278)
Ratio of cashflow to asset	0.00 (0.263591)	-0.0083 (0.318346)	-0.0228 (0.317192)	-0.0157 (0.285828)	-0.0059 (0.264683)	0.02 (1.377258)
Taxable income		38,799 (191006.2)	30,928 (139237.3)	35,595 (157896.2)	41,859 (262474.4)	46,091 (262474.4)
Corporate income tax		1,391 (1453.429)	6,681 (30589.51)	6,660 (311113.1)	9,073 (67854.66)	9,993 (57714.51)
R&D tax credit amount		105 (206.5311)	314 (2300.504)	280 (2138.311)	273 (2025.475)	307 (5219.614)
R&D tax credit rate		0.0702 (0.060329)	0.0946 (0.146797)	0.0889 (0.138594)	0.0715 (0.074412)	0.079 (0.292873)
Carryover of R&D tax credit		84 (1545.475)	184 (2074.874)	53 (930.2892)	193 (1937.201)	232 (3111.382)
CFRD		. .	1.089877 (2.725774)	1.058493 (1.129765)	1.122286 (1.889715)	1.129035 (1.785811)
observations	18,943	19,017	18,519	18,673	18,238	18,592

Table 5: Estimation results on the effects of enhancing deduction ceiling (2008-09)

	Large firms		SMEs	
	R&D intensive	Others	R&D intensive	Others
Variables	(1)	(2)	(3)	(4)
$\tau_{it} \times AFTER_{i,\,2009}$	2.381***	1.879**	1.545***	0.396
	(0.479)	(0.850)	(0.560)	(0.338)
τ_{it}	-2.343***	-0.653	1.348	1.646***
	(0.855)	(1.189)	(0.923)	(0.531)
$AFTER_{i,\,2009}$	-0.223***	-0.296***	-0.288***	-0.225***
	(0.0358)	(0.0625)	(0.0540)	(0.0345)
$lnSIZE_{it-1}$	0.244**	-0.325**	-0.0130	0.158*
	(0.110)	(0.160)	(0.183)	(0.0941)
$\frac{b_{it-1}}{A_{it-1}}$	-0.0406	0.0315	0.236	0.114
	(0.228)	(0.458)	(0.186)	(0.0828)
$\tau_{it}\frac{b_{it-1}}{A_{it-1}}$	2.837***	0.387	-0.551	0.0739
	(1.039)	(1.091)	(1.048)	(0.513)
$\frac{CF_{it-1}}{A_{it-1}}$	0.248	0.365	0.432*	0.00229
	(0.172)	(0.560)	(0.248)	(0.205)
$\tau_{it}\frac{CF_{it-1}}{A_{it-1}}$	5.213*	16.34***	-5.541**	0.119
	(2.784)	(3.265)	(2.492)	(1.305)
Constant	11.96***	11.98***	6.523***	6.660***
	(0.757)	(1.077)	(1.243)	(0.811)
Industry dummies	Yes	Yes	Yes	Yes
Settlement month dummies	Yes	Yes	Yes	Yes
Firm-fixed effects	Yes	Yes	Yes	Yes
Observations	2,626	1,582	6,058	9,530
R^2	0.149	0.233	0.093	0.111

Standard errors in parentheses

*** $p<0.01$, ** $p<0.05$, * $p<0.1$

Table 6: Estimation results on the extension of carryover period (2009-12)

	All firms				Top 25% of firms			
	Large firms		SMEs		Large firms		SMEs	
	R&D intensive	Others	R&D intensive	Others	R&D intensive	Others	R&D intensive	Others
Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$CFRD_{it}$	0.000242	0.0105	-0.000547	-0.00737	-0.000552	0.00256	-0.000842	0.00658
	(0.00413)	(0.0138)	(0.00364)	(0.00900)	(0.00290)	(0.0140)	(0.00346)	(0.00913)
$lnSIZE_{it-1}$	0.153**	0.137	-0.0375	0.0845*	0.750***	-0.103	0.184	0.241
	(0.0755)	(0.0913)	(0.0856)	(0.0444)	(0.285)	(0.452)	(0.207)	(0.178)
$\frac{b_{it-1}}{A_{it-1}}$	0.0522	0.205	0.289*	-0.284***	-0.745*	0.115	-0.122	-0.257
	(0.218)	(0.331)	(0.173)	(0.107)	(0.446)	(1.082)	(0.410)	(0.346)
$\frac{CF_{it-1}}{A_{it-1}}$	0.860***	1.940***	-0.0642	0.415**	1.443***	0.147	0.263	0.422
	(0.254)	(0.495)	(0.244)	(0.194)	(0.478)	(1.041)	(0.584)	(0.568)
Constant	11.93***	9.087***	6.804***	6.593***	9.429***	11.60***	7.303***	4.175***
	(0.518)	(0.632)	(0.484)	(0.784)	(1.845)	(2.608)	(0.802)	(1.028)
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Settlement month dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year-fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm-fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	3,802	2,653	9,077	16,705	821	274	1,597	3,140
R-squared	0.028	0.037	0.003	0.006	0.055	0.002	0.014	0.059

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 7: Robustness check of the effects of extending carryover period (2009-14)

	All firms				Top 25% of firms			
	Large firms		SMEs		Large firms		SMEs	
	R&D intensive	Others	R&D intensive	Others	R&D intensive	Others	R&D intensive	Others
Variables	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
$CFRD_{it}$	-6.49e-05	0.00592	0.00332	-0.00104	-8.42e-05	0.0468	-0.00649	0.000248
	(0.00062)	(0.0684)	(0.00820)	(0.00267)	(0.00033)	(0.0438)	(0.00800)	(0.00254)
$lnSIZE_{it-1}$	0.280***	0.187**	0.0244	0.176***	0.378***	-0.235	0.285	0.0917
	(0.0536)	(0.0733)	(0.0665)	(0.0308)	(0.109)	(0.374)	(0.188)	(0.134)
$\frac{b_{it-1}}{A_{it-1}}$	-0.0250	0.110	0.169	-0.155**	-0.506	-0.194	0.0686	0.00305
	(0.170)	(0.223)	(0.127)	(0.0751)	(0.310)	(0.697)	(0.403)	(0.283)
$\frac{CF_{it-1}}{A_{it-1}}$	0.685***	1.260***	0.243	0.337***	1.072***	0.447	0.322	0.309
	(0.218)	(0.372)	(0.190)	(0.112)	(0.340)	(0.867)	(0.589)	(0.430)
Constant	10.72***	8.569***	6.639***	5.058***	11.57***	12.81***	6.983***	6.969***
	(0.433)	(0.486)	(1.120)	(0.427)	(0.720)	(2.173)	(0.771)	(0.900)
Industry dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Settlement month dummies	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Year-fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Firm-fixed effects	Yes	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Observations	5,684	4,290	12,737	29,950	1,127	347	1,998	4,222
R-squared	0.030	0.025	0.006	0.005	0.038	0.017	0.020	0.011

Standard errors in parentheses

*** p<0.01, ** p<0.05, * p<0.1

Table 8: First-difference estimations on the effects of Δ tax deduction ratio **($\Delta\tau_{it}$)**

	Large firms		SMEs	
	R&D intensive	Others	R&D intensive	Others
Variables	(1)	(2)	(3)	(4)
$\Delta\tau_{it}$	1.405***	1.568***	1.930***	1.208***
	(0.237)	(0.243)	(0.289)	(0.0905)
$\Delta lnSALE_{it-1}$	0.0785	-0.128	-0.0655	0.0376
	(0.0486)	(0.0821)	(0.0915)	(0.0346)
$\Delta\frac{b_{it-1}}{A_{it-1}}$	0.0247	-0.306***	-0.0574	-0.00543
	(0.0569)	(0.0900)	(0.118)	(0.0526)
$\Delta(\tau_{it}\frac{b_{it-1}}{A_{it-1}})$	0.152	-0.125	-0.130	0.208*
	(0.365)	(0.353)	(0.402)	(0.123)
$\Delta\frac{CF_{it-1}}{A_{it-1}}$	0.349***	0.504***	0.166	0.163***
	(0.0620)	(0.164)	(0.116)	(0.0613)
$\Delta(\tau_{it}\frac{CF_{it-1}}{A_{it-1}})$	1.304	0.354	1.313	0.289
	(1.168)	(1.314)	(1.081)	(0.397)
Constant	0.832*	-0.796*	-0.587	0.573
	(0.448)	(0.410)	(0.426)	(0.540)
Industry dummies	YES	YES	YES	YES
Settlement month dummies	YES	YES	YES	YES
Year-fixed effects	YES	YES	YES	YES
Observations	5,904	4,207	11,236	31,142
R^2	0.090	0.122	0.084	0.072

Standard errors in parentheses

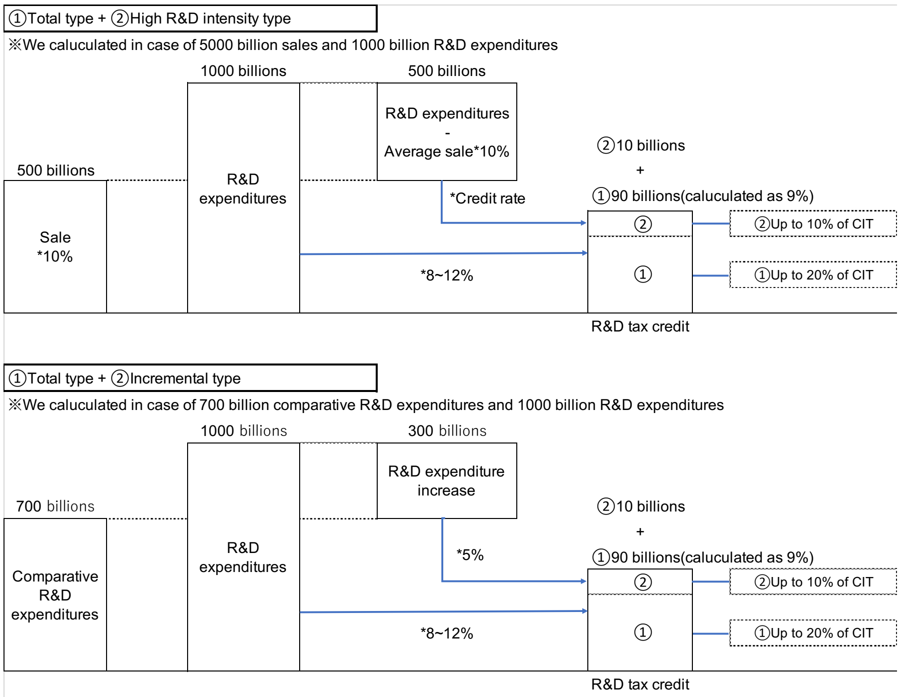
*** p<0.01, ** p<0.05, * p<0.1

Table 9: The direct and indirect effects of Δ tax deduction ratio ($\Delta\tau_{it}$) using SEM

		coefficient	Std.dev.	Z value	P>z	95% confidence interval
Large firms in R&D intensive industries	direct	-0.160	0.116	-1.38	0.168	[-0.387, 0.0674]
	indirect	0.0483	0.0140	3.45	0.001	[0.0208, 0.0758]
	total	-0.112	0.116	-0.96	0.336	[-0.338, 0.115]
Large firms in other industries	direct	0.0914	0.140	0.65	0.515	[-0.184, 0.367]
	indirect	-0.0152	0.0113	-1.34	0.179	[-0.0374, 0.00696]
	total	0.0762	0.140	0.54	0.587	[-0.198, 0.351]
SMEs in R&D intensive industries	direct	-0.253	0.123	-2.06	0.04	[-0.495, -0.0118]
	indirect	0.0301	0.0160	1.88	0.06	[-0.00126, 0.0615]
	total	-0.223	0.122	-1.83	0.068	[-0.463, 0.0165]
SMEs in R&D intensive industries	direct	-0.0598	0.0611	-0.98	0.327	[-0.179, 0.0599]
	indirect	0.00789	0.00533	1.48	0.138	[-0.00255, 0.0183]
	total	-0.0519	0.0608	-0.85	0.394	[-0.171, 0.0673]

Note: The mediator in indirect effects is Δ cash flow/asset.

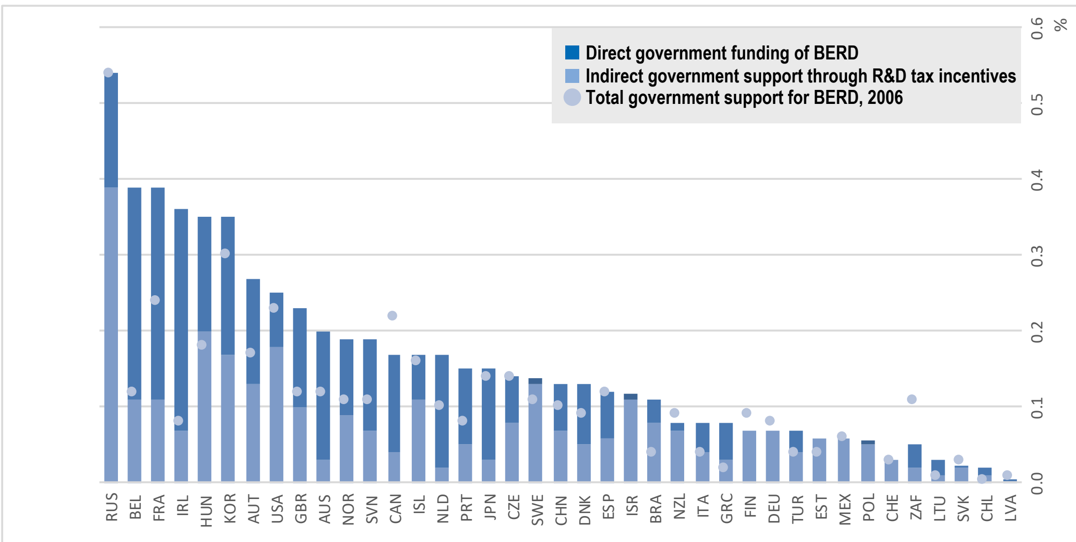
Figure 1: Japanese R&D tax credits system, 2008



Source: METI (2008).

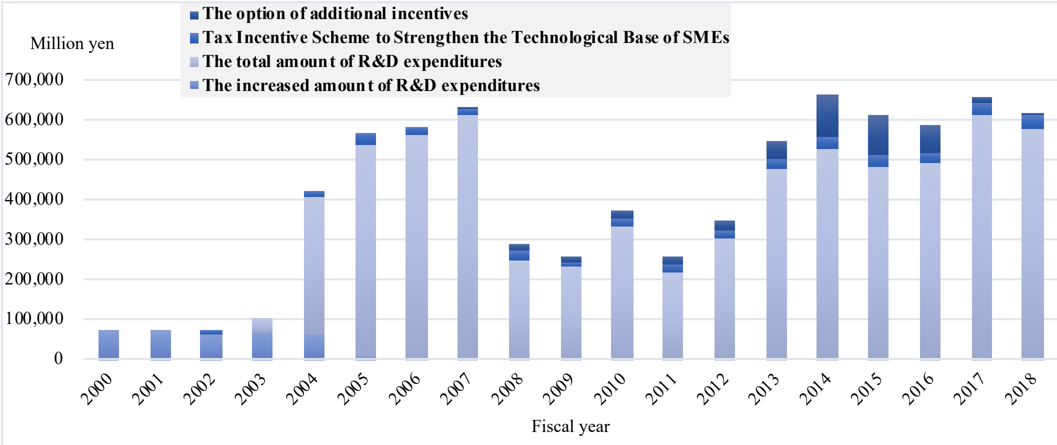
Note: “Comparative R&D expenditures” are defined as average R&D expenditures for the preceding three fiscal years. “Average sale” is defined as average sales for the preceding three fiscal years and the currency fiscal year. ”CIT” is defined as a corporate income tax.

Figure 2: Direct government funding and tax support for business R&D, 2015, as a percentage of GDP



Source: OECD (2017).

Figure 3: The transition of the amounts of R&D tax deduction in Japan



Source: National Tax Agency, *Corporation Sample Survey* and Ministry of Finance, *Survey report about the application of Act on Special Measures Concerning Taxation.*

Figure 4: The median of firm's R&D expenditures from 2005 to 2007