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Abstract

To what extent does a tax credit affect firms' R&D activity? What are the mechanisms? This paper examines the effect of R&D tax credits on firms' R&D expenditure by exploiting the variation across firms in the changes in the eligible tax credit rate between 2000 and 2003. Estimating the first-difference equation of the linear R&D model by panel GMM, we find the estimated coefficient of an interaction term between the eligible tax credit rate and the debt-to-asset ratio is positive and significant, indicating that the effect of tax credit is significantly larger for firms with relatively large outstanding debts. Conducting counterfactual experiments, we found that the aggregate R&D expenditure in 2003 would have been lower by 3.0-3.4 percent if there had been no tax credit reform in 2003, where 0.3-0.6 percent is attributable to the effect of financial constraint, and that the aggregate R&D expenditure would have been larger by 3.1-3.9 percent if there had been no cap on the amount of tax credits, where 0.3-0.8 percent is attributable to relaxing the financial constraint of firms with outstanding debts.

Journal of Economic Literature Classification Numbers: D22; H25; H32; K34; O31; O38
Keywords: R&D; tax credit; financial constraint; Japan.

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1 Introduction

To what extent does a tax credit affect firms' R&D activity? What are the mechanisms? Because R&D has some characteristics of a public good, government subsidies of R&D investment could be justifiable to bridge the gap between the private and social rates of return. Furthermore, R&D investment plays an important role in long-run economic growth (Romer (1986) and Aghion and Howitt (1998)). Therefore, understanding the mechanisms through which tax policies affect R&D investment is a prerequisite for designing effective growth-promoting tax policies.

Proprietary information, highly uncertain returns, and a lack of collateral value for R&D capital may hinder the ability to finance R&D investment with external funds (see Arrow (1962)).[1] When firms do not hold sufficient internal funds, R&D investment may be restricted by financial constraint. From this perspective, a tax credit may promote R&D investment not only by increasing the private return from R&D investment but also by relaxing the financial constraint on R&D expenditure. While a small number of empirical studies provide micro-level evidence for the financial constraint of R&D investment (see Hall (2002), Himmelberg and Petersen (1994), and Brown et al. (2009)), few empirical studies directly examine the effect of tax credit policy changes on firms' R&D investment and quantify the importance of financial constraints to explain the policy effect on R&D investment. The present paper fills this gap by empirically examining the effect of the 2003 Japanese tax credit reform on firms' R&D expenditure using the panel data of Japanese manufacturing firms.

Estimating the effect of R&D tax credit policy is often difficult because, typically, the same R&D tax credit rate uniformly applies to all firms, and hence, there is no variation across firms to identify the effect of R&D tax credit policy on R&D expenditure. The 2003 Japanese tax credit reform provides an interesting case in which the changes in the eligible tax credit rate are not uniform across firms. In the 2003 tax reform, the Japanese government introduced a total tax credit system under which the aggregate tax credit was substantially larger than it had been under the incremental tax credit system that was in effect until 2002. In the incremental system, firms can apply for the tax credit only if R&D expenditure in the current fiscal year is greater than the average of the three largest yearly R&D expenditures from the previous five years. In the total tax credit system, the tax credit is applied on total R&D expenditure, independent of previous R&D expenditures. Because the tax credit depends on past R&D expenditure under the incremental system, but is independent of a firm's R&D history under the total tax credit system, changes in the eligible tax credit rate due to the 2003 reform vary across firms. The firms with high R&D expenditure prior to 2002 experienced a large increase in the eligible tax credit rate between 2002 and 2003, while the eligible tax credit rate remained roughly the same between 2002 and 2003 for firms without any R&D expenditure prior to 2002. We exploit this variation in the changes in the eligible tax credit rate across firms to identify the extent to which

[1] See also Brown, Fazzari, and Petersen (2009) and Ogawa (2007).

a tax credit affects firms' R&D expenditure.

Focusing on the details of the R&D tax credit policy in Japan, we use the variation across firms in the changes in the eligible tax credit rate between 2000 and 2003 to estimate the elasticity of R&D expenditure with respect to the eligible tax credit rate, and we examine the empirical validity of the financial constraint mechanism. Motivated by Hall and Van Reenen (2000), Bloom, Griffith, and Van Reenen (2002), and Brown et al. (2009), we consider a linear R&D investment model that includes terms representing possible interactions between the eligible tax credit rate and the measure of financial constraints. The model is estimated by the Generalized Method of Moments (GMM) using firm-level panel data from the *Basic Survey of Japanese Business Structure and Activities* [BSJ, hereafter] with a proxy we construct for the eligible tax credit rate under the Japanese tax credit system.

To understand how the 2003 tax credit reform affects firms' R&D investment, we develop a simple two-period model of R&D investment and examine the optimal R&D investment policy. First, even though the shift from the incremental to the total tax credit system increases credit substantially, it does not necessarily affect R&D investment. If the current R&D expenditure is greater than the base level expenditure defined in the incremental system, this R&D investment remains unaffected because investment is determined by equating marginal benefit and marginal cost, and the tax credit reform does not change the marginal cost in such a case. However, once we consider the possibility of financial constraint, the tax reform may have a large effect on R&D investment. When we extend the model by explicitly taking into account the possibility that the borrowing rate depends on the probability of default, an increase in the tax credit may increase the available internal funds and thus increase R&D investment.

Estimating the first-difference equation of the linear R&D model by panel GMM, we find that the estimated coefficient of an interaction term between the eligible tax credit rate and the debt-to-asset ratio is positive and significant, indicating that the effect of tax credit is significantly larger for firms with relatively large outstanding debts. Furthermore, splitting the benchmark sample into a sample of small firms and a sample of large firms, we find an interaction term between the eligible tax credit rate and the debt-to-asset ratio is estimated significantly with a positive sign in the sample of small firms but the interaction term becomes insignificant in the sample of large firms. This result is largely consistent with the financial constraint mechanism stated above if small firms are more likely to face financial constraint than large firms are.

Using the estimated model, we quantify what would have happened to the aggregate R&D expenditure if there had been no tax credit reform in 2003, i.e., if the incremental tax credit system had been implemented in 2003. Using the estimates, we find that the aggregate R&D expenditure would have been reduced by 3.0-3.4 percent had there been no tax credit reform in 2003. Out of 3.0-3.4 percent, we find that 0.3-0.6 percent is attributable to the interaction term between the eligible tax credit rate and the debt-to-asset ratio, suggesting that the tax credit reform in 2003 had increased the aggregate R&D expenditure by 0.3-0.6 percent specifically through relaxing the financial constraint of firms with outstanding debts. We also conduct a counterfactual experiment of what would have happened to the aggregate R&D expenditure in 2003 if the tax credit had not been capped by the 20 percent of corporate tax when the total tax credit system was introduced, and we find that removing the cap would have increased 3.1-3.9 percent of the aggregate R&D expenditure while 0.3-0.8 percent is attributable to the financial constraint term.

The remainder of this paper is organized as follows. Section 2 reviews the related literature. Section 3 explains our data source and presents summary statistics. Section 4 explains the Japanese R&D tax credit policy between 2000 and 2003 in detail. Section 5 develops a simple model of R&D expenditure featuring the tax credit and examines how it affects R&D investment. Section 6 explains our empirical framework and reports the estimation results. Section 7 concludes the paper.

2 Literature Review

The effectiveness of the R&D tax credit has recently attracted considerable attention and has been studied extensively. The overall results suggest that the elasticity of R&D with respect to price is approximately 1. Hall and Van Reenen (2000) survey 10 U.S. studies and 10 international studies of the econometric evidence on the effectiveness of fiscal incentives for R&D. From the U.S. studies, Hall and Van Reenen (2000) conclude that "the tax price elasticity of total R&D spending during the 1980s is on the order of unity, maybe higher."

The results from more recent studies appear to support the conclusion by Hall and Van Reenen (2000), at least qualitatively. Bloom, Griffith and Van Reenen (2002) examine the impact of fiscal incentives on the level of R&D investment using a panel of data on tax changes and R&D spending in nine OECD countries over a 19-year period (1979-1997). Bloom et al. (2002) estimate the following dynamic specification:

$$r_{it} = \lambda r_{i,t-1} + \beta y_{it} - \gamma \rho_{it} + f_i + t_t + u_{it},$$

where r_{it} = log(industry-funded R&D), y_{it} = log(output), ρ_{it} = log(user cost of R&D), f_i is a country-specific fixed effect, and t_t is a time dummy. Their estimate of λ is 0.868, and that of γ is -0.144, implying short-run and long-run elasticities of -0.144 and -1.088, respectively. This estimate suggests that a 10-percent decrease in the cost of R&D stimulates a 1.44-percent increase in R&D in the short run, and approximately a 10.1-percent rise in R&D in the long run. A similar specification is used by Hall (1993) and other studies reported below.

Paff (2005) estimates the tax price (user cost) elasticity of in-house (i.e., not contract) R&D expenditure of biopharmaceutical and software firms in California by exploiting California's changes in R&D tax credit rates from 1994 to 1996 and from 1997 to 1999. The estimates by Paff

(2005) are substantially higher than 1 and higher than 20 in some cases. Possible explanations include firms' greater sensitivity to state-level policy, industry factors, sample characteristics, and measurement error.

Huang and Yang (2009) investigate the effect of tax incentives on R&D activities in Taiwanese manufacturing firms using a firm-specific panel data set from 2001 to 2005. Propensity score matching reveals that, on average, recipients of the R&D tax credit have a 93.53 percent higher R&D expenditure and a 14.47 percent higher growth rate for R&D expenditure than do non-recipients with similar characteristics. Huang and Yang (2009) estimate a panel fixed effect model by a GMM and report that the estimated (short-run) elasticity of R&D with respect to the R&D tax credit is 0.197 for all firms, 0.149 for high-tech firms, and 0.081 for non-high-tech firms.

Regarding the studies focused on the Japanese case, Koga (2003) examines the effectiveness of the R&D tax credit using data from 904 Japanese manufacturing firms over 10 years (1989 to 1998). Koga (2003) finds evidence that tax price elasticity is -0.68 when estimated from all the firms and -1.03 when estimated from large firms, using the R&D data from Research on R&D Activities in Private Firms (*Minkan kigyou no kenkyuu katsudou ni kansuru chousa*) by the Science and Technology Agency supplemented by Nikkei Annual Corporation Reports (Nikkei Shinbun Inc). Koga (2003) estimates the following dynamic specification:

$$r_{it} = \beta y_{i,t-1} - \gamma \rho_{i,t-1} + f_i + t_t + u_{it},$$

where r_{it} = log(corporate R&D investment), y_{it} = log(sales) and ρ_{it} = log(user cost of R&D), f_i is a firm-specific fixed effect, and t_t is a time dummy. The estimate of γ is -0.68 for all firms and -1.03 for large firms. Koga excluded lagged r from the model because he found its coefficient to be insignificant.

Motohashi (2010) combines firm-specific panel data over the period 1983-2005 from the Report on the Survey of Research and Development (Kagaku gijutu kenkyu chousa) and from financial data published by the Japan Economic Research Institute to estimate the following R&D investment function:

$$\frac{R\&D_{it}}{A_{it}} = \beta_1 \frac{R\&D_{i,t-1}}{K_{i,t-1}} + \beta_2 \frac{R\&D^2_{i,t-1}}{K^2_{i,t-1}} + \beta_3 \frac{\mathrm{output}_{i,t-1}}{K_{i,t-1}} + \beta_4 tax_{it} + \beta_5 tax_{i,t-1} + \beta_6 f_i + \beta_7 t_t,$$

where K is R&D capital stock constructed by the author, tax is the tax-adjusted cost of R&D, f is a firm-specific fixed effect, and t is a time dummy. The estimated long-run effect of the unit R&D cost reduction ($= \beta_4 + \beta_5$) is approximately -0.5.

Cash flow constraints have been documented to have a significant effect on firms' R&D activities. Because the tax system affects the after-tax cash flow, cash flow is a potentially important channel through which business tax policies affect firms' R&D activities. Ogawa

(2007) investigates the extent to which outstanding debt affected firms' R&D activities during the 1990s using a panel data set of Japanese manufacturing firms in research-intensive industries. Ogawa (2007) finds that the ratio of debt to total assets had a significant negative effect on R&D investment in the late 1990s but had an insignificant effect on R&D investment in the late 1980s.

Brown, Fazzari, and Petersen (2009) examined the role of cash flow and stock issues in financing R&D expenditure and found significant effects of cash flow and external equity on the R&D expenditure of young high-tech firms in the United States. Their result suggests that young firms invest approximately 15 percent of additional equity funds in R&D.

Onishi and Nagata (2010) [O&N, hereafter] investigate the effect of the 2003 R&D tax credit reform using a data set of 485 firms after combining three different data sets.[2] Using difference-in-difference propensity score matching (DID-PSM), O&N compare the change in the R&D expenditures from 2002 to 2003 between those firms that use the new total (*Sougaku gata*) tax credit system and those firms that do not use the new tax credit system. Firms that used the new *Sougaku gata* tax credit system increased their R&D expenditure by 1.2 percent, whereas those that did not use the new tax credit system decreased their R&D expenditure by 0.9 percent. However, O&N conclude that the increases in the R&D expenditures of these two groups of firms are not significantly different.

The main contribution of our paper relative to that of O&N is our empirical finding of the importance of financial constraints in determining the effect of R&D tax credits on R&D expenditure. O&N have no comparable result for the role of financial constraints because they did not analyze the role of financial constraints. On the other hand, we find that the effect of R&D tax credit on R&D expenditure is statistically insignificant *for firms less likely to be financially constrained*, which is largely consistent with the findings of O&N.

In addition, there are several differences between our approach and that of O&N which are important in obtaining reliable estimates of the role of financial constraints. First, O&N use the DID-PSM method, while we use the panel generalized method of moments (GMM). While the panel GMM has a disadvantage over the DID-PSM method in that identification relies on a linear specification, the GMM has a potential advantage in dealing with endogeneity, by using past variables as instruments for endogenous variables. Dealing with endogeneity is particularly important in this context because both the R&D tax credit rate and the variable that captures the degree of financial constraint are likely to be endogenous. Second, O&N estimate the average treatment effect while we estimate the semi-elasticity of R&D expenditures with respect to the R&D tax credit rates. While identification of the average treatment parameter relies on the

[2] O&N combined three different data sets: the BSJ data set, which we also use, the "Survey on R&D Activities of Private Firms" [MEXT's survey, hereafter] conducted by the Ministry of Education, Culture, Sports, Science and Technology, and "Survey on Science and Technology Research" [MIC's survey, hereafter] conducted by the Ministry of Internal Affairs and Communications. The original sample in the MEXT's survey consists of 1951 large firms that engaged in R&D activities in 2002. To construct the two-year panel data and to combine the MEXT's survey with the BSJ data set and the MIC survey, many of these observations were dropped, and their sample size becomes 485.

difference between the users and non-users of the R&D tax credits, identification of the semi-elasticity parameter utilizes not only the variation between the users and non-users, but also the variation *within* the group of firms that use the R&D tax credits. This variation *within* the group of R&D tax credit users is important to identify how the semi-elasticity parameter depends on the degree of financial constraint. Furthermore, with the estimated semi-elasticity parameter, we can potentially quantify the effect of interesting counterfactual policies on aggregate R&D expenditure, which is not possible in O&N's approach. Finally, our data set covers R&D-intensive firms more comprehensively than that used by O&N, as reported in Table 5. The number of observations in our sample is substantially greater than in O&N's sample, so we might expect our estimates to be more reliable than theirs, especially given the concern about sample selection.

Similar to our paper, Kobayashi (2011) examines the role of financial constraint in the context of the Japanese R&D tax credit reform in 2003 but focusing on the small and the medium firms. Using cross-sectional data based on the propensity score matching, Kobayashi finds that financial constraint plays an important role in explaining the effect of R&D tax credit reform. Omitting large R&D intensive firms from his sample, however, he does not analyze the effect of the R&D tax credit reform on the aggregate R&D expenditure.

3 Data

3.1 Data Source

We use the BSJ data mentioned in the introduction. This survey is conducted by the Ministry of Economy, Trade and Industry (METI) and covers *all* Japanese firms with 50 or more employees, whose paid-up capital or investment fund is over 30 million yen and whose operations are classified as mining, manufacturing, or wholesale and retail trade, and eating and drinking establishments. The survey collects basic corporate finance data and detailed data on various business activities, such as R&D activities. This survey began in 1991 and has been conducted annually since 1994. All firms with the characteristics stated above receive a survey questionnaire and report data for the last or most recent fiscal year. Response rates have been high, and thus, the size of the cross-section sample has been large, comprising 25,000 to 30,000 firms each year.[3]

3.2 Sample Selection and Summary Statistics

We focus our attention on manufacturing firms. Furthermore, we select our sample as described in Table 1. First, to focus on large firms, we exclude observations of firms with capital smaller than or equal to 100 million yen. Because small or medium firms can choose between the R&D

[3]For example, the response rates for the 2002 and 2003 surveys were 77.7 and 75.9 percent, respectively.

tax credit system for small or medium enterprises and that for all firms, including small or medium firms in the sample substantially complicates our analysis. In our sample for 2000 to 2003, the fraction of the aggregate R&D expenditure explained by these small/medium firms is small, only 2.0 percent for the manufacturing industry.

Second, while the fiscal year closes in March for the majority of Japanese manufacturing firms in the data, a substantial number of firms close their fiscal year in the months other than March. The corporate tax applies to the firm-specific fiscal year, and the new total tax credit system became available for the fiscal year that began after January 2003. Accordingly, to analyze the effect of the changes in the tax credit system, we define year "2003" as the (firm-specific) fiscal year that begins after January 2003 and before December 2003 in our sample, where we include dummy variables to control for differences in the closing months in our regression. A small number of observations are excluded from our sample because closing months of fiscal year changed over the sample years as reported in Table 1.

Third, because the tax credit under the incremental system crucially depends on firms' R&D expenditure over the previous 5 years, we reject observations for which prior R&D expenditures are missing. Specifically, given that the incremental tax credit system sets the base level to the average R&D expenditure over the selected three of the five previous years, we exclude observations with more than two years of missing R&D expenditures from the previous five years.

Fourth, as we discuss later, the lagged values for R&D expenditures and various endogenous regressors are necessary to estimate our empirical model by the GMM. Therefore, we eliminate observations for which lagged variables to estimate equation (10) are missing.[4] This is our benchmark sample. When we estimate the specification using the logarithm of R&D expenditure as a dependent variable in (9), we further exclude observations with zero R&D expenditure.

Table 2 reports summary statistics for the benchmark sample from 2000 to 2003. Each entry except for the last row refers to the average of the corresponding variable in the benchmark sample. The last row reports the number of observations. Our measure of R&D expenditure is the sum of own and outsourced research and development expenses. Row designated as "R&D Exp./Y" reports the average of the ratio of R&D expenditure to sales across the observations with strictly positive R&D expenditures. "Fixed Asset" refers to the tangible fixed assets. "Debt" refers to the sum of liquid and fixed debts in the beginning of year. We also report the ratio of debt to fixed asset, b_t/A_t, and the ratio of the lagged value of cash flow to fixed asset, CF_{t-1}/A_t, where cash flow is defined as the sum of net profit and accounting depreciation. Both b_t/A_t and CF_{t-1}/A_t are used in our empirical analysis.

As reported in the row of "Frac. of Positive Ordinary Profit" in Table 2, the fraction of

[4]Firms may increase their capital to a level above 100 million yen by issuing new equity. For such firms that become large during the sample period, some lagged variables may be missing because we drop observations when the corresponding firm is classified as a small or medium firm.

observations with strictly positive ordinary profit increased from 0.78 to 0.91 between 2000 and 2003. Figures 1 and 2 present histograms on ordinary profits weighted by sales to compare our benchmark sample to the original BSJ sample in manufacturing. Compared to the population of Japanese firms, the BSJ draws from large firms with 50 or more employees, and our benchmark sample further excludes "small or medium firms" with capital smaller than or equal to 100 million yen. As a result, a large fraction of observations in our sample report positive ordinary profit despite the fact that 73 percent of all corporations in Japan reported tax losses in 2003.

4 R&D tax credit reform in 2003

This section describes the 2003 reform of the Japanese R&D tax credit system.[5] We measure the eligible tax credit rate for firm i in period t, denoted by τ_{it}, as

$$\tau_{it} = \frac{X_{it}}{RD_{it}^{\text{tax}}}, \tag{1}$$

where RD_{it}^{tax} denotes R&D expenditure for tax purposes and X_{it} denotes the *eligible* amount of tax credit.[6] The 2003 tax reform substantially changed the amount of tax credit (X_{it}) for which each firm is eligible. Below, we explain how to compute X_{it} before and after the reform.

We first explain the tax credit prior to 2002 (before the reform). Prior to 2002, the Japanese R&D tax credit policy was characterized by the *incremental tax credit system.* We denote the average of firm i's three largest yearly R&D expenditures for tax purposes over the previous five years by $\overline{RD}_{it}^{\text{tax}}$. Let T_{it} denote the amount the corporate tax firm i owes *before R&D tax credit but after other deductions including loss carry forward* in year t. Then, the R&D tax credit in year t for $t \leq 2002$ is given by

$$X_{it} = \begin{cases} X_{it}^{*} & \text{if } 0.12T_{it} \geq X_{it}^{*} \\ 0.12T_{it} & \text{if } 0.12T_{it} < X_{it}^{*}, \end{cases} \tag{2}$$

[5] We do not address the R&D tax credit for "special experimental research expenses," including industry-university cooperation R&D expenditures, because we cannot distinguish such expenses from other types of R&D expenditures in our data set. Also, we do not address "the R&D tax credit system for small or medium enterprises" (*Chusho kigyou gijutsu kiban kyouka zeisei* in Japanese). Small or medium firms can choose between "the R&D tax credit system for small or medium enterprises" and the tax credit system described in this section. The R&D tax credit system for small or medium enterprises defines small or medium enterprises as (i) firms with capital smaller than or equal to 100 million yen, (ii) firms without stockholder's equity or contribution to capital, the number of employees is less than 1000, and (iii) agricultural cooperative and similar institutions.

[6] Using the BSJ data, we compute RD_{it}^{tax} as the sum of own and outsourced research and development expenses net of the amount received to conduct research projects that include subsidies from the government and the amount received for commissioned R&D projects. Our measure of RD_{it}^{tax} does not exactly correspond to the R&D expenditure subject to Japanese tax credit system. For example, Japanese tax credit system does not recognize research expense in the humanities and social science as R&D expenditure, while the BSJ survey includes it in R&D expenditure.

where X_{it}^* is defined by

$$X_{it}^* = 0.15 \max\{RD_{it}^{\text{tax}} - \overline{RD}_{it}^{\text{tax}}, 0\} \mathbb{I}(RD_{it}^{\text{tax}} > \max\{RD_{i,t-1}^{\text{tax}}, RD_{i,t-2}^{\text{tax}}\}).$$

and $\mathbb{I}(x > y)$ represents an indicator function. When $RD_{it}^{\text{tax}} \leq \overline{RD}_{it}^{\text{tax}}$ or the R&D expenditure in t is smaller than the last two years R&D expenditures, a firm receives no tax credit; otherwise, the eligible amount of tax credits is roughly proportional to the difference between the current R&D expenditure and the previous R&D expenditure ($RD_{it}^{\text{tax}} - \overline{RD}_{it}^{\text{tax}}$) up to the cap given by 12 percent corporate tax, $0.12T_{it}$. Thus, under the incremental tax credit system, an established R&D firm with a large R&D expenditure receives little tax credit if the firm's R&D expenditure is constant over the years, whereas a new R&D firm with no past R&D experience may receive up to 15 percent of the total amount of R&D expenditure as tax credit.

In 2003, the Japanese government introduced the *total tax credit system*, in which a firm is potentially eligible for a tax credit equal to 10 percent to 12 percent of the R&D expenditure, regardless of previous R&D expenditures, while the cap on the eligible tax credit increased from 12 percent to 20 percent of corporate tax. At the same time, the deferred tax credit was introduced: if a firm's tax credit exceeds 20% of the corporate tax paid in 2003, it can re-claim the remaining amount above the cap in the following year, as long as the tax credit in 2004 does not exceed 20% of the corporate tax paid in 2004. We take the deferred tax credit into account under the perfect foresight assumption using the realized value of corporate tax paid and R&D expenditure in 2004. Specifically, we compute the R&D tax credit in 2003, denoted by X_{i2003}, as

$$X_{i2003} = \begin{cases} X_{i2003}^* & \text{if } 0.20T_{i2003} \geq X_{i2003}^* \\ 0.20T_{i2003} + (X_{i2003}^* - 0.20T_{i2003}) & \text{if } 0.20T_{i2003} < X_{i2003}^* \text{ and} \\ & \quad X_{i2003}^* - 0.20T_{i2003} < 0.20T_{i2004} - X_{i2004}^* \\ 0.20T_{i2003} + (0.20T_{i2004} - X_{i2004}^*) & \text{if } 0.20T_{i2003} < X_{i2003}^* \text{ and} \\ & \quad X_{i2003}^* - 0.20T_{i2003} > 0.20T_{i2004} - X_{i2004}^* > 0. \end{cases} \tag{3}$$

where $X_{i2003}^* = \kappa(RD_{i2003}^{\text{tax}}/\overline{Y}_{i2003})RD_{i2003}^{\text{tax}}$ with $\kappa(x) = (0.2x + 0.1)\mathbb{I}(x < 0.1) + 0.12\mathbb{I}(x \geq 0.1)$, and $\overline{Y}_{it} = \sum_{s=0}^{3} Y_{it-s}/4$. Unlike the incremental tax credit system before 2002, the amount of tax credit does not depend on past R&D expenditure under the total tax credit system.

We compute the eligible tax credit rate using the BSJ data set according to (2)-(3). In computing the eligible rate of tax credits, the cap on the eligible tax credit, determined as 12 percent and 20 percent of tax liabilities before and after the reform, respectively, is important because 9-22 percent of firms report negative ordinary profits in 2001-2003 as reported in Table 2.[7] In addition, firms were able to choose between the old incremental tax credit system and

[7]For a corporate group filing a joint tax return, the cap on R&D tax credit is based on group-level income,

the new total tax credit system in 2003. To consider this choice, we take the maximum value between the tax credit under the incremental system and the tax credit under the total system as our measure for the tax credit in 2003.

Because the BSJ data set does not contain data on corporate tax, we compute a proxy for corporate tax liabilities from ordinary profit while taking into account loss carry forward. Let Y_{it}^{tax}, π_{it}^{ord}, L_{it}, and τ_{it}^{tax} denote taxable income, ordinary profit, accumulated tax losses under loss carry provision, and corporate tax rate in firm i's fiscal year t, respectively.[8] Then, we have $T_{it} = \tau_{it}^{tax} Y_{it}^{tax}$ while taxable income is related to ordinary profit and loss carry forward as $Y_{it}^{tax} = \pi_{it}^{ord} - L_{it} + \epsilon_{it}$, where ϵ_{it} is other adjustments including extraordinary gain, extraordinary loss, and other deductions. Because we do not have information on ϵ_{it}, we set ϵ_{it} equal to zero, and we compute a proxy for corporate tax liabilities as $T_{it} = \tau_{it}^{tax}(\pi_{it}^{ord} - L_{it})$, where accumulated tax losses, L_{it}, is computed using data on ordinary profit.[9] Note that our proxy, T_{it}, contains measurement errors because extraordinary gain, extraordinary loss, and other deductions are not taken into account.

Table 3 reports the mean and the standard deviation of our measure of the eligible tax credit rate, τ_{it}, and its change over one year, $\Delta\tau_{it} = \tau_{it} - \tau_{it-1}$, across firms from 2000 to 2003. Looking at the years 2002 and 2003, we notice that the average eligible tax credit rate increased from almost 0.1 percent to 7.0 percent between 2002 and 2003. This suggests the substantial impact of the 2003 tax credit reform on the average eligible tax credit rate.[10] Furthermore, the standard deviation of the changes in the eligible tax credit rate over a single year increased from 0.024 in 2001-2002 to 0.044 in 2002-2003, suggesting that the variation in the changes in the eligible tax credit rates between 2002 and 2003 is large relative to other years.

The introduction of the total tax credit system in 2003 induced heterogeneous changes in the eligible tax credit rate across firms because the tax credit crucially depends on previous

rather than on entity level income. Thus, the consolidated tax filing may potentially increase R&D incentives through increasing caps. Unfortunately, it is difficult to properly handle this issue because the BSJ does not contain the information about whether a firm is filing a tax jointly or not. According to the National Tax Agency, there are only 208 out of 2892679 corporations who filed a tax jointly in 2003. Therefore, the number of firms who filed a tax jointly in 2003 in our sample is likely to be small.

[8]The corporate tax rate τ_{it}^{tax} decreased in April 1998 from 0.375 to 0.345 and in April 1999 from 0.345 to 0.3. See Appendix A.2 for more details.

[9]More specifically, for each t, we first compute $\{L_{it}^{t-k}\}_{k=1}^{K_0}$ recursively as

$$L_{it}^{t-K_0} = \max\{-\pi_{i,t-K_0}^{ord}, 0\} \quad \text{and} \quad L_{it}^{t-k} = \max\{L_{it}^{t-k-1} - \pi_{i,t-k}^{ord}, 0\} \quad \text{for } k = 1, \ldots, K_0 - 1,$$

and we set $L_{it} = L_{it}^{t-1}$. Following the system of loss carry forward, we set K_0 to 5 for fiscal years starting before April 1, 2001, and to 7 for fiscal years starting after April 1, 2001. Note that we compute the accumulated losses independently for each year, by setting the initial value $L_{it}^{t-K_0} = \max\{-\pi_{i,t-K_0}^{ord}, 0\}$. In the actual implementation of the loss carry provision, firms can use the losses accumulated before $t - K_0$ to deduct taxable income from $t - K_0 + 1$ to $t - 1$. Therefore, though it depends on the unused amount of the accumulated losses before $t - K_0$, our measure L_{it} may understate the actual amount. For more details on the loss carry forward, see Appendix A.2.1.

[10]Using data from the Corporation Sample Survey conducted by the National Tax Agency, Onishi and Nagata (2010) report that the amount of aggregate tax credit after the 2003 tax credit reform is 6 to 11 times as large as that before the reform.

R&D expenditures in the incremental tax system while that is not the case in the total tax credit system. The upper and the middle panels of Table 4 report the average eligible tax credit rate in 2002 and its change between 2002 and 2003, respectively, across four groups of firms with positive R&D expenditures in 2002, classified according to their R&D experiences over the previous five years: (1) no past experience in R&D, (2) one year of R&D experience, (3) two years of R&D experience, and (4) more than three years of R&D experience.

The average eligible tax credit rate in 2002 decreases with the years of R&D experience before 2002 from 0.067 to 0.007. To understand this, consider a firm that began its R&D activity in 2000. Because this firm's previous R&D expenditure before 2000 is equal to zero, this firm is eligible for a tax credit up to 15 percent of its 2000 R&D expenditure as long as that expenditure is below the cap on the eligible tax credit. In 2001, this firm faces an eligible tax credit rate lower than 15 percent because, now, the previous R&D expenditure is no longer zero. Thus, under the incremental tax system, the eligible tax credit rate tends to decrease over time for the first three years of R&D activity. Reflecting the difference in eligible tax credit rates under the incremental tax system, the average change in the eligible tax credit rate between 2002 and 2003 also increases with the years of past R&D experience from 0.005 to 0.062 as reported in the middle panel of Table 4. We note that a substantial variation in the changes in the eligible tax credit rate between 2001 and 2002 also exists as reported in the lower panel of Table 4, which we exploit in our empirical analysis.

Figures 3 and 4 plot a relationship between the log of R&D expenditure and the eligible tax credit rate across firms in 2002 and 2003, respectively, while Figure 5 plots a change in the log of R&D expenditure against the change in the eligible tax credit rate between 2002 and 2003. In Figure 3, a large number of firms have a zero tax credit rate but a positive R&D expenditure in 2002. These R&D firms are not eligible for a tax credit in 2002 because their R&D levels in 2002 are not as high as the previous R&D levels, but they may become eligible for a tax credit in 2003. In fact, as shown in Figure 4, a large number of R&D firms become eligible for at least 10 percent of the tax credit rate in 2003, and Figure 5 shows that the changes in the eligible tax credit rates across different firms between 2002 and 2003 exhibit a large variation.[11]

We emphasize that our measure of R&D tax credits is the *eligible* amount of R&D tax credits rather than the *actual* amount of R&D tax credits because it is possible that firms may not apply for the total R&D tax credits even when they are eligible for R&D tax credit if the cost of applying for the R&D tax credit (e.g., the accounting cost) is higher than its benefit. Also, some firms might not have used R&D tax credits simply because they did not know the eligibility of R&D tax credits.

Because R&D tax credit policy often specifies the eligible amount of R&D tax credits rather

[11] The maximum value of $\Delta\tau_{2003}$ is 0.15, because for 2003, we compute the tax credit as the maximum value between the tax credit under the incremental system and the tax credit under the total system, taking into account that firms could choose between the two systems.

than the actual amount of R&D tax credits, the effect of the eligible amount of R&D tax credits on the R&D expenditures itself could be a quantity of policy interest. However, the estimated effect of the eligible amount of R&D tax credits should be viewed as a reduced-form parameter because the actual amount of R&D tax credits is likely to be endogenously determined given the eligibility. Understanding how the actual amount of R&D tax credits is related to the eligible amount of R&D tax credits is important in this context.

How different is our measure of the eligible amount of R&D tax credits from the actual amount of R&D tax credits? This question cannot be answered by examining the BSJ data because it does not contain the information on the actual amount of R&D tax credits. To investigate this issue, we examine the "2005 Survey on the Use of R&D Tax Credit System" [METI's survey, hereafter] administered by Technology Promotion Division of Industrial Science and Technology Policy and the Environment Bureau in the Ministry of Economy, Trade and Industry. The METI's survey was conducted in June and July of 2005 and it retrospectively asked firms the detailed information on their R&D activities and their use of R&D tax credits in 2003-2004, including the reasons why firms did not use the R&D tax credits in 2003-2004. The survey was originally sent to 1,492 large R&D intensive firms by mail but only 288 out of 1,492 firms returned the survey. Table 5 compares the mean and the standard deviation of R&D expenditures, sales, the number of workers, the ratio of ordinary profit to sales, and the growth rate of R&D expenditures in the sample of METI's survey with those in the original BSJ sample, our benchmark sample, and the sample of Ohnish and Nagata (2010). Because these 288 firms include most of the largest R&D intensive firms, the sample of 288 firms cover 46.2 percent of the aggregate R&D expenditure defined as the sum of R&D expenditures across all firms in the original BSJ data set. Given a potential concern for selection, however, one should be cautious of fully extending the implications of the result of the METI's survey to interpret our measure of R&D tax credit. Nonetheless, because we know little about the reasons for not utilizing the R&D tax credits, the result of the METI's survey is informative.[12]

The result of the METI's survey is reported in Table 6. Among 287 firms who answer the survey question regarding the use of R&D tax credits, 207 firms state that they use the R&D tax credits; among these 207 firms, 204 firms choose to use the total R&D tax credits rather than the incremental R&D tax credits. Therefore, in this sample, most firms who applied for the R&D tax credits chose to use the total R&D tax credits.[13] Among 80 firms who did not use

[12] As far as we are aware, this is the only survey that explicitly asked the reasons why firms did not use the R&D tax credits in 2003-2004. While O&N discuss potential reasons for not using R&D tax credits, O&N did not have information in their data sets regarding the reasons why firms did not use R&D tax credits.

[13] On the other hand, when we compare our measure of the total R&D tax credits with that of the incremental R&D tax credits in the BSJ data, we sometimes found that the latter is larger than the former in the BSJ data even for firms who answer in METI's survey that they use the total R&D tax credits. Some R&D intensive firms may automatically adopt the new system without carefully comparing the R&D tax credits between two systems. This suggests that we may have to be concerned with the validity of our measurement because some firms choose to apply for the total R&D tax credits even when the incremental R&D tax credits is larger. When we estimated the benchmark specification by assuming that all firms use the total R&D tax credits, we found that the results

the R&D tax credits, 73 firms report their primary reasons for not using the R&D tax credits. Out of these 73 firms, $(39 + 15 =)54$ firms did not use it because their taxable income is zero once loss carry forward is taken into account (so that the cap is zero) while 14 firms did not use it because their R&D expenditure that is defined for tax-purposes is zero although their R&D expenditure broadly defined is positive. In other words, among firms who report their primary reasons for not using the R&D tax credits in the METI's survey, 93.2 percent of non-users of the total R&D tax credit system did not use the R&D tax credits simply because they are not eligible for R&D tax credits; for those 93.2 percent of firms, the eligible R&D tax credit is equal to the actual amount of R&D tax credit because both are zero.

Our measure for the eligible amount of R&D tax credits is computed based on the tax-purpose definition of R&D expenditure while taking into account the cap and the loss carry forward. Hence, to the extent that non-eligibility of R&D tax credits is the primary reason for not using R&D tax credits, our measure of the eligible amount of R&D tax credits would be a good proxy for the actual amount of R&D tax credits.[14] In METI's survey, 2 firms state the difficulty of computing the R&D expenditure that is eligible for tax credits as the primary reason for not applying for the R&D tax credit, which could be a source of measurement errors.

Table 7 reports the high correlation between our measure of the eligible R&D tax credits and R&D expenditures for tax purposes constructed from the BSJ data in 2003 and the actual amount of R&D tax credits and tax purpose R&D expenditures reported in the METI's survey, using the observations that are matched between the METI's survey and the BSJ data. For example, the correlation between our measure for R&D tax credits and the actual amount of R&D tax credits is 0.98. This provides some evidence that our measure for R&D tax credits may be a good proxy for the actual amount of R&D tax credits.

5 An R&D Investment Model

To understand how a tax credit affects R&D expenditure, this section examines a simple two-period model of R&D expenditure with financial constraint. We denote the first period by t and the second period by $t+1$. Let $\pi_t = \pi(K_t, z_t)$ be the profit function, where K_t represents the stock of R&D capital and z_t represents productivity that follows a first-order Markov process with transition distribution function $F(z_{t+1}|z_t)$. Given z_t, the support of $F(\cdot|z_t)$ is given by

are similar to those reported in Table 8.

[14] O&N reports that, among non-users of the total R&D tax credit system in their original sample from "Survey on R&D Activities of Private Firms" (MEXT's survey, hereafter) administered by Ministry of Education, Culture, Sports, Science and Technology, 19.5 percent of firms replied that they did not know the existence of the total R&D tax credit system in 2003. On the other hand, in METI's survey, only 2 out 73 firms state that being unaware of the total R&D tax credit system is the primary reason for not applying for R&D tax credits. One possible explanation for this discrepancy between what MEXT's survey reports and what METI's survey reports is that many of those firms who answered that they did not know the R&D tax credits in the MEXT's survey are firms with no taxable income or firms with no R&D expenditure for tax purposes, although the difference might simply reflect a difference in characteristics of firms between two surveys.

$[\underline{z}(z_t), \bar{z}(z_t)]$, where $\underline{z}(z_t)$ is increasing in z_t. The law of motion for R&D capital stock is given by $K_{t+1} = (1-\delta)K_t + I_t$, where I_t is the R&D expenditure and δ is the depreciation rate.

R&D capital stock is subject to adjustment costs given by $\psi(I_t, K_t) = I_t + \frac{\gamma}{2}(I_t/K_t)^2 K_t$. The quadratic form $\frac{\gamma}{2}(I_t/K_t)^2 K_t$ captures the difficulty of adjusting the amount of R&D capital. Because a large portion of R&D spending is the wages and salaries of highly educated scientists and engineers (see Lach and Schankerman (1989)), the coefficient γ partially reflects the degree of difficulty to hire and fire these knowledge workers in a short period of time.

We consider the following simplified tax credit systems for periods before 2002 and after 2003:

$$\varphi_t = \varphi_t(I_t, I_{t-1}) = \begin{cases} \max\{0.15(I_t - I_{t-1}), 0\} & \text{if } t \leq 2002 \\ \max\{0.15 I_t, 0\} & \text{if } t \geq 2003, \end{cases}$$

where $\varphi_t(I_t, I_{t-1})$ denotes the amount of tax credit for R&D expenditure. The total tax credit system after 2003 provides a larger amount of tax credit than the incremental tax credit system before 2002, especially for the firms with large amounts of previous R&D expenditure.

5.1 An R&D investment model without financial friction

We first analyze a firm's R&D investment decision without financial constraint by considering a simple two-period investment model given by

$$\max_{I_t \geq 0} \Pi(K_t, z_t, I_{t-1}) \equiv (1-\xi)\pi(K_t, z_t) - \psi(I_t, K_t) + \varphi_t(I_t, I_{t-1}) + \frac{1}{1+r}E[(1-\tau)\pi(K_{t+1}, z_{t+1}) + pK_{t+1}|z_t],$$

where $p < 1-\delta$ is the resale value of R&D capital and ξ is a tax rate on profit.

To analyze the optimal investment decisions, we define

$$MR(I_t) = \frac{1}{1+r}E[(1-\xi)\pi_K((1-\delta)K_t + I_t, z_{t+1}) + p|z_t],$$
$$MC^*(I_t) = 0.85 + \gamma\frac{I_t}{K_t}, \quad MC^{**}(I_t) = 1 + \gamma\frac{I_t}{K_t},$$

where $MR(I_t)$ is the marginal revenue of R&D investment and MC^* and MC^{**} represent the marginal costs of R&D investment when $\frac{\partial\varphi_t(I_t, I_{t-1})}{\partial I_t}$ is equal to 0.15 and 0, respectively. Let I^* and I^{**} be the optimal amount of R&D expenditure when the marginal costs are given by MC^* and MC^{**}, respectively, so that $MR(I^*) = MC^*(I^*)$ and $MR(I^{**}) = MC^{**}(I^*)$.

Under the total tax credit system after 2003, the marginal cost function is given by $MC(I_t) = MC^*(I_t)$, and the optimal amount of R&D expenditure is given by $I_t = I^*$. Conversely, under the incremental tax credit system before 2002, $\frac{\partial\varphi_t(I_t, I_{t-1})}{\partial I_t}$ is a discontinuous function of I_t at $I_t = I_{t-1}$. As a result, the marginal cost function under the incremental tax credit system is also discontinuous and given by

$$MC(I_t) = \begin{cases} MC^*(I_t) & \text{if } I_t > I_{t-1}, \\ MC^{**}(I_t) & \text{if } I_t \leq I_{t-1}. \end{cases}$$

Figures 6 to 8 illustrate how the amount of R&D expenditure is determined under the incremental tax credit system. In Figure 6, when the previous R&D expenditure is low enough that $I_{t-1} < I^{**}$, a firm benefits from the tax credit by choosing the current year's R&D expenditure to be greater than the past year's R&D expenditure, where the optimal R&D expenditure is determined by $MR(I_t) = MC^*(I_t)$. In contrast, in Figure 7, the past R&D expenditure is high enough that a firm's optimal choice of R&D expenditure is lower than the previous R&D expenditure; in this case, a firm receives no tax credit. Figure 8 illustrates the intermediate case $I^{**} \leq I_{t-1} < I^*$, in which a firm chooses $I_t = I^*$ only if it yields a profit higher than the profit from choosing $I_t = I^{**}$. Thus, the optimal R&D expenditure under the incremental tax credit system is given by

$$I_t = \begin{cases} I^* & \text{if } I_{t-1} < I^{**} \text{ or if } I^{**} \leq I_{t-1} < I^* \text{ and } \Pi(I^*, K_t, I_{t-1}, z_t) > \Pi(I^{**}, K_t, I_{t-1}, z_t), \\ I^{**} & \text{if } I_{t-1} \geq I^* \text{ or if } I^{**} \leq I_{t-1} < I^* \text{ and } \Pi(I^*, K_t, I_{t-1}, z_t) \leq \Pi(I^{**}, K_t, I_{t-1}, z_t). \end{cases}$$

The effect of tax reform may depend on the previous year's R&D expenditure. Consider a firm whose previous year's R&D expenditure is sufficiently lower than the current year's "optimal" R&D expenditure. In this case, $\frac{\partial \varphi_t(I_t, I_{t-1})}{\partial I_t} = 0.15$ for both tax regimes, and the firm would choose the identical R&D expenditure across two different tax policies under the optimality condition $0.85 + \gamma(I_t/K_t) = \frac{1-\xi}{1+r} E[\pi_K(K_{t+1}, z_{t+1}) + p|z_t]$. Thus, for such firms, the change from the incremental to the total tax credit system does not affect the decision rule for R&D expenditure.[15]

In contrast, for a firm whose previous year's R&D expenditure is sufficiently higher than the current year's optimal R&D expenditure, the tax credit reform in 2003 may positively affect the R&D expenditure. When a firm invests less in R&D than in the previous year (i.e., $I_t < I_{t-1}$), that firm is not eligible for any tax credit under the incremental tax credit system but eligible for a tax credit of 15 percent under the total tax credit system. Consequently, the change from the incremental to the total tax credit system will decrease the firm's marginal cost of R&D investment by 15 percent and, as a result, its R&D expenditure will increase.

The model implies that the effect of tax credit reforms on R&D expenditure would be heterogeneous across firms and that this effect depends on the pre-2002 R&D expenditures. The firms with a large amount of R&D expenditure from 1997 to 2001 may experience a substantial change in the eligible tax credit rate in 2003. In contrast, the eligible tax credit rate does not

[15]This result follows because the optimal investment level is determined by equating the marginal return to the marginal cost of R&D investment, and the tax credit reform affects neither the marginal cost nor the marginal return as long as the current year's investment is larger than the previous year's.

change before and after the 2003 tax reform (given at 15 percent) for the firms without any R&D investment from 1997 to 2001. We exploit this variation in the eligible tax credit rate across firms in our empirical analysis.

5.2 An R&D investment model with financial constraint

Because the 2003 tax reform may have a substantial impact on the after-tax cash flow, the change from the incremental to the total tax credit system may have had an impact on R&D expenditure by relaxing firms' financial constraints. To address this issue, we extend a two-period investment model by incorporating financial constraint.

We introduce "land," denoted by N_t, which plays the role of collateral. For simplicity, we assume that N_t is constant over time except that a firm can sell N_t in the period $t+1$. Consider a firm with state $(b_t, K_t, N_t, z_t, I_{t-1})$ in the first period, where b_t represents the outstanding short-term debt at the beginning of period t. Here, b_t refers to the amount that the firm is supposed to repay in period t. We consider bank loans as debts and explicitly take into account the possibility that the borrowing rate depends on the probability of default in the second period. Reflecting the positive probability of default, the bond price for b_{t+1}, denoted by $q^b(z_t, K_{t+1}, N_t, b_{t+1})$, could be strictly smaller than $1/(1+r)$ when $b_{t+1} > 0$, where r is the risk-free interest rate. We assume that a firm earns r when $b_{t+1} \leq 0$. The bond price schedule q^b is endogenously derived through the zero profit condition for the financial intermediaries as described below.

The dividend in the first period is given by $d_t(K_t, I_t, I_{t-1}, z_t, b_t, b_{t+1})$, where

$$d(K_t, I_t, I_{t-1}, z_t, b_t, b_{t+1}) := (1-\xi)\pi(K_t, z_t) - \psi(I_t, K_t) + \varphi_t(I_t, I_{t-1}) - b_t + q^b(z_t, I_t + (1-\delta)K_t, N_t, b_{t+1})b_{t+1}. \tag{4}$$

For simplicity, we assume that a firm cannot raise funds by issuing equity: $d_t \geq 0$.[16] In the following, we consider a firm such that $d_t \geq 0$ for some choice of (I_t, b_{t+1}). Then, the firm's investment problem in the first period t is given by

$$\max_{b_{t+1}, I_t} \; d_t + \beta E_{z_{t+1}|z_t} \left[\max \left\{ \underbrace{(1-\xi)\pi(K_{t+1}, z_{t+1}) - b_{t+1} + A_{t+1}}_{\text{no default}}, \; \underbrace{0}_{\text{default}} \right\} \right] \tag{5}$$

where $d_t = d(K_t, I_t, I_{t-1}, z_t, b_t, b_{t+1})$ is defined by (4) and $A_{t+1} := pK_{t+1} + N_t$ is the resale value of K_{t+1} and N_t. In the $t+1$ period, the firm will default when it cannot repay the outstanding debt, i.e., when $(1-\xi)\pi(K_{t+1}, z_{t+1}) + A_{t+1} < b_{t+1}$. Let $\Pr(D_{t+1} = 1 | z_t, K_{t+1}, N_t, b_{t+1})$ be the probability of default, where $D_{t+1} := \mathbb{I}((1-\xi)\pi(K_{t+1}, z_{t+1}) + A_{t+1} < b_{t+1})$.

Financial intermediaries are assumed to be risk-neutral and have the information about the

[16] A similar argument applies when we alternatively assume that there is a convex adjustment cost of issuing equity.

firm's state variables. We assume that the financial intermediaries earn zero profit in equilibrium:

$$\underbrace{\Pr(D_{t+1}=1|z_t,K_{t+1},N_t,b_{t+1})}_{\text{default probability}}\underbrace{A_{t+1}}_{\text{collat.}}+\underbrace{\Pr(D_{t+1}=0|z_t,K_{t+1},N_t,b_{t+1})}_{\text{non-default probability}}b_{t+1}=\frac{q^b(z_t,K_{t+1},N_t,b_{t+1})b_{t+1}}{1/(1+r)} \quad (6)$$

for $b_{t+1} > A_{t+1}$, where the left-hand side is the bank's expected return from lending the amount $q^b(z_t, K_{t+1}, N_t, b_{t+1})b_{t+1}$ to a firm while the right-hand side is the bank's cost of raising $q^b(z_t, K_{t+1}, N_t, b_{t+1})b_{t+1}$ in the market with the risk-free rate r. Solving (6), we have

$$q^b(z_t,K_{t+1},N_t,b_{t+1})=\frac{\Pr(D_{t+1}=1|z_t,K_{t+1},N_t,b_{t+1})(A_{t+1}/b_{t+1}-1)+1}{1+r} \quad (7)$$

when $b_{t+1} > A_{t+1}$ and $q^b(z_t, K_{t+1}, N_t, b_{t+1}) = 1/(1 + r)$, otherwise.

Equation (7) indicates that the borrowing rate is increasing in both the default probability and the debt-to-collateral ratio, b_{t+1}/A_{t+1}, implying that the firm's investment would be higher when the probability of default is lower and the debt-to-collateral ratio is lower. An increase in outstanding debts increases both the default probability and the debt-to-collateral ratio, and, as a result, will reduce the R&D investment. In the presence of such financial constraint, the 2003 tax credit reform may positively affect the R&D investment by relaxing the financial constraint. This effect can be seen from the firm's R&D investment problem (4)-(5) with the state-dependent bond price (7). The effect of tax reform is represented by the change in the tax credit function $\varphi_t(I_t, I_{t-1})$. For any firm that conducted R&D investment during the previous year (i.e., $I_{t-1} > 0$), the tax credit $\varphi_t(I_t, I_{t-1})$ would be higher after the tax reform than before. As a result, the tax reform increases the R&D investment by increasing the internal funds for R&D investment and decreasing the outstanding debts in period $t + 1$. Furthermore, the effect of increasing the internal funds for R&D investment would be larger for those firms who face the higher borrowing rate, i.e., of those with the higher value of the debt-to-collateral ratio. This implication is tested in our empirical analysis by including the interaction term between a proxy for the debt-to-collateral ratio and the eligible tax credit rate in our specifications.

6 Empirical Analysis

To examine the tax credit effect on R&D expenditure and the role of financial constraints, we estimate an econometric model similar to that of Bloom, Griffith, and Van Reenen (2002):

$$\ln RD_{it}=\beta\tau_{it}+\gamma\ln Y_{it}+\delta\frac{b_{it}}{A_{it}}+\theta\tau_{it}\frac{b_{it}}{A_{it}}+Z'_{it}\alpha+\eta_t+\mu_i+\epsilon_{it}, \quad (8)$$

where RD_{it} is firm i's R&D expenditure in year t, τ_{it} is the rate of the eligible R&D tax credit, Y_{it} is the sales, and b_{it} and A_{it} represent firm i's outstanding debt and fixed assets in the beginning of year t, respectively. Z_{it} represents other controls, including the ratio of previous period's cash flow to fixed asset, denoted by CF_{it-1}/A_{it}, and its interaction with τ_{it}, $\tau_{it} \times (CF_{it-1}/A_{it})$. We also include the interaction of year dummies with industry/regional dummies, as well as quarter dummies that control for the difference in the closing months of firm-specific fiscal years.[17] The term η_t captures an aggregate time effect, μ_i is a firm fixed effect, and ϵ_{it} is an idiosyncratic unobservable shock that affects firm i's decision concerning R&D expenditure in year t.

Our measure of R&D expenditure, RD_{it}, in (8) is the sum of own and outsourced research and development expenses.[18] We construct a measure for the eligible tax credit rate, τ_{it}, defined by (1) using the tax credit formulas described in Section 4. The log of sales controls for the firm's transitory shock to the return to R&D. We use the sum of the liquid and fixed debts for b_{it}, and we use the stock of fixed asset constructed by the perpetual inventory method for A_{it}, as explained in Appendix A.4. We consider the stock of fixed asset, A_{it}, as a proxy for the value of collateral when firms borrow from banks in the model of Section 5.2.

The ratio of previous period's cash flow to fixed asset, CF_{it-1}/A_{it}, is included as one of the controls because it may affect the extent to which a firm is financially constrained in period t, where we expect its coefficient to be positive. We include the interaction of year dummies with industry and regional dummy variables in the regression to partially control for industry- and region-specific shocks and business cycle effects. Furthermore, the closing month of the fiscal year is different across firms and, we also include dummy variables for the closing month of the firm-specific fiscal year using quarter dummies.

To control for endogeneity due to the firm-specific effects μ_i, we take the first difference of (8) to obtain

$$\Delta \ln RD_{it} = \beta \Delta \tau_{it} + \gamma \Delta \ln Y_{it} + \delta \Delta \left(\frac{b_{it}}{A_{it}} \right) + \theta \Delta \left(\tau_{it} \frac{b_{it}}{A_{it}} \right) + \Delta Z_{it}' \alpha + \Delta \eta_t + \Delta \epsilon_{it}. \quad (9)$$

The parameter β represents the semi-elasticity of the eligible tax credit rate on the R&D expenditure when debt-asset ratio is zero. The negative value of δ implies that an increase in debt-asset ratios leads to a decrease in R&D expenditure when the eligible tax credit is zero, indicating a possibility of financial constraint. The positive value of θ implies that the effect of R&D tax credit rates is especially large for the firms with high debt-to-asset ratios. To the extent that a higher debt-to-asset ratio leads to a tighter financial constraint, the positive value of θ provides evidence that the 2003 tax credit reform promotes the R&D expenditure of financially constrained firms.

[17] Specifically, we construct firm-specific quarter dummies that depend on the closing months of firm-specific fiscal years, where, for example, the first quarter dummy takes the value equal to one if the closing month of fiscal year is between January and March.

[18] Unlike the definition of the R&D expenditure for tax purpose, RD_{it}^{tax}, we do not subtract the amount received for commissioned R&D projects to define RD_{it}. The sum of RD_{it} across firms will be a more appropriate measure for the aggregate R&D than the sum of RD_{it}^{tax}. The estimation results are similar to those reported in Table 8, however, even when we use RD_{it}^{tax} in place of RD_{it}.

In estimating (9), we need to restrict the sample to the observations with strictly positive values of R&D expenditures in two consecutive years because the dependent variable is the change in the logarithm of R&D expenditure. By omitting the observations with zero R&D expenditure in $t-1$ but positive R&D expenditure in t, however, we lose an important source of variations in the sample to identify the effect of R&D tax credits on R&D expenditures. Furthermore, the omission of observations with zero R&D expenditure could potentially lead to sample selection bias. For this reason, we also consider an alternative specification in which the variables are normalized using the fixed asset A_{it} as

$$\Delta \frac{RD_{it}}{A_{it}} = \beta \Delta \frac{X_{it}}{A_{it}} + \gamma \Delta \frac{Y_{it}}{A_{it}} + \delta \Delta \left(\frac{b_{it}}{A_{it}} \right) + \theta \Delta \left(\frac{X_{it}}{A_{it}} \frac{b_{it}}{A_{it}} \right) + \Delta Z_{it}' \alpha + \Delta \eta_t + \Delta \epsilon_{it}, \tag{10}$$

where X_{it} is the eligible amount of R&D tax credit defined in equations (2)-(3). Comparing the specification (10) with (9), we replace $\ln RD_{it}$, $\tau_{it} = X_{it}/RD_{it}^{\text{tax}}$, and $\ln Y_{it}$ with RD_{it}/A_{it}, X_{it}/A_{it}, and Y_{it}/A_{it}, respectively. The interpretation of the coefficients in (10) differs from that in (9) because the coefficients in (10) represent the effect of a change in explanatory variables on the R&D–asset ratio, while the coefficients in (9) are the semi-elasticities of the explanatory variables for R&D expenditures.

Even after taking the first difference, there are potential concerns for endogeneity in estimating (9) and (10) by the Ordinary Least Squares. First, although taking the first difference eliminates the endogeneity due to a positive correlation between τ_{it} and the firm-specific effect μ_i, a contemporary positive correlation between τ_{it} and the idiosyncratic factor ϵ_{it} may cause a positive correlation between $\Delta\tau_{it}$ and $\Delta\epsilon_{it}$ in (9). For example, R&D intensive firms may increase R&D spending more quickly in response to an improvement in business conditions. Second, if a firm correctly expects a higher return on R&D, say, after 2003, then a firm might borrow more to increase R&D expenditure before 2002 in the presence of adjustment cost for R&D; in such a case, a higher value of b_{it-1}/A_{it-1} reflects a higher expected value of $\Delta\epsilon_{it}$ for $t = 2003$, leading to a negative correlation between $\Delta(b_{it}/A_{it})$ and $\Delta\epsilon_{it}$.

To deal with these endogeneity issues, we estimate the first-difference equations (9)-(10) by the two-step panel GMM. To estimate (9), we use the two- and three-year lagged values of the eligible tax credit rate, τ_{it-2} and τ_{it-3}, as instruments for $\Delta\tau_{it}$.[19] Furthermore, we use b_{it-2}/A_{it-2}, b_{it-3}/A_{it-3}, $\tau_{it-2}(b_{it-2}/A_{it-2})$, and $\tau_{it-3}(b_{it-3}/A_{it-3})$ as instruments for $\Delta(b_{it}/A_{it})$ and $\Delta(\tau_{it}(b_{it}/A_{it}))$ to estimate the equation (9).[20] Similarly, we use CF_{it-2}/A_{it-2}, CF_{it-3}/A_{it-3}, $\tau_{it-2}(CF_{it-2}/A_{it-2})$, and $\tau_{it-3}(CF_{it-3}/A_{it-3})$ as instruments for $\Delta(CF_{it}/A_{it})$ and $\Delta(\tau_{it}(CF_{it}/A_{it}))$. In estimating (10), the instruments are similarly defined using the two- or three-year lagged values of endogenous variables.

[19]We treat ΔY_{it} as an exogenous variable; we also estimated the specification in which ΔY_{it} is instrumented with Y_{it-2} and Y_{it-3} in some cases, and found that the estimation results are qualitatively similar.

[20]If it is easy to misclassify R&D expenses for tax purpose, the coefficient on the interaction term between the tax credit rate and debt-asset could be biased.

Our choice of instruments is motivated by their ability to predict the value of endogenous variables while we will examine the validity of moment conditions by an over-identifying restriction test. For example, correlation between $\Delta(b_{it}/A_{it})$ and b_{it-2}/A_{it-2} for $t = 2003$ is found to be -0.28 with p-value less than 0.0001 in the benchmark sample, indicating that firms with higher debt-asset ratio in the beginning of 2001 tend to experience a lower rate of growth of debt-asset ratios between 2002 and 2003 presumably because those with higher debts are difficult to borrow more.

We estimate (9) and (10) using the panel data for $t = 2001$, 2002, and 2003. As reported in the lower panel of Table 3, there exists a substantial variation in the changes in the eligible tax credit rate across firms not only in 2002-2003 but also prior to 2002, where the variation in $\Delta\tau_{it}$ across firms for $t = 2001$ and $t = 2002$ arises under the incremental tax credit system because firms change their past R&D experiences over time as shown in the lower panel of Table 4.

Table 8 reports the estimation results. Columns (1)-(4) report the GMM estimates of equation (9) using the observations with strictly positive values of R&D expenditure across six-consecutive years in the benchmark sample while columns (5)-(8) report the GMM estimates of equation (10) using all observations in the benchmark sample. The p-value of Hansen's J test provides evidence for the validity of the moment conditions across different specifications except for the specification in column (6).

In column (1) of Table 8, the estimated coefficient of $\Delta(b_{it}/A_{it})$ is significantly negative, which suggests a negative effect of financial constraints on R&D expenditures. The estimated coefficient of the R&D tax credit $\Delta\tau_{it}$ or $\Delta(X_{it}/A_{it})$ is positive but insignificant across different specifications, except for column (7), indicating that, for those firms facing no financial constraints, the R&D tax credit may not affect their R&D expenditures. This result is largely consistent with the finding of O&N, although it is possible that the insignificance of our estimated coefficient for the R&D tax credit is due to measurement errors because, after we take the first difference, the remaining variation in our measure of the R&D tax credit could severely suffer from measurement error, as discussed by Griliches and Hauseman (1986).

The estimated coefficient of the interaction term $\Delta(\tau_{it}b_{it}/A_{it})$ or $\Delta((X_{it}/A_{it})(b_{it}/A_{it}))$ is significantly positive in columns (2), (3), (7), and (8), providing some evidence that the positive effect of R&D tax credits on R&D expenditure is especially large for firms with high debt-to-asset ratios that may have difficulty obtaining additional external financing for their R&D expenditures. The estimated coefficient of the interaction term $\Delta(\tau_{it}b_{it}/A_{it})$ is positive but becomes insignificant in column (4) when we introduce the additional interaction term $\Delta(\tau_{it}CF_{it-1}/A_{it})$ possibly because the variation in the data is not rich enough to identify two interaction terms separately. The point estimate of the interaction term $\Delta((X_{it}/A_{it})(b_{it}/A_{it}))$ is negative but not significant in column (6), where the J-test indicates the possibility of misspecification. Also, in columns (7)-(8), the estimated coefficients of the ratio of cash flow to asset are positive and significant; the higher level of cash flow in the previous period may increase the internal fund for R&D expenditure, leading to an increase in R&D expenditures. On the other hand, the interaction term $\Delta(\tau(CF_{it-1}/A_{it}))$ in column (4) and $\Delta((X_{it}/A_{it})(CF_{it-1}/A_{it}))$ in column (8) are not significant, providing no evidence that the effect of the R&D tax credit depends on the cash–asset ratio.

Based on the estimate in column (3) of Table 8, Table 9 reports how the tax credit semi-elasticities depend on the value of the debt-to-asset ratios, where the tax credit semi-elasticities are estimated as 0.81, 0.91, and 1.21 at the 5th percentile, median, and 95th percentile of the debt-to-asset ratio, respectively. Therefore, the effect of tax credits on R&D expenditures substantially differ across different firms depending on their debt-to-asset ratios.

Firms without fixed assets may face higher cost in external finance because they do not have collateral. If firms with little fixed assets are more likely to face financial constraint for their R&D expenditures than firms with large fixed assets, the effect of the tax credit is expected to be larger for the former than for the latter. To address this difference, we split the benchmark sample at the median value of the fixed asset in 2003 and estimate equation (9) separately for each sample.[21]

Table 10 reports the results of small firms and large firms, separately. In columns (1)-(2) and (8)-(9) of Table 10, the estimated coefficients of $\Delta(\tau_{it}(b_{it}/A_{it}))$ or $\Delta((X_{it}/A_{it})(b_{it}/A_{it}))$ are positive and significant for small firms while the estimated coefficients of $\Delta(\tau_{it}(b_{it}/A_{it}))$ or $\Delta((X_{it}/A_{it})(b_{it}/A_{it}))$ are negative and sometimes significant in columns (4)-(6) and (10)-(12) for large firms. Overall, Table 10 suggests that financial constraint measured by debt-to-asset ratios could be important in explaining the effect of tax credit ratios on R&D expenditures for small firms but not for large firms although the significantly negative coefficients of the interaction term $\Delta((X_{it}/A_{it})(b_{it}/A_{it}))$ for large firms in columns (10) and (12) are difficult to explain.

What was the effect of the change from the incremental to the total tax credit system on aggregate R&D expenditure in 2003? How important was the role of financial constraint? To answer this question, we compute the counterfactual value of aggregate R&D expenditure in 2003 if there had been no change in the R&D tax credit system in 2003. Given the insignificance of the coefficient of the interaction term $\Delta\tau_{it}CF_{it-1}/A_{it}$ or $\Delta((X_{it}/A_{it})(CF_{it-1}/A_{it}))$ in columns (4) and (8) of Table 8, we use the estimates in columns (3) and (7) of Table 8 to compute the counterfactual value of R&D expenditure. For example, to compute the counterfactual value of R&D expenditure based on the estimate in column (3) of Table 8, we first compute the counterfactual values of the R&D tax credit rate, denoted by $\hat{\tau}_{it}^{\text{inc}}$, under the incremental tax credit system using equation (2). The counterfactual values of firm's R&D expenditure is then computed as the predicted value for the log of R&D expenditure using the estimate in columns (3) of Table 8 but replacing the observable values of τ_{it} and $\tau_{it}(b_{it}/A_{it})$ with their counterfactual values, $\hat{\tau}_{it}^{\text{inc}}$ and $\hat{\tau}_{it}^{\text{inc}}(b_{it}/A_{it})$. Finally, the counterfactual aggregate R&D expenditure is com-

[21]We compute the median value of the fixed asset in the sample before we drop the observations for which lagged IV variables are missing.

puted by aggregating the counterfactual values of firm's R&D expenditure.[22] The counterfactual value of R&D expenditure based on the estimate in column (7) of Table 8 is similarly computed by using the counterfactual values of the ratio of R&D tax credit to asset in 2003, denoted by $\hat{X}_{it}^{\text{inc}}/A_{it}$, in place of $\hat{\tau}_{it}^{\text{inc}}$.[23]

As shown in column (1) of Table 11, the aggregate R&D expenditure in 2003 would have been lower by 3.0-3.4 percent if the incremental tax credit system had been implemented in 2003. This suggests that the impact of the tax credit reform on the aggregate R&D expenditure was substantial. To examine the role of financial constraint, column (2) reports the change in the aggregate R&D expenditure when we replace the value of $\tau_{it}(b_{it}/A_{it})$ with its counterfactual value $\hat{\tau}_{it}^{\text{nc}}(b_{it}/A_{it})$ while keeping the value of τ_{it} as it is. The effect of no tax credit reform on the aggregate R&D expenditure through the interaction term ranges from -0.3 percent to -0.6 percent, indicating that the financial constraint plays a small but non-negligible role in determining the effect of tax credit reform.

One of the controversial aspects of the total tax credit system in 2003 is that the amount of the tax credit was capped by 20 percent of corporate tax. As shown in Table 6, in the METI's survey, the cap is binding for 47 percent of firms who use the R&D tax credits; therefore, many R&D intensive firms might have received a larger amount of R&D credit if the amount of the tax credit had not been capped by 20 percent of corporate tax. To examine the effect of the cap on the aggregate R&D expenditure, we compute the counterfactual value of the R&D tax credit rate and the ratio of R&D tax credit to asset in 2003 if there had been no cap on the amount of the tax credit, denoted by $\hat{\tau}_{it}^{\text{nc}}$ and $\hat{X}_{it}^{\text{nc}}/A_{it}$, respectively, and then compute the counterfactual value of aggregate R&D expenditure in 2003 using $\hat{\tau}_{it}^{\text{nc}}$ and $\hat{X}_{it}^{\text{nc}}/A_{it}$.

In column (3) of Table 11, the overall effect of removing the cap is computed as 3.1-3.9 percent. Column (4) of Table 11 reports the effect of removing the cap through the interaction term $\tau_{it}(b_{it}/A_{it})$ or $(X_{it}/A_{it})(b_{it}/A_{it})$, showing that the aggregate R&D expenditures would have been larger by 0.3-0.8 percent if the value of $\tau_{it}(b_{it}/A_{it})$ or $(X_{it}/A_{it})(b_{it}/A_{it})$ is replaced with its counterfactual value $\hat{\tau}_{it}^{\text{nc}}(b_{it}/A_{it})$ or $(\hat{X}_{it}^{\text{nc}}/A_{it})(b_{it}/A_{it})$. These results of the counterfactual experiments show that removing the cap could have a large impact on the aggregate R&D expenditure, a part of which is attributable to relaxing the financial constraint of firms with outstanding debts.

[22] Full details of the construction of the counterfactual values are available from the authors upon request.

[23] In principle, the counterfactual value $\hat{\tau}_{it}^{\text{inc}}$ and $\hat{X}_{it}^{\text{inc}}/A_{it}$ must also depend on the counterfactual value of RD_{it} because computing the counterfactual tax credit $\hat{X}_{it}^{\text{inc}}$ requires the counterfactual value of RD_{it}. Table 11 reports the counterfactual aggregate R&D expenditure based on the values of $\hat{\tau}_{it}^{\text{inc}}$ and $\hat{X}_{it}^{\text{inc}}/A_{it}$ that are computed by fixing the value of RD_{it} at the actual value. We also computed the counterfactual aggregate R&D expenditure based on the counterfactual values $\hat{\tau}_{it}^{\text{inc}}$ and $\hat{X}_{it}^{\text{inc}}/A_{it}$ that take into account their dependency on the counterfactual value of RD_{it} and found that the results are quite similar to those reported in Table 11.

7 Conclusion

This paper investigates the effect of R&D tax credits on firms' R&D expenditure, paying particular attention to the role of financial constraint, by using the panel data of Japanese manufacturing firms. By estimating the effect of a change in the eligible tax credit rate on a change in the log of R&D expenditure by panel GMM, we find that an increase in the tax credit has a positive effect on R&D expenditure especially for firms with higher debt-to-asset ratios.

The results of the counterfactual experiment suggest that the effect of introducing the total tax credit system on the aggregate R&D expenditure was substantial while the aggregate R&D expenditure would have been even larger if the cap on the tax credit based on 20 percent of corporate tax had been removed. We also found that the financial constraint of firms with outstanding debts would play a small but non-negligible role to explain the effect of these counterfactual policies on the aggregate R&D expenditures.

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Table 1: Sample Selection

	Observations deleted	Remaining observations
Original sample (manufacturing, 2001–2003)		38491
Small or medium firms	23260	15231
Year-end month changed	166	15065
Missing past R&D	1562	13503
Sample for Tables 3 and 4		**13503**
Missing lagged variables	3331	10172
Benchmark Sample for Tables 2, 8, 10 and 11		**10172**
zero R&D expenditure	4016	6156
Sample for Tables 8-10		**6156**

Notes. "Small or medium firms" exclude observations of firms with capital smaller than or equal to 100 million. For each year, "missing past R&D" excludes observations with more than two years of missing R&D expenditures in the five years prior to the given year. "Missing lagged variables" excludes observations with lagged variables necessary for our panel GMM estimation missing.

Table 2: Mean Characteristics of Benchmark Sample

	2000	2001	2002	2003
Sales (Y)	54456	50433	52025	55425
	(258411)	(245575)	(250693)	(264520)
Ordinary Profit	2636	1613	2235	2743
	(15586)	(17721)	(19027)	(20777)
Frac. of Positive Ordinary Profit	0.87	0.78	0.86	0.91
	(0.33)	(0.42)	(0.35)	(0.29)
# Employee (N)	911	868	851	885
	(3084)	(2915)	(2794)	(2974)
Fixed Asset (A)	68329	65097	62178	61292
	(291579)	(275083)	(260692)	(263913)
Debt (b)	33665	33985	33469	34332
	(155356)	(154090)	(154374)	(159471)
b_t/A_t	0.6523	0.7344	0.7295	0.7872
	(1.54)	(1.65)	(1.75)	(2.71)
CF_{t-1}/A_t	0.0367	0.0389	0.0333	0.0464
	(0.21)	(0.34)	(0.21)	(0.13)
R&D Expenditure (RD)	2172	2210	2244	2403
	(17378)	(17979)	(18190)	(19377)
Frac. of Positive RD	0.6930	0.6930	0.6974	0.7058
	(0.46)	(0.46)	(0.46)	(0.46)
$\Delta \ln RD$	-0.00	-0.04	-0.03	-0.01
	(0.67)	(0.60)	(0.67)	(0.61)
R&D Exp./Y	0.0239	0.0273	0.0265	0.0258
	(0.03)	(0.04)	(0.03)	(0.03)
Observation	3358	3453	3401	3318

Notes. Each entry except for the last row refers to the average of the corresponding variable in the benchmark sample. The last row reports the number of observations. The row designated as “RD/Y” reports averages of the ratio of R&D expenditure to sales across the observations with strictly positive R&D expenditure. “Asset” refers to the tangible fixed asset in the beginning of the period. “Debt” refers to the sum of liquid and fixed debts in the beginning of the period. “Frac. of Positive RD” refers to the fraction of observations with a strictly positive R&D expenditure. “Frac. of Positive Ordinary Profit” refers to the fraction of observations with a strictly positive ordinary profit. Sample standard deviation is in parentheses. All monetary values are nominal and in units of million yen.

Table 3: Mean and Standard Deviations of τ_{it} and $\Delta\tau_{it}$ from 2000 to 2003

Year	2000	2001	2002	2003
Mean of τ_{it}	0.0118	0.0089	0.0092	0.0704
S.D. of τ_{it}	0.0282	0.0243	0.0240	0.0437
No. of Observations	3090	3110	3022	2959
Year	1999-2000	2000-2001	2001-2002	2002-2003
Mean of $\Delta\tau_{it}$	-0.0013	-0.0048	-0.0009	0.0608
S.D. of $\Delta\tau_{it}$	0.0262	0.0275	0.0232	0.0445
No. of Observations	2708	2721	2700	2585

Table 4: Mean and Standard Deviations of τ_{it} and $\Delta\tau_{it}$ across Different Past R&D experiences

Past R&D experience before 2002	(1) zero year	(2) one year	(3) two years	(4) three years
Mean of $\tau_{i,2002}$	0.0671	0.0230	0.0176	0.0071
S.D. of $\tau_{i,2002}$	0.0727	0.0459	0.0336	0.0177
No. of Observations	38	58	141	2766
Past R&D experience before 2002	(1) zero year	(2) one year	(3) two years	(4) three years
Mean of $\Delta\tau_{i,2003}$	0.0049	0.0358	0.0571	0.0622
S.D. of $\Delta\tau_{i,2003}$	0.0564	0.0565	0.0454	0.0433
No. of Observations	24	40	93	2416
Past R&D experience before 2001	(1) zero year	(2) one year	(3) two years	(4) three years
Mean of $\Delta\tau_{i,2002}$	-0.0417	-0.0105	-0.0045	0.0002
S.D. of $\Delta\tau_{i,2002}$	0.0690	0.0455	0.0399	0.0191
No. of Observations	21	70	117	2479

Table 5: Comparison of Sample Characteristics in 2003 across Different Data Sets

	BSJ	BSJ Benchmark		METI's Survey matched with BSJ			Onishi and Nagata (2010)[(a)]		
Data Set	Original	All	$RD > 0^{(c)}$	All	Users	Non-Users	All	Users	Non-Users
$RD^{\text{tax(b)}}$	369	2354	3754	18881	18384	20301	11093	14982	6852
	(6922)	(19181)	(24311)	(52192)	(51464)	(54617)	(−)	(3514)	(2334)
$RD^{(b)}$	376	2403	3804	19184	18539	21026	n/a	n/a	n/a
	(6992)	(19377)	(24542)	(52685)	(51454)	(56442)			
Sales	21691	55425	78287	435305	453387	383644	239239	338914	130541
	(147381)	(264520)	(330930)	(854495)	(880193)	(780757)	(−)	(50596)	(26201)
No. of Workers	407	885	1201	5355	5188	5833	2837	3863	1718
	(1621)	(2974)	(3619)	(8770)	(7805)	(11136)	(−)	(444)	(253)
Ordinary Profit/Sales	0.03	0.04	0.05	0.06	0.08	0.02	0.03	0.06	-0.01
	(0.31)	(0.11)	(0.06)	(0.07)	(0.07)	(0.05)	(−)	(0.00)	(0.05)
$\Delta \ln RD^{\text{tax(c)}}$	0.005	-0.009	-0.004	0.000	0.016	-0.044	-0.014	0.01	-0.04
	(0.721)	(0.618)	(0.576)	(0.315)	(0.251)	(0.451)	(−)	(0.018)	(0.028)
$\Delta \ln RD^{(c)}$	0.004	-0.006	-0.001	-0.001	0.014	-0.044	n/a	n/a	n/a
	(0.722)	(0.613)	(0.567)	(0.308)	(0.248)	(0.435)			
No. of Observations	26936	3318	2041	243	180	63	485	253	232
% of Aggregate RD^{tax}	100	78.7	77.2	46.2	33.3	12.9	54.3	38.2	16
% of Aggregate RD	100	78.7	76.6	46.0	32.9	13.1	n/a	n/a	n/a

Notes. Sample means are reported except for the last three rows. Sample standard deviation in parenthesis. All monetary values are nominal and in units of million yen. (a) Computed from Tables 1 and 2 of Onishi and Nagata (2010). (b) See Appendix A.1 for the definition of RD^{tax} and RD. (c) Computed from the observations with positive R&D values in 2002 and 2003.

Table 6: The Survey Results on the Use of R&D Credits among 288 Large R&D Firms

Do You Use R&D Credits?		
N/A[(a)]	Yes	No
1	207	80

Among 207 firms with "Yes"					Among 80 firms with "No"				
Increment or Total Tax Credits?			20% Cap Binding?		Reasons for Not Using R&D Tax Credits				
Increment	Total	N/A[(a)]	Not Binding	Binding	No[(b)] R&D	No Taxable Income	Loss Carry	Others	N/A[(a)]
3	204	1	110	97	14	39	15	5	7

Notes. (a) "N/A" indicates that a firm did not answer the question; (b) "No R&D" indicates that a firm did not apply for R&D tax credits because R&D expenditure defined for tax purposes is zero.

Table 7: Correlation Between BSJ and METI'S Survey Using the Matched Observations

	RD_{it}^{tax}	X_{it}	$\ln RD_{it}^{tax}$	$\ln X_{it}$
Correlation	0.9903	0.9804	0.9349	0.8789
p-value	0.0000	0.0000	0.0000	0.0000
Observations	158	156	147	140

Table 8: Panel GMM Estimation of Equations (9) and (10) for Benchmark Sample

	Equation (9): $\Delta \ln RD_{it}$					Equation (10): $\Delta \frac{RD_{it}}{A_{it}}$			
	(1)	(2)	(3)	(4)		(5)	(6)	(7)	(8)
$\Delta \tau_{it}$	1.1584	0.7860	0.7543	0.1421	$\Delta \frac{X_{it}}{A_{it}}$	0.4396	1.3655	0.7288***	2.7469
	[1.586]	[1.615]	[1.613]	[1.653]		[0.620]	[1.049]	[0.279]	[2.861]
$\Delta \ln Y_{it}$	0.4321***	0.4074***	0.4025***	0.4007***	$\Delta \frac{Y_{it}}{A_{it}}$	0.0048***	0.0043**	0.0048***	0.0041***
	[0.058]	[0.061]	[0.060]	[0.058]		[0.002]	[0.002]	[0.001]	[0.001]
$\Delta \frac{b_{it}}{A_{it}}$	−0.2112***	0.1506	0.1040	0.0423	$\Delta \frac{b_{it}}{A_{it}}$	−0.0004	0.0118	−0.0142**	−0.0098
	[0.028]	[0.151]	[0.129]	[0.133]		[0.009]	[0.020]	[0.006]	[0.008]
$\Delta\left(\tau_{it} \frac{b_{it}}{A_{it}}\right)$		0.3776***	0.2945*	0.3004	$\Delta\left(\frac{X_{it}}{A_{it}} \frac{b_{it}}{A_{it}}\right)$		−0.0742	0.1204***	0.1187***
		[0.146]	[0.162]	[0.191]			[0.170]	[0.019]	[0.022]
$\Delta \frac{CF_{it-1}}{A_{it}}$			0.0563	1.0460	$\Delta \frac{CF_{it-1}}{A_{it}}$			0.0414***	0.0413***
			[0.348]	[0.927]				[0.012]	[0.015]
$\Delta\left(\tau_{it} \frac{CF_{it-1}}{A_{it}}\right)$				19.6189	$\Delta\left(\frac{X_{it}}{A_{it}} \frac{CF_{it-1}}{A_{it}}\right)$				−2.4327
				[15.023]					[3.565]
Quarter× Year	Yes	Yes	Yes	Yes	Quarter× Year	Yes	Yes	Yes	Yes
Industry× Year	Yes	Yes	Yes	Yes	Industry× Year	Yes	Yes	Yes	Yes
Region× Year	Yes	Yes	Yes	Yes	Region× Year	Yes	Yes	Yes	Yes
p-value of J-test	0.1527	0.2059	0.1165	0.5086	p-value of J-test	0.6261	0.0514	0.1420	0.1489
Observations	6156				Observations	10172			

Notes. *** p<0.01, ** p<0.05, * p<0.1. For columns (1)-(4), instruments include $\Delta \ln Y_{it}$, τ_{it-2}, τ_{it-3}, $\frac{b_{it-2}}{A_{it-2}}$, $\frac{b_{it-3}}{A_{it-3}}$, the full set of year dummies, the full set of quarter, region, industry dummies and their interactions with year dummies. Furthermore, we include $\tau_{it-2}\frac{b_{it-2}}{A_{it-2}}$ and $\tau_{it-3}\frac{b_{it-3}}{A_{it-3}}$ as instruments for $\Delta\left(\tau_{it} \frac{b_{it}}{A_{it}}\right)$ in columns (2)-(4), $\frac{CF_{it-3}}{A_{it-2}}$ and $\frac{CF_{it-4}}{A_{it-3}}$ as instruments for $\Delta \frac{CF_{it-1}}{A_{it}}$ in columns (3)-(4), and $\tau_{it-2}\frac{CF_{it-3}}{A_{it-2}}$, $\tau_{it-3}\frac{CF_{it-4}}{A_{it-3}}$, as instruments for $\Delta\left(\tau_{it} \frac{CF_{it-1}}{A_{it}}\right)$ in column (4). The instruments for columns (5)-(8) are similar to those for columns (1)-(4) except that we replace τ_{it-s} with $\frac{X_{it-s}}{A_{it-s}}$ for $s = 2$ and 3. Robust standard errors are in brackets.

Table 9: Tax Credit Semi-Elasticity by percentiles of b_{it}/A_{it}

	5%	25%	50%	75%	95%
$\frac{b_{it}}{A_{it}}$	0.188	0.357	0.521	0.766	1.555
$\hat{\beta} + \hat{\theta}(\frac{b_{it}}{A_{it}})$	0.810	0.859	0.908	0.980	1.212

Notes. The row of b_{it}/A_{it} reports the value of debt-to-asset ratios at the 5th, 25th, ... , and 95th percentiles, and the last row reports the estimated tax credit semi-elasticities at these percentiles using the estimates reported in column (3) of Table 8.

Table 10: Panel GMM Estimation of Equations (9) and (10) for Small Firms vs. Large Firms

Equation (9): $\Delta \ln RD_{it}$	Small Firms			Large Firms		
	(1)	(2)	(3)	(4)	(5)	(6)
$\Delta\tau_{it}$	1.6185	1.8282	1.9416	−0.1495	1.6717	1.5844
	[2.705]	[2.710]	[2.611]	[2.004]	[2.504]	[2.255]
$\Delta \ln Y_{it}$	0.4574***	0.4498***	0.4463***	0.4271***	0.3569***	0.3483***
	[0.100]	[0.098]	[0.097]	[0.100]	[0.108]	[0.095]
$\Delta \frac{b_{it}}{A_{it}}$	0.1402	0.0960	0.0400	−0.7473	0.6982	0.7020
	[0.146]	[0.130]	[0.108]	[1.115]	[1.606]	[1.303]
$\Delta\left(\tau_{it}\frac{b_{it}}{A_{it}}\right)$	0.3580**	0.2867*	0.2818	−0.3247	−0.4743	−0.6626
	[0.143]	[0.151]	[0.138]	[1.528]	[2.048]	[1.757]
$\Delta\frac{CF_{it-1}}{A_{it}}$		0.0398	0.1886		4.2760*	2.6486
		[0.319]	[0.499]		[2.534]	[2.440]
$\Delta\left(\tau_{it}\frac{CF_{it-1}}{A_{it}}\right)$			4.6879			13.4709
			[10.105]			[19.574]
Quarter× Year	Yes	Yes	Yes	Yes	Yes	Yes
Industry× Year	Yes	Yes	Yes	Yes	Yes	Yes
Region× Year	Yes	Yes	Yes	Yes	Yes	Yes
p-value of J-test	0.5567	0.4100	0.5146	0.2523	0.6309	0.3730
Observations		2310			3846	

Equation (10): $\Delta\frac{RD_{it}}{A_{it}}$	Small Firms			Large Firms		
	(7)	(8)	(9)	(10)	(11)	(12)
$\Delta\frac{X_{it}}{A_{it}}$	1.3168	0.8166***	5.3259*	14.0345**	12.2069	11.2110
	[0.919]	[0.251]	[2.988]	[7.127]	[7.495]	[7.404]
$\Delta\frac{Y_{it}}{A_{it}}$	0.0044**	0.0048***	0.0031**	0.0029	0.0039	0.0019
	[0.002]	[0.001]	[0.001]	[0.005]	[0.006]	[0.004]
$\Delta\frac{b_{it}}{A_{it}}$	0.0089	−0.0141***	−0.0029	0.2995*	0.2835	0.2222
	[0.018]	[0.005]	[0.010]	[0.166]	[0.183]	[0.154]
$\Delta\left(\frac{X_{it}}{A_{it}}\frac{b_{it}}{A_{it}}\right)$	−0.0566	0.1192***	0.1097***	−15.7011*	−14.1060	−10.5775*
	[0.152]	[0.018]	[0.041]	[9.149]	[9.053]	[6.175]
$\Delta\frac{CF_{it-1}}{A_{it}}$		0.0412***	0.0427*		0.2816	0.3270
		[0.012]	[0.024]		[0.217]	[0.200]
$\Delta\left(\frac{X_{it}}{A_{it}}\frac{CF_{it-1}}{A_{it}}\right)$			−5.3706			−6.0716
			[3.645]			[24.261]
Quarter× Year	Yes	Yes	Yes	Yes	Yes	Yes
Industry× Year	Yes	Yes	Yes	Yes	Yes	Yes
Region× Year	Yes	Yes	Yes	Yes	Yes	Yes
p-value of J-test	0.1533	0.3416	0.6560	0.65	0.7630	0.8389
Observations		4993			5179	

Notes. *** p<0.01, ** p<0.05, * p<0.1. For columns (1)-(6), instruments include $\Delta \ln Y_{it}$, τ_{it-2}, τ_{it-3}, $\frac{b_{it-2}}{A_{it-2}}$, $\frac{b_{it-3}}{A_{it-3}}$, $\tau_{it-2}\frac{b_{it-2}}{A_{it-2}}$, $\tau_{it-3}\frac{b_{it-3}}{A_{it-3}}$, the full set of year dummies, the full set of quarter, region, industry dummies and their interactions with year dummies. In addition, we include $\frac{CF_{it-3}}{A_{it-2}}$ and $\frac{CF_{it-4}}{A_{it-3}}$ as instruments for $\Delta\frac{CF_{it-1}}{A_{it}}$ in columns (2), (3), (5), and (6). We also include $\tau_{it-2}\frac{CF_{it-3}}{A_{it-2}}$ and $\tau_{it-3}\frac{CF_{it-4}}{A_{it-3}}$ as instruments for $\Delta\left(\tau_{it}\frac{CF_{it-1}}{A_{it}}\right)$ in columns (3) and (6). The instruments for columns (7)-(12) are similar to those for columns (1)-(6) except that we replace τ_{it-s} with $\frac{X_{it-s}}{A_{it-s}}$ for $s = 2$ and 3. Robust standard errors are in brackets.

Table 11: Counterfactual Experiments

The Change in the *Aggregate* R&D Expenditure				
	No Reform in 2003		No Cap in 2003	
	(1)	(2)	(3)	(4)
Counterfactual Experiments	$\tau_{it} = \hat{\tau}_{it}^{\text{inc}}$ $\tau_{it}\frac{b_{it}}{A_{it}} = \hat{\tau}_{it}^{\text{inc}}\frac{b_{it}}{A_{it}}$	$\tau_{it}\frac{b_{it}}{A_{it}} = \hat{\tau}_{it}^{\text{inc}}\frac{b_{it}}{A_{it}}$	$\tau_{it} = \hat{\tau}_{it}^{\text{nc}}$ $\tau_{it}\frac{b_{it}}{A_{it}} = \hat{\tau}_{it}^{\text{nc}}\frac{b_{it}}{A_{it}}$	$\tau_{it}\frac{b_{it}}{A_{it}} = \hat{\tau}_{it}^{\text{nc}}\frac{b_{it}}{A_{it}}$
Column (3) of Table 8	-3.4%	-0.6%	3.9%	0.8%
Counterfactual Experiments	$\frac{X_{it}}{A_{it}} = \frac{\hat{X}_{it}^{\text{inc}}}{A_{it}}$ $\frac{X_{it}}{A_{it}}\frac{b_{it}}{A_{it}} = \frac{\hat{X}_{it}^{\text{inc}}}{A_{it}}\frac{b_{it}}{A_{it}}$	$\frac{X_{it}}{A_{it}}\frac{b_{it}}{A_{it}} = \frac{\hat{X}_{it}^{\text{inc}}}{A_{it}}\frac{b_{it}}{A_{it}}$	$\frac{X_{it}}{A_{it}} = \frac{\hat{X}_{it}^{\text{nc}}}{A_{it}}$ $\frac{X_{it}}{A_{it}}\frac{b_{it}}{A_{it}} = \frac{\hat{X}_{it}^{\text{nc}}}{A_{it}}\frac{b_{it}}{A_{it}}$	$\frac{X_{it}}{A_{it}}\frac{b_{it}}{A_{it}} = \frac{\hat{X}_{it}^{\text{nc}}}{A_{it}}\frac{b_{it}}{A_{it}}$
Column (7) of Table 8	-3.0%	-0.3%	3.1%	0.3%

Figure 1: Manufacturing (weighted by sales)

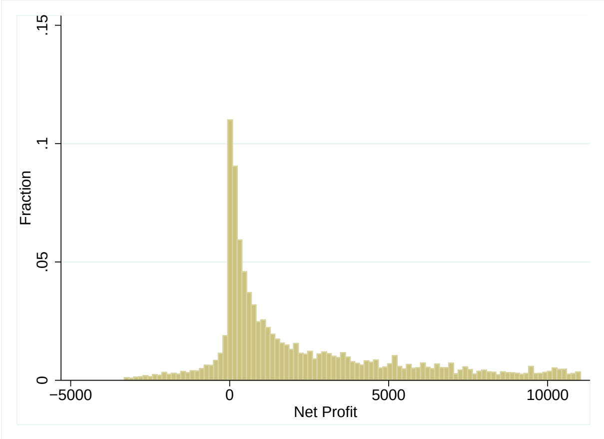


Figure 2: Benchmark (weighted by sales)

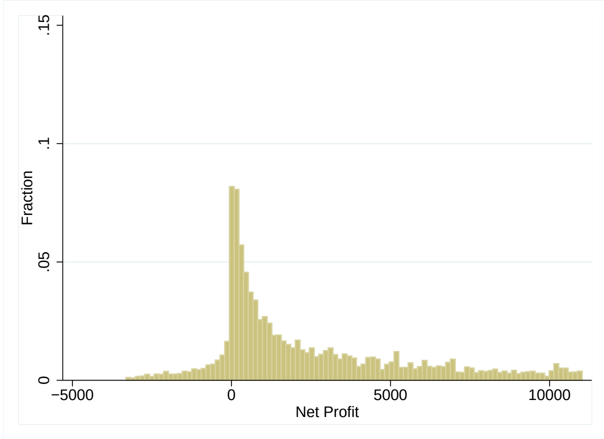


Figure 3: Level (2002)

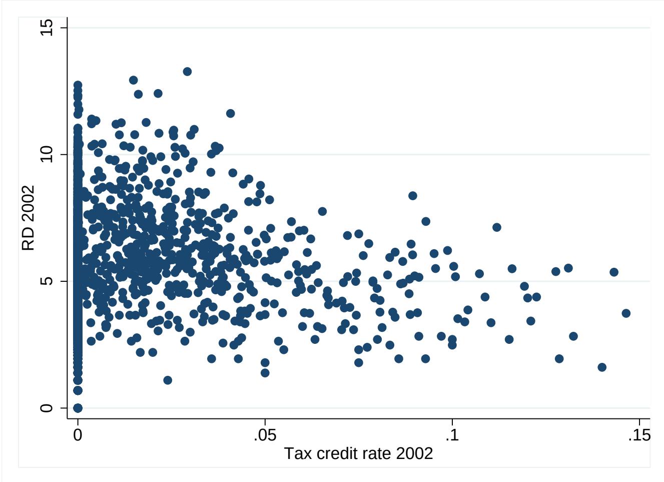


Figure 4: Level (2003)

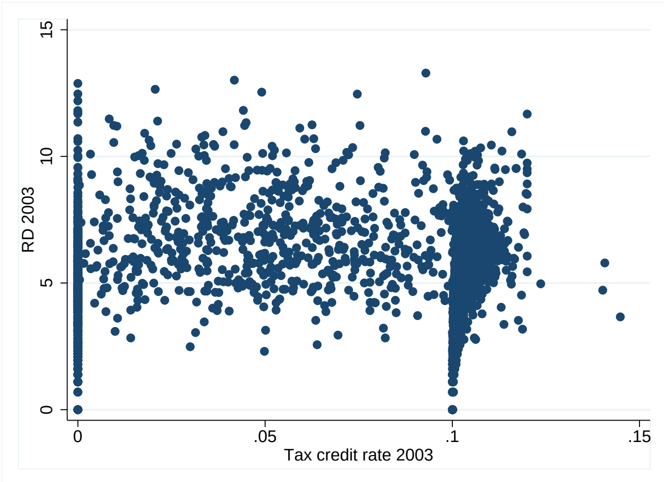


Figure 5: Difference (2002-2003, All)

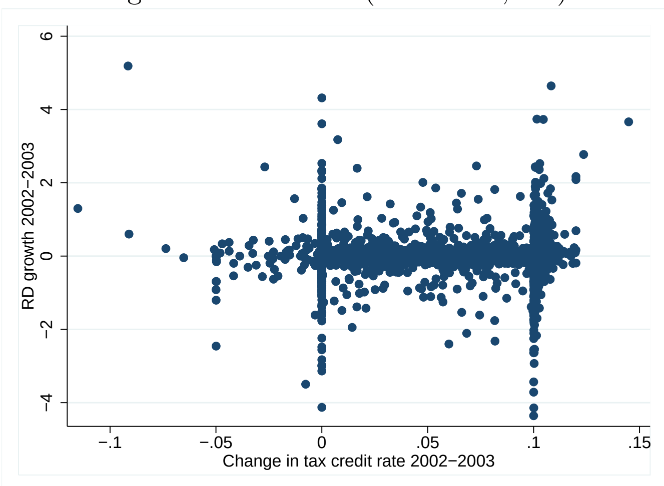


Figure 6: R&D Investment Decision for Low Value of I_{t-1}

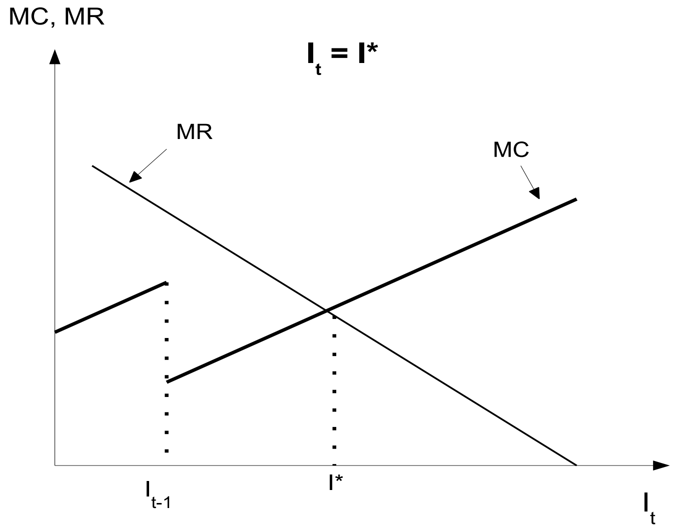


Figure 7: R&D Investment Decision for High Value of I_{t-1}

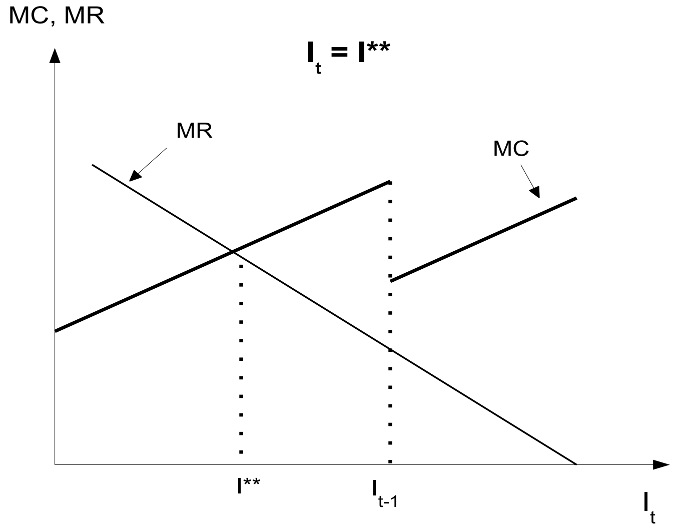
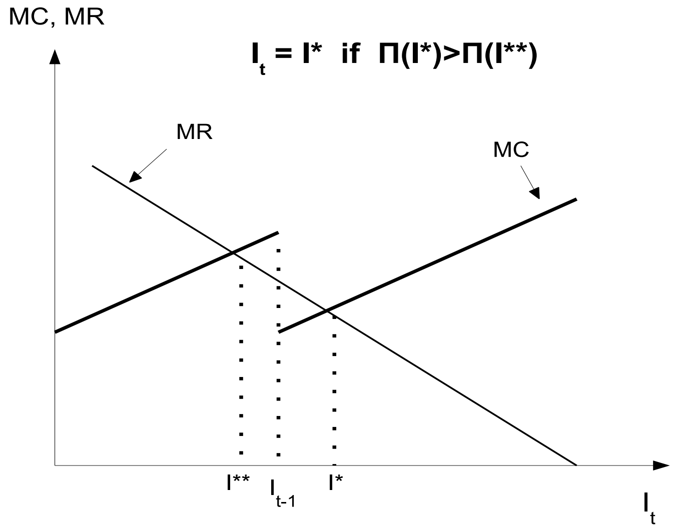


Figure 8: R&D Investment Decision when $I^{**} < I_{t-1} < I^{*}$



Appendix A: Data

This section explains how to construct the variables for our empirical analysis of the Basic Survey of Japanese Business Structure and Activities (BSJ) data.

A.1 R&D Expenditure

We use two different measures of R&D expenditure. For the dependent variable in our empirical analysis, our measure of R&D expenditure, denoted by RD_{it}, is the sum of own and outsourced research and development expenses. To construct eligible tax credit rate, we use the R&D expenditure for tax purposes, denote by RD_{it}^{tax}, computed as the sum of own and outsourced research and development expenses net of the amount received to conduct research projects that include subsidies from the government and the amount received for commissioned R&D projects.

A.2 Corporate Tax

We compute the following proxy for corporate tax using the BSJ data: $T_{it} = \tau_{it}^{tax}(\pi_{it}^{ord} - L_{it})$, where π_{it}^{ord} and L_{it} represent ordinary profit and accumulated tax losses of firm i in year t and τ_{it}^{tax} is the rate of corporate tax of firm i in year t. The corporate tax rate decreased in April 1998 from 0.375 to 0.345 and in April 1999 from 0.345 to 0.3. Thus, we set $\tau_{it}^{tax} = 0.375$ for firm's fiscal years starting after April 1, 1990 and before April 1, 1998, $\tau_{it}^{tax} = 0.345$ for firm's fiscal years starting after April 1, 1998 and before April 1, 1999, and $\tau_{it}^{tax} = 0.3$ for firm's fiscal years starting after April 1, 1999. Note that lower tax rates apply to taxable income up to 8 million yen for small and medium firms. However, the aspect of the corporate tax system is not relevant in our analysis because we focus on large firms.

Because of data limitation, we abstract from extraordinary gain and loss and tax deductions other than the loss carry provision. We compute L_{it} as follows. For each t, we first compute $\{L_{it}^{t-k}\}_{k=1}^{K_0}$ recursively as

$$L_{it}^{t-K_0} = \max\{-\pi_{i,t-K_0}^{ord}, 0\} \quad \text{and} \quad L_{it}^{t-k} = \max\{L_{it}^{t-k-1} - \pi_{i,t-k}^{ord}, 0\} \quad \text{for } k = 1, \ldots, K_0 - 1,$$

and we set $L_{it} = L_{it}^{t-1}$. Following the system of loss carry forward, we set K_0 to 5 for fiscal years starting before April 1, 2001, and to 7 for fiscal years starting after April 1, 2001.

A.2.1 Loss Carry Forward

As discussed above, the system of loss carry forward allows firms to deduct taxable income by accumulated past losses. For fiscal years starting before April 1, 2001, firms could use losses in the past 5 years. The Japanese government extended the period to 7 years for fiscal years starting after April 1, 2001, or ending before April 1, 2008, and to 9 years for fiscal years starting after April 1, 2008. If firms record loss in multiple years over the specified reference period, the loss in the earlier years is deducted first and the remaining amount is carried over to the next year.

A.2.2 Validity of Our Proxy for Tax

We examine the validity of our proxy T_{it} by using the Development Bank of Japan data (the DBJ data set, hereafter), where total tax paid, the sum of corporate tax, corporate residents' tax, and business tax net of deductions, is recorded.[24] For firms in the DBJ data set, we constructed our proxy T_{it} as $T_{it} = 0.4(\pi_{it}^{ord} - L_{it})$ and compare it with reported tax data. The fraction 0.4 is the effective tax rate. For 1998-2005, the correlation between reported tax and our proxy is significant and high at 0.92.

A.3 Debt (b_{it})

We use the book value of total debt, which is the sum of short- and long-term debts.

A.4 Capital Stock (A_{it})

We construct data on the nominal value of the beginning-of-period capital stock (A_{it}) by the perpetual inventory method. For capital stock, we use data on the total tangible fixed asset consisting of building, structure, machinery, transportation equipment, and land, which is the only variable consistently available over the sample period in the BSJ data. The detailed procedure of the perpetual inventory method is as follows. First, we compute nominal investment (I_{it}) by $I_{it} = A_{it}^{book} - A_{it-1}^{book} + AD_{it}$, where A_{it}^{book} represents the book value of the tangible fixed asset at the end of period t, and AD_{it} represents accounting depreciation on the tangible fixed asset in period t. Second, we deflate the nominal investment data by the Corporate Goods Price Index (CGPI) for capital goods. Third, we construct data on the real capital stock series by $A_{it}^{real} = (1 - \delta)A_{it-1}^{real} + I_{it}^{real}$, where δ represents the depreciation rate and I_{it}^{real} and A_{it}^{real} represent real investment and real capital stock at the end of the period, respectively. For the initial value of capital stock, we take data on the deflated book value of the fixed asset at the end of 1994 (or in the year of the firm's first appearance in the BSJ survey).[25] We set δ to 0.05, which is the weighted average of the depreciation rates of the fixed assets with the share of each asset as weight. The depreciation rates for tangible fixed assets are taken from Hayashi and Inoue (1991). Because the BSJ survey does not provide data on tangible fixed assets at its component level, we compute the share of each fixed asset using other corporate finance data compiled by the Development Bank of Japan (DBJ). Finally, we compute the nominal value of

[24]The DBJ dataset contains detailed data on financial statements for non-financial publicly traded Japanese firms. Note, however, that the DBJ data set is not suitable for examining the effect of R&D tax credits because it contains very limited information on firms' R&D expenditures.

[25]Recall that the BSJ survey has been conducted yearly since 1995.

the capital stock using, again, the CGPI for capital goods and refer to the end-of-period capital stock in period $t-1$ as the beginning-of-period capital stock in period t.

Because of differences between accounting and physical depreciation, the book value of capital stock in 1995 is likely to be lower than the nominal value of the corresponding capital stock, thus understating the initial capital stock in the perpetual inventory method. In fact, with the constructed data on A_{it}, the mean and median debt-asset ratios (b_{it}/A_{it}) are much larger than those for a similar sample of the large manufacturing firms in the DBJ data: the mean and median b_{it}/A_{it} are 4.14 and 1.63 in the BSJ data for 1998-2005, while they are 1.03 and 0.36 in the DBJ data, respectively. Note that the DBJ data set provides a more reliable estimate of the capital stock because it starts in 1969.[26] To correct the undervaluation in the BSJ data, we multiply the book value of capital stock by 5 so that the mean and median debt-asset ratios in the BSJ data become comparable to those in the DBJ data. With this adjustment, the mean and the median debt-asset ratios become 1.14 and 0.49, respectively.

[26]The DBJ data are available from 1956. However, detailed data on accounting depreciation were not available until 1969.