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Does an R&D Tax Credit Affect R&D Expenditure? The Japanese Tax Credit Reform in 2003*

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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 the 2003 Japanese tax credit reform on firms' R&D investment by exploiting cross-sectional variation across firms in the changes in the effective tax credit rate between 2002 and 2003. When we use the benchmark sample to estimate the first-difference equation between 2002 and 2003, our estimate for the elasticity of R&D investment with respect to the effective tax credit rate is 2.05% with a standard error of 0.60, and the estimated effect of the R&D tax credit on R&D investment is significantly larger for small firms with relatively large outstanding debts. When we use different methods and different samples, we find mixed evidence for the positive effect of the R&D tax credit, but an interaction term between the effective tax credit rate and the debt-to-asset ratio is always estimated to be significant for small firms, providing robust evidence for the role of financial constraint in determining the effect of the R&D tax credit.

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 effective 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 accounting 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 effective 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 effective tax credit rate between 2002 and 2003, while the effective 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 effective tax credit rate across firms to identify

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

the extent to which a tax credit affects firms' R&D expenditure.

Focusing on the details of the R&D tax policy changes in Japan, we use the cross-sectional variation across firms in the changes in the effective tax credit rate between 2002 and 2003 to estimate the elasticity of R&D expenditure with respect to the effective 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 effective tax credit rate and the measure of financial constraints. The model is estimated by using firm-level panel data from the *Basic Survey of Japanese Business Structure and Activities* with a proxy we construct for the effective 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 either 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 the financial constraint is binding, preventing a firm from raising external funds for R&D, an increase in the tax credit may increase the available internal funds in a one-to-one manner and thus substantially increase R&D investment.

The baseline regression result suggests a significantly positive effect of the change in the effective tax credit rate on corporate R&D investment. Estimating the first-difference equation of the linear R&D model between 2002 and 2003 by the Ordinary Least Squares (OLS) method using the benchmark sample, we estimate the elasticities of the effective tax credit rate on R&D investment at 2.05% with a standard error of 0.60. When we estimate the R&D investment equation with an interaction term between the effective tax credit rate and the debt-to-asset ratio as an additional regressor, 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 a significant positive effect of the tax credit on R&D investment for small firms with high debt-to-asset ratios, but we find no evidence for a positive effect of the tax credit on 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 are large firms. Using the baseline estimate, we find that the aggregate value of R&D expenditure would have been lower by 18.40% if the incremental tax credit system had been implemented in 2003, suggesting a substantial impact of the Japanese tax credit reform on R&D expenditure.

To further examine the effect of the tax credit on R&D investment, we estimate a linear R&D investment model using different samples and different methods. First, to address a potential sample selection issue, we estimate the R&D investment model together with a probit selection equation using the Heckman two-step method. Second, to control for the endogeneity issue, we estimate the first-difference equation by the generalized method of moments (GMM). Third, we use the panel data from 2000 to 2003. Finally, we examine the effect of the tax credit on R&D investment using an alternative measure of the effective tax credit rate that takes into account the cap on the tax credit and the possibility of a deferred tax credit. In some cases, the elasticities of the effective tax credit rate on R&D investment are estimated to be insignificant, providing mixed evidence for the positive effect of the tax credit on R&D investment. Conversely, across different methods, an interaction term between the effective tax credit rate and the debt-to-asset ratio is always estimated to be significant for small firms, and thus, we find robust evidence for the importance of financial constraints in determining the effect of an R&D tax credit.

The remainder of this paper is organized as follows. Section 2 reviews the related literature. Section 3 explains the 2003 Japanese tax credit reform in detail. Section 4 explains our data source and presents summary statistics. 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.

2 Literature Review

The effectiveness of the R&D tax credit has recently attracted considerable attention and been studied extensively. The overall results suggest that the elasticity of R&D with respect to price is approximately 1. In other words, 1 yen in tax credit for R&D stimulates approximately 1 yen of additional R&D. 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% decrease in the cost of R&D stimulates a 1.44% increase in R&D in the short-run, and approximately a 10.1% 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 dataset from 2001 to 2005. Propensity score matching reveals that, on average, recipients of the R&D tax credit have a 93.53% higher R&D expenditure and a 14.47% 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 $r_{it} = \log(\text{corporate R\&D investment})$, $y_{it} = \log(\text{sales})$ and 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. The coefficient of lagged r_{it} is reported to be insignificant.

Ohnishi and Nagata (2010) investigate the effect of the 2003 R&D tax credit reform using a dataset of 485 firms from the Report on the Survey of Research and Development (*Kagaku gijutu kenkyuu chousa*) by the Ministry of Internal Affairs and Communications. Using propensity score matching, Ohnishi and Nagata (2010) 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%, whereas those that did not use the new tax credit system decreased their R&D expenditure by 0.9%. Ohnishi and Nagata (2010) conclude that the increases in the R&D expenditures of these two groups of firms are essentially the same. The dataset of Ohnishi and Nagata (2010) is peculiar. The firms are restricted to the respondents of Kagaku Gijyutu Kenkyuu Chyosa, which may induce a sample-selection bias. Furthermore, in their data set Ohnishi and Nagata (2010) observe little overall change in the R&D expenditure between 2002 and 2003, whereas in our dataset the R&D expenditure increases more than 5% between 2002 and 2003.

Motohashi (2010) combines firm-specific panel data over the period 1983 to 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:

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

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 $(= \beta_1 + \beta_2)$ 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% of additional equity funds in R&D.

3 R&D tax credit reform in 2003

This section describes the 2003 reform of the Japanese R&D tax credit system.[2] We measure the effective tax credit rate for firm i in period t, denoted by τ_{it}, as

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

where RD_{it} denotes the R&D expenditure of firm i in period t and X_{it} denotes the amount of tax credit[3]. 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 tax reform.

We first explain the tax credit prior to 2002 (before the reform). Prior to 2002, the Japanese R&D tax policy was characterized by the *incremental tax credit system*. We denote the average of firm i's three largest yearly R&D expenditures over the previous five years by $\overline{RD}_{it}$. Let T_{it} denote the amount of the corporate tax that firm i owes in year t. Then, the R&D tax credit in 2002 is computed as

$$X_{i2002} = \begin{cases} X^*_{i2002} & \text{if } 0.12T_{i2002} \geq X^*_{i2002} \\ 0.12T_{i2002} & \text{if } 0.12T_{i2002} < X^*_{i2002}, \end{cases} \tag{2}$$

where

$$X^*_{i2002} = 0.15\max\{RD_{i2002} - \overline{RD}_{i2002}, 0\}\mathbb{I}(RD_{i2002} > \max\{RD_{i2001}, RD_{i2000}\})$$

and $\mathbb{I}(x > y)$ represents an indicator function. When $RD_{i2002} \leq \overline{RD}_{i2002}$ or the R&D expenditure in 2002 is smaller than the last two years R&D expenditures, a firm receives no tax credit; otherwise, the tax credit amount is roughly proportional to the difference between the current R&D expenditure and the previous R&D expenditure ($RD_{i2002} - \overline{RD}_{i2002}$). 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% of the total amount of R&D expenditure as tax credit.

[2] 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 dataset. 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.

[3] The Japanese R&D tax credit system defines R&D expenditure 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. This definition of R&D expenditure is used to compute the tax credit in our data.

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 to 12% of the R&D expenditure, regardless of previous R&D expenditures. Note that from 2003 to 2005, firms were able to choose between the old incremental tax credit system and the new total tax credit system. The R&D tax credit under the total tax credit system, denoted by X_{i2003}, is computed as

$$X_{i2003} = \begin{cases} X^*_{i2003} & \text{if } 0.20T_{i2003} \geq X^*_{i2003} \\ 0.20T_{i2003} & \text{if } 0.20T_{i2003} < X^*_{i2003}. \end{cases} \tag{3}$$

where $X^*_{i2003} = \kappa(RD_{i2003}/\overline{Y}_{i2003})RD_{i2003}$ with $\kappa(x) = (0.2x + 0.1)\mathbb{I}(x < 0.1) + 0.12\mathbb{I}(x \geq 0.1)$, and $\overline{Y}_{it} = \sum_{s=0}^{3} Y_{it-s}/4$.

We compute the effective tax credit rate using data from the Basic Survey of Japanese Business Structure and Activities, following the formulas described above.[4]. Table 1 reports the mean and the standard deviation of the changes in our measure of the effective tax credit rate, $\Delta\tau_{it} = \tau_{it} - \tau_{it-1}$, across firms for each year from 2000 to 2005. Looking at the years 2002 and 2003, we notice that the average effective tax credit rate increased by 9.27% between 2002 and 2003, indicating the substantial impact of the 2003 tax credit reform on the average effective tax credit rate.[5] In contrast, the average change in the effective tax credit rate is close to zero for years other than 2002 and 2003.

Figures 1 and 2 plot a relationship between the log of R&D expenditure and the effective tax credit rate across firms in 2002 and 2003, respectively, while Figure 3 plots a change in the log of R&D expenditure against the change in the effective tax credit rate between 2002 and 2003. As shown in Figure 1, 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 become eligible for the tax credit in 2003. As shown in Figure 2, all R&D firms are eligible for at least 10% of the effective tax rate in 2003. Thus, the changes in the effective tax rates across different firms between 2002 and 2003 exhibit a large variation. In Figure 3, a group of firms have $\Delta\tau_{2003}$ values between 0.10 and 0.15; many of these firms were not eligible for any tax credit in 2002.[6] On average, firms without any tax credit in 2002 experience a 10.5% increase in the effective tax credit rate, while firms with positive tax credit in 2002 experience a 6.0% increase.

Because the tax credit crucially depended on previous R&D expenditures in the incremental tax system, the introduction of the total tax credit system in 2003 induced heterogeneous

[4]For details on how to compute the effective tax credit rate for our data, see Appendix A.2

[5]Using data from the Corporation Sample Survey conducted by the National Tax Agency, Ohnishi 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.

[6]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.

changes in the effective tax credit rate across firms. Those firms that conducted large R&D investment before 2002 gained a large benefit from the 2003 tax reform, while those who did not conduct R&D investment before 2002 gained little. As Table 2 reports, comparing across different quartiles of the previous R&D expenditure $\overline{RD}_{i2002}$, we find that the higher the R&D expenditure was before 2002, the larger the increase in the effective tax credit rate between 2002 and 2003. This cross-sectional variation in the changes in the effective tax credit rate before and after the tax reform enables us to identify the effect of the tax credit on R&D expenditure.

Table 3 shows the average effective tax credit rate 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 effective tax credit rate decreases with the years of R&D experience from 0.15 to 0.01. To explain, consider an example 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 of 15% of its 2000 R&D expenditure as long as that expenditure is below the corporate tax owed by the firm. In 2001, this firm faces an effective tax credit rate lower than 15% because now the previous R&D expenditure is no longer zero. Thus, under the incremental tax system, the effective tax credit rate tends to decrease over time for the first three years of R&D activity.

4 Data

4.1 Data Source

We use data from the *Basic Survey of Japanese Business Structure and Activities* (BSJ, hereafter) conducted by the Ministry of Economy, Trade and Industry (METI). This survey 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 exports/imports and 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 accounting 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.[7]

4.2 Sample Selection and Summary Statistics

We focus our attention on manufacturing firms. Furthermore, we select our sample as described in Table 4. Fist, to focus on large firms, we exclude observations of firms with asset values

[7] For example, the response rate for the 2010 survey was 83.8%.

smaller than or equal to 100 million yen. Because small or medium firms can choose between the R&D 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 2005, the fraction of the aggregate R&D investment explained by these small/medium firms is small, only 1.2% for the manufacturing industry.

Second, we only consider firms whose accounting year closes in March. The new total tax credit system became available for the accounting year that began after January 2003. Because the BSJ survey was conducted in June until 2007, in the 2004 BSJ survey any firm whose accounting year closes *before June* would report the data for the 2003 accounting year, and thus, the new total tax credit system would apply to the accounting year of the 2004 survey. In contrast, any firm whose accounting year closes *after June* would report the data for the 2002 accounting year so that the old incremental tax credit system still applied. By tracking which accounting years close in March, we keep the former groups of the firms in the sample; a majority of Japanese firms close their accounting years in March.

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.

Tables 1- 3 are constructed from the sample that is obtained by applying these three criteria. Table 5 reports summary statistics for this sample from 2001 to 2004. 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. Rows designated as 'R&D Exp./Y' and 'R&D Exp./N' report the averages of the ratio of R&D expenditure to sales and that to the number of employees, respectively. For those rows, the sample is restricted to the observations with strictly positive R&D expenditures. 'Asset' refers to the sum of liquid and fixed assets. 'Debt' refers to the sum of liquid and fixed debts. 'Positive R&D' refers to the fraction of observations with strictly positive R&D expenditures.

For the basic regression analysis using the sample observations from 2002 and 2003, we further exclude the observations for which R&D expenditures are missing or zero as well as the observations for which some variables that are necessary to compute the effective tax credit rate are missing. When we estimate the regression equation with the debt-to-asset ratio as an additional regressor, we use a sample that excludes the observations for which the debt-to-asset ratio is missing in either 2002 or 2003.

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 $[\underline{z}(z_t), \bar{z}(z_t)]$, 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 4 to 6 illustrate how the amount of R&D expenditure is determined under the incremental tax credit system. In Figure 4, 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 5, 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 6 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.[8]

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% 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

[8] 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.

investment by 15% 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 effective tax credit rate in 2003. In contrast, the effective tax credit rate does not change before and after the 2003 tax reform (given at 15%) for the firms without any R&D investment from 1997 to 2001. We exploit this variation in the effective 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.

Consider a firm with state (b_t, K_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. The real interest rate is denoted by r. In the second period $t+1$, this firm is forced to sell itself after obtaining the profit.

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

$$d_t = (1-\xi)\pi(K_t, z_t) - \psi(I_t, K_t) + \varphi_t(I_t, I_{t-1}) - b_t + b_{t+1}/(1+r). \quad (4)$$

We assume that the firm faces financial constraint such that the maximum amount of bond it can issue is limited by the amount it can repay without any possibility of default. This restriction requires that the maximum amount of borrowing be less than the worst possible profit plus the resale value of firm in the second period:

$$b_{t+1} \leq (1-\xi)\pi(K_{t+1}, \underline{z}(z_t)) + pK_{t+1}.$$

Furthermore, we assume that a firm cannot raise funds by issuing equity: $d_t \geq 0$.[9] Then, the firm's investment problem in the first period t is given by

$$\begin{aligned}
\Pi(b_t, K_t, z_t, I_{t-1}) \quad &= \quad \max_{b_{t+1}, I_t} \; d(K_t, I_t, I_{t-1}, z_t, b_t, b_{t+1}) + \frac{1}{1+r} E[(1-\xi)\pi(K_{t+1}, z_{t+1}) + pK_{t+1} | z_t] \quad (5) \\
\text{s.t.} \quad & \quad b_{t+1} \leq (1-\xi)\pi(K_{t+1}, \underline{z}(z_t)) + pK_{t+1}, \\
& \quad d(K_t, I_t, I_{t-1}, z_t, b_t, b_{t+1}) \geq 0.
\end{aligned}$$

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

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 budget constraint in the firm's R&D investment problem (5). 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. The larger the amount of R&D investment before the tax reform is, the larger the effect of tax reform on the current year's investment.

The essence of this argument can be understood by considering the extreme case of $\pi(K_{t+1}, \underline{z}(z_t)) = 0$ and $p = 0$. The assumption that $\pi(K_{t+1}, \underline{z}(z_t)) = 0$ implies that a firm might earn zero profit with some positive probability, and $p = 0$ implies that the resale value of R&D capital is zero. In this case, the financial constraint is given by $b_{t+1} \leq 0$ so that borrowing is impossible. Because equity financing is also assumed to be restricted, the maximum amount of R&D expenditure a firm can possibly finance is limited by the internal cash flow. Specifically, the constraint $d(K_t, I_t, I_{t-1}, z_t, b_t, b_{t+1}) \geq 0$ implies that

$$I_t \leq \bar{I}(z_t, K_t, I_{t-1}, b_t),$$

where $\bar{I}(z_t, K_t, I_{t-1}, b_t)$ is defined by $(1-\xi)\pi(K_t, z_t) - \psi(\bar{I}(z_t, K_t, I_{t-1}, b_t), K_t) + \varphi_t(\bar{I}(z_t, K_t, I_{t-1}, b_t), I_{t-1}) - b_t = 0$. When the optimal R&D expenditure under no financial constraint discussed in the previous section is higher than $\bar{I}(z_t, K_t, I_{t-1}, b_t)$, the financial constraint is binding, and the R&D expenditure under financial constraint is $\bar{I}(z_t, K_t, I_{t-1}, b_t)$. Because $\bar{I}(z_t, K_t, I_{t-1}, b_t)$ is decreasing in the amount of debt b_t and the previous R&D expenditure I_{t-1}, the R&D expenditure I_t is decreasing in b_t and I_{t-1} when the constraint is binding.

The 2003 tax credit reform increases the internal cash flow by $0.15I_{t-1}$, and the reform may thus increase the R&D expenditure of financially constrained firms by as much as $0.15I_{t-1}$. The model implies that the larger the amount of debt b_t, the more likely the firm is to be financially constrained. Therefore, we expect that the effect of the tax credit reform in 2003 through a change in the effective tax credit rate would be increasing in the amount of debt b_t. This implication is tested in our empirical analysis by including the interaction term between the debt-to-asset ratio and the effective tax credit rate in our specifications.

6 Empirical Analysis

To examine the tax credit effect on R&D investment, we estimate linear investment models using the BSJ data. Our baseline model follows that of Bloom, Griffith, and Van Reenen (2002) and is given by

$$\ln RD_{it} = \beta\tau_{it} + \gamma \ln Y_{it} + \eta_t + \mu_i + \epsilon_{it}, \tag{6}$$

where RD_{it} is firm i's R&D expenditure in year t, τ_{it} is the effective rate of the R&D tax credit for firm i's R&D expenditure in year t, and Y_{it} is the sales of firm i in year t. 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 is the sum of own and outsourced research and development expenses. Following the tax credit formulas described in Section 3, we construct a measure for the effective tax credit rate, τ_{it}, defined by (1) using the BSJ data on R&D expenditure and sales. As explained in Appendix A.2, there are two omissions due to a lack of information in the BSJ data. First, for the benchmark analysis, we do not take into account that the credit is capped by a certain fraction (12 to 20%) of the corporate tax.[10] Second, we do not distinguish special experimental research expenses from other types of R&D expenditure.

To control for endogeneity due to the firm-specific effects μ_i, we take the first difference of (6) to obtain

$$\Delta \ln RD_{it} = \beta \Delta \tau_{it} + \gamma \Delta \ln Y_{it} + \Delta \eta_t + \Delta \epsilon_{it}. \tag{7}$$

This expression is our basic econometric specification.

As we discussed in the previous section, the shift from the incremental to the total tax credit system in 2003 may increase R&D investment for financially constrained firms with insufficient internal funds. To examine whether the financial constraint affects R&D investment, we incorporate into the above model a debt-to-asset ratio that partially accounts for the cross-sectional variation in firms' internal funds. Specifically, we include the level of a debt-to-asset ratio and its interaction with the effective tax credit rate in equation (6) as

$$\ln RD_{it} = \beta \tau_{it} + \gamma \ln Y_{it} + \delta \frac{b_{it}}{K_{it}} + \theta \tau_{it} \frac{b_{it}}{K_{it}} + \eta_t + \mu_i + \epsilon_{it}. \tag{8}$$

where b_{it} and K_{it} represent firm i's outstanding debt and fixed assets in the beginning of year t, respectively. 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 K_{it}, as explained in Appendix A.3-A.4. We estimate the first-difference version of (8):

$$\Delta \ln RD_{it} = \beta \Delta \tau_{it} + \gamma \Delta \ln Y_{it} + \delta \Delta \left(\frac{b_{it}}{K_{it}} \right) + \theta \Delta \left(\tau_{it} \frac{b_{it}}{K_{it}} \right) + \Delta \eta_t + \Delta \epsilon_{it}. \tag{9}$$

The positive value of θ implies that the effect of the 2003 tax credit reform 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.

We first estimate the first-difference equations (7) and (9), respectively, by the OLS using the

[10] A deferred tax credit was introduced in 2003 so that, even when the credit cap was binding in 2003, firms were able to reclaim the remaining amount above the credit cap in the following year.

benchmark sample with strictly positive values of R&D expenditure in 2002 and 2003. The result is reported in columns (1) and (2) of Table 6. In column (1), the estimated elasticity of R&D expenditure with respect to the effective tax credit rate is 2.05% with a standard error of 0.60. Estimating the first-difference equation with the debt-to-asset ratio (9), we obtain a significantly positive estimate of the coefficient of $\Delta\tau_{it}$ (2.02, in column (2)), while the estimated coefficient of $\Delta(b_{it}/K_{it})$ is insignificantly negative. Conversely, the estimated coefficient of the interaction term $\Delta(\tau_{it}b_{it}/K_{it})$ is significantly positive, indicating that the positive effect of the 2003 tax credit reform 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. As reported in Table 7, the tax credit elasticities depend on the value of the debt-to-asset ratio, and they are estimated to be 2.06, 2.10, and 2.31 at the 5th percentile, median, and 95th percentile of the debt-to-asset ratio, respectively.

How large was the effect of the change from the incremental to the total tax credit system on R&D expenditure in 2003? Based on the estimate in column (2) of Table 6, we compute the counterfactual value of aggregate R&D expenditure in 2003 if the incremental tax credit system were to have been implemented in 2003. The results are reported in Table 8.[11] The "Aggregate" row indicates that had the total tax credit system not been introduced in 2003, the aggregate value of R&D expenditure would have been lower by 18.40 percent. Conversely, the "Average," "Average ($b_{it}/K_{it} \leq p10$)," and "Average ($b_{it}/K_{it} \geq p90$)" rows report that, had the incremental tax credit system been implemented in 2003, the average value of R&D expenditure would have been lower by 18.06 percent, 17.91 percent, and 19.33% for the sample used in column (2) of Table 6, for the subsample with a debt-to-asset ratio smaller than its 10th percentile value, and for the subsample with a debt-to-asset ratio greater than its 90th percentile, respectively. These decreases indicate that the introduction of the total tax credit system had a larger impact on firms with high debt-to-asset ratios than firms with low debt-to-asset ratios.

Columns (3) to (6) of Table 6 compare the effects of the effective tax credit rate on R&D expenditure for small and large firms. When small firms are more likely than large firms to face financial constraint for their R&D expenditures, the effect of the tax credit is expected to be larger for small firms than for large firms. To address this difference, we split the benchmark

[11]To obtain the estimates reported in Table 8, we first compute the counterfactual value of the effective tax credit rate in 2003 for each firm using the formula for the incremental tax credit system as described in Appendix A.2. Then, with this counterfactual value of the effective tax credit rate, we compute the counterfactual value of firms' R&D expenditure in 2003 predicted by the estimate in column (2) of Table 6 when the incremental tax credit system had been implemented. Finally, this counterfactual value of firms' R&D expenditure in 2003 under the incremental tax credit system is compared with the value of the firms' R&D expenditure under the total tax credit system in 2003 predicted by the estimate in column (2) of Table 6. The "Aggregate" row reports a percentage difference in the sum of the predicted R&D expenditure under the total tax credit system and the sum of the predicted R&D expenditure under the incremental tax credit system across all firms in 2003. The "Average," "Average ($b_{it}/K_{it} \leq p10$)," and "Average ($b_{it}/K_{it} \geq p90$)" rows report the average percentage difference between the predicted R&D expenditure under the total tax credit system and those under the incremental tax credit system for the sample used in column (2) of Table 6, that for the subsample with b_{it}/K_{it} smaller than its 10th percentile value, and that for the subsample with b_{it}/K_{it} greater than its 90th percentile, respectively.

sample at the median value of the fixed asset in 2003 and estimate equations (7) and (9) separately for each sample. Columns (3) and (4) report the results for small firms, and columns (5) and (6) report the results for large firms. The coefficients of $\Delta\tau_{it}$ are significantly positive at 2.92 and 2.81 in columns (3) and (4), but they are insignificantly positive in columns (5) and (6). Furthermore, the estimated coefficient of $\Delta(\tau_{it}b_{it}/K_{it})$ is significant with the expected sign in column (4), but it is not significant in column (6). Thus, we find evidence for the positive effect of the 2003 tax credit reform on R&D expenditure among small firms with high debt-to-asset ratios but no evidence for the effect of the tax credit among large firms.

The result reported in Table 6 is based on the observations with strictly positive values of R&D expenditure in 2002 and 2003. We restrict the data in such a way because the dependent variable is the logarithm of R&D expenditure and so cannot assume zero R&D expenditure values. The omission of observations with zero R&D expenditure may lead to sample selection bias. To control for selection bias, we consider a probit selection equation:

$$s_i = \begin{cases} 0 & \text{if } Z_i'\psi + v_i \leq 0, \\ 1 & \text{if } Z_i'\psi + v_i > 0, \end{cases} \tag{10}$$

where s_i is a selection indicator equal to 1 if $RD_{it} > 0$ for both $t = 2002$ and $t = 2003$ and equal to 0 otherwise. Following Heckman (1979), we first estimate a probit equation (10) to obtain an estimate of ψ, denoted by $\hat{\psi}$, and compute $\hat{\lambda}_i \equiv \lambda(Z_i'\hat{\psi}) = E[v_i|Z_i, v_i > -Z_i'\hat{\psi}]$, where $\lambda(\cdot)$ is the inverse Mill's ratio; in the second step, we estimate the parameters in (7) and (9) by the OLS with $\hat{\lambda}_i$ as an additional regressor. The presence of selection bias can be tested by examining whether the coefficient of $\hat{\lambda}_i$ is significantly different from zero. We choose $Z_i = (1, \ln Y_{i2002}, \ln Y_{i2003}, \mathbb{I}(RD_{i2000} > 0), \mathbb{I}(RD_{i2001} > 0))'$ to estimate (7) and $Z_i = (1, \ln Y_{i2002}, \ln Y_{i2003}, b_{i2002}/K_{i2002}, b_{i2003}/K_{i2003}, \mathbb{I}(RD_{i2000} > 0), \mathbb{I}(RD_{i2001} > 0))'$ to estimate (9). Appendix Appendix B discusses in detail the motivation for our choice of Z_i and the required assumption for consistency under endogenous sample selection.

Table 9 reports the results of estimating equations (7) and (9) with the probit selection equation (10) using Heckman's two step method.[12] For the benchmark sample and for the sample of large firms, the coefficient of $\hat{\lambda}_i$ is significantly positive, providing evidence for sample selection. Comparing the estimates in Table 9 with those in Table 6, we notice that the estimated effect of the effective tax credit rate on R&D expenditure becomes larger after controlling for selection, while the estimated coefficients of $\Delta(b_{it}/K_{it})$ and $\Delta(\tau_{it}b_{it}/K_{it})$ remain roughly the same before and after controlling for selection. The estimated coefficient of $\Delta(b_{it}/K_{it})$ is significantly negative, and thus, an increase in the debt-to-asset ratio is positively correlated with a decline in R&D expenditure between 2002 and 2003; one possible reason for this correlation is that a

[12] To save space, we do not report the estimates of the probit selection equation, but they are summarized as follows: across different samples and different specifications, the coefficients of $\mathbb{I}(RD_{i2000} > 0)$ and $\mathbb{I}(RD_{i2001} > 0)$ are significantly positive, while the coefficients of other variables are insignificant.

firm with a higher debt-to-asset ratio faces a tighter financial constraint for R&D investment. Furthermore, in columns (5) and (6) of Table 9, the estimated coefficient of $\Delta\tau_{it}$ is now significantly positive, suggesting a positive effect of the tax credit on R&D expenditure for large firms. Conversely, the estimated coefficient of $\Delta(\tau_{it}b_{it}/K_{it})$ remains insignificant in column (6), and we continue to find no evidence for the importance of financial constraint among large firms.[13]

The validity of OLS regression analysis based on the first-difference specifications (7) and (9) depends on the assumption that the tax credit change, $\Delta\tau_{it}$, is uncorrelated with the change in the unobserved determinants of R&D expenditure, $\Delta\epsilon_{it}$. As shown in Figure 2, the effective tax credit rate τ_{it} is positively correlated with the R&D expenditure in 2003, suggesting that the effective tax credit rate, τ_{it}, and unobserved determinants of R&D expenditure, $\mu_i + \epsilon_{it}$ in equations (6) and (8), may be positively correlated. While taking the first difference between 2002 and 2003 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 $\Delta\epsilon_{it}$ and may lead to the endogeneity bias.

To address this endogeneity issue, we estimate the first-difference equations (7) and (9) by the two-step GMM. We use the two- and three-year lagged values of the effective tax credit rate, τ_{it-2} and τ_{it-3}, and the two-year lagged value of the ratio of the "past average R&D expenditure" to capital stock, $\overline{RD}_{it-2}/K_{it-2}$, as instruments for $\Delta\tau_{it}$ to estimate the equation (7), where $\overline{RD}_{it}$ is defined in Section 3. Furthermore, we use τ_{it-2}, τ_{it-3}, $\overline{RD}_{it-2}/K_{it-2}$, $\tau_{it-2}(b_{it-2}/K_{it-2})$, and $(\overline{RD}_{it-2}/K_{it-2})(b_{it-2}/K_{it-2})$ as instruments for $\Delta\tau_{it}$ and $\Delta(\tau_{it}(b_{it}/K_{it}))$ to estimate the equation (9). Our choice of instruments is motivated by their ability to predict the value of τ_{it-1} while we will examine the validity of moment conditions by an over-identifying restriction test.[14]

The result of the GMM estimation is reported in Table 10. The p-value of Hansen's J test provides evidence for the validity of the moment conditions across different specifications using different samples. While the estimated coefficient of $\Delta\tau_{it}$ is not significant, the estimated coefficient of $\Delta(\tau_{it}(b_{it}/K_{it}))$ is significant and positive in columns (2) and (4), providing evidence for the importance of financial constraint as a determinant of the effect of the tax credit on R&D expenditure among small firms. As reported in columns (5) and (6), neither the coefficient of $\Delta\tau_{it}$ nor that of $\Delta(\tau_{it}(b_{it}/K_{it}))$ is significant for large firms.[15]

[13]As a robustness check, to minimize the functional form assumption on the probit selection equation, we also estimated (7) and (9) with the probit selection equation (10) using the quadratic and interaction terms of $(\ln Y_{i2002}, \ln Y_{i2003}, \mathbb{I}(RD_{i2000} > 0), \mathbb{I}(RD_{i2001} > 0))$ and $(\ln Y_{i2002}, \ln Y_{i2003}, b_{i2002}/K_{i2002}, b_{i2003}/K_{i2003}, \mathbb{I}(RD_{i2000} > 0), \mathbb{I}(RD_{i2001} > 0))$, respectively, as additional elements for Z_i, and we found that the estimates were similar to those reported in Table 9.

[14]When we regress τ_{it-2}, τ_{it-3}, and $\overline{RD}_{it-2}/K_{it-2}$ on $\Delta\tau_{it}$ in the benchmark sample, τ_{it-2}, τ_{it-3}, and $\overline{RD}_{it-2}/K_{it-2}$ are significantly negative (with the F-test statistic for the joint significance equal to 32.71), implying a p-value less than 0.001. Similarly, regressing $\tau_{it-2}(b_{it-2}/K_{it-2})$ and $(\overline{RD}_{it-2}/K_{it-2})(b_{it-2}/K_{it-2})$ on $\Delta(\tau_{it}(b_{it}/K_{it})$, the F-test statistic is determined to be 40.85, indicating their joint significance.

[15]When we estimate (7) and (9) with $\hat{\lambda}_i$ as an additional regressor by the GMM to correct for sample selection [not reported here], we obtain estimates similar to those reported in Table 10 except that the point estimates for

While we have so far focused on the change in the effective tax credit rate between 2002 and 2003, it is also possible to analyze the effect of the tax credit on R&D expenditure using the observations prior to 2002 under the incremental tax system. As reported in the upper panel of Table 1, there exists a substantial variation in the effective tax credit rate across firms prior to 2002, and we may use this cross-sectional variation to empirically analyze the effect of the tax credit on R&D expenditure.

Table 11 reports the result of the GMM estimation using the panel observations from 2000 to 2003; the set of instruments used is the same as the one we used in Table 10. While the test for over-identifying restrictions is rejected at a 10% significance level in column (1), it is not rejected at a 10% significance level in column (2), providing some evidence for the validity of moment conditions based on the specification (9). The estimated coefficient of $\Delta\tau_{it}$ is significant at 3.36 and 2.63 in columns (1) and (2), respectively, while the estimated coefficient of $\Delta(\tau_{it}(b_{it}/K_{it}))$ is significant and positive at 0.23 in column (2). For the sample of small firms, the coefficient of $\Delta\tau_{it}$ is insignificantly positive in columns (3) and (4), but the coefficient of $\Delta(\tau_{it}(b_{it}/K_{it}))$ is significantly positive at 0.22. For the sample of large firms, the coefficients of $\Delta\tau_{it}$ and $\Delta(\tau_{it}(b_{it}/K_{it}))$ are not significant. Overall, these results indicate that the tax credit promotes R&D investment for small, financially constrained firms, but not for large firms.

In the benchmark sample for Tables 6-11, we use the tax credit variable τ_{it}, which does not take into account that the tax credit is capped by a certain fraction of the corporate tax. Using a tax credit variable that ignores such a cap could lead to bias in our estimates. To partially address this issue, we use a difference between ordinary and net profits as a proxy for the amount of corporate tax and construct the effective tax credit rate under the cap. We also consider the deferred tax credit in 2003, as explained in Appendix A.2. Note, however, that this alternative measure of corporate tax is likely to contain substantial measurement errors because, for example, it contains accounting depreciation and gains and losses from sales/revaluation of liquid and fixed assets in addition to corporate tax paid.

Tables 12, 13, 14, and 15 report the results corresponding to Tables 6, 9, 10, and 11, respectively, using this alternative measure of tax credit that takes into account the credit cap and the deferred tax credit. Comparing Tables 12, 13, 14, and 15 with Tables 6, 9, 10, and 11, we notice that the coefficient of $\Delta\tau_{it}$ tends to be estimated using this alternative measure of tax credit at values smaller, and often insignificantly so, than those estimated using the original measure of tax credit. This lack of significance for the coefficient of $\Delta\tau_{it}$ might reflect the measurement errors in the alternative measure of tax credit. Nonetheless, an interaction term between the effective tax credit rate and the debt-to-asset ratio is significantly positive for small firms across different methods in Tables 12-15, providing further evidence for the role of financial constraint in determining the effect of the tax credit on R&D expenditure.

the coefficient of $\Delta\tau_{it}$ tend to be slightly larger.

7 Conclusion

This paper investigates the effect of the Japanese tax credit policy change in 2003 on firms' R&D investment by using the panel data of Japanese manufacturing firms. By regressing a change in the effective tax credit rate on a change in the log of R&D expenditure between 2002 and 2003 in the benchmark sample, we find that an increase in the tax credit has a significantly positive effect on R&D expenditure and that this positive effect is especially large for small firms with high debt-to-asset ratios. When we use different methods and different samples, we find mixed evidence for the positive effect of the tax credit on R&D expenditure; however, the overall results suggest that the impact of the tax credit on R&D expenditure is larger for small firms with financial constraint than for large firms without financial constraint.

The results of this paper must be interpreted with caution. First, owing to the lack of data, our measure of the effective tax credit rate is far from perfect. Second, we use the debt-to-asset ratio to capture the extent to which a firm is financially constrained, but there are alternative measures that serve as a proxy for financial constraint, such as the value of collateral (e.g., land), which we were not able to use in our empirical analysis because of data limitations. Addressing these data limitations is important for future research.

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Table 1: Mean and Standard Deviations of $\Delta\tau_{it}$ for each year from 2000 to 2005

Year	1999-2000	2000-2001	2001-2002	2002-2003	2003-2004	2004-2005
Mean of $\Delta\tau_{it}$	-0.0028	-0.0059	-0.0035	0.0917	-0.0006	-0.0006
S.D. of $\Delta\tau_{it}$	0.0346	0.0356	0.0316	0.0307	0.0061	0.0062
No. of Observations	2108	2131	2101	2012	2052	2077
Year	2000	2001	2002	2003	2004	2005
Mean of τ_{it}	0.0182	0.0158	0.0145	0.1062	0.1064	0.1062
S.D. of τ_{it}	0.0360	0.0337	0.0323	0.0081	0.0085	0.0081
No. of Observations	2341	2374	2292	2242	2338	2267

Table 2: Effective Tax Credit Rate and Past R&D Expenditure

$\overline{RD}_{i2002}$	$<= p25$	$(p25, p50]$	$(p50, p75]$	$> p75$
Mean of $\Delta\tau_{i2003}$	0.0736	0.0931	0.0968	0.1026
	0.0021	0.0010	0.0009	0.0007

Notes. The row designated by Mean of $\Delta\tau_{i2003}$ reports the sample average of the change in the effective tax credit rate in the benchmark sample for 2003 conditional on the reference level for tax credit, $\overline{RD}_{i2002}$, in the 2002 incremental tax credit system. Standard errors are in parentheses.

Table 3: Mean of τ_{it} in 2002 and Past R&D experience

Past R&D experience	(1) zero year	(2) one year	(3) two years	(4) three years
Mean of τ_{it}	0.1500	0.0652	0.0315	0.0104
S.D. of τ_{it}	0.0000	0.0620	0.0462	0.0237
No. of Observations	31	41	104	2111

Table 4: Benchmark Sample Selection

	Observations deleted	Remaining observations
Original sample (manufacturing, 1991, 1994–2007)		204091
Small or medium firms	126800	77291
Accounting year closed not in March	26003	51288
Missing past R&D	11744	39544
Sample for Table 1-3, 5		**39547**
Original sample (manufacturing, 1991, 1994–2007)		204091
Year other than 2003	191431	12660
Small or medium firms	7591	5069
Accounting year closed not in March	1428	3641
Missing past R&D in 2002 or 2003	556	3085
Missing/zero R&D in 2002 or 2003	1040	2045
Missing effective tax credit rate in 2002 or 2003	33	2012
Benchmark Sample for Column (1) of Table 6		**2012**
Benchmark Sample for Column (1) of Table 6		2012
Missing debt-to-asset ratio in 2002 or 2003	104	1908
Benchmark Sample for Column (2) of Table 6		**1908**

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.

Table 5: Mean Characteristics of Sample

	2001	2002	2003	2004
Sales (Y)	51476.78	53191.27	56468.82	58291.98
Net Profit	-134.79	684.71	1250.60	1533.76
# Employee (N)	903.81	878.36	909.51	897.81
Fixed Asset (K)	71851.97	69074.05	65674.43	61108.93
Debt (b)	36704.31	35101.80	35379.58	35120.36
b/K	0.8119	0.7826	0.9874	1.0510
R&D Expenditure	2331.98	2315.35	2445.58	2460.50
R&D Exp./Y	0.0281	0.0272	0.0266	0.0260
R&D Exp./N	1.1588	1.1918	1.2280	1.2570
Positive R&D	0.7008	0.6939	0.6915	0.7001
Observation	3442	3349	3290	3391

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. Rows designated as 'R&D Exp./Y' and 'R&D Exp./N' report averages of the ratio of R&D expenditure to sales and that to the number of employees, respectively. For those rows, the sample is restricted to the observations with strictly positive R&D expenditure. 'Fixed 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. 'Positive R&D' refers to the fraction of observations with a strictly positive R&D expenditure. All monetary values are nominal and in units of million yen.

Table 6: Regression Results ($t = 2003$)

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	$\Delta \ln RD_{it}$	$\Delta \ln RD_{it}$	$\Delta \ln RD_{it}$	$\Delta \ln RD_{it}$	$\Delta \ln RD_{it}$	$\Delta \ln RD_{it}$
SAMPLE	Benchmark	Benchmark	Small K	Small K	Large K	Large K
$\Delta\tau_{it}$	2.0524***	2.0171***	2.9189***	2.8077***	1.1609	0.9846
	[0.596]	[0.623]	[0.766]	[0.767]	[1.072]	[1.125]
$\Delta \ln Y_{it}$	0.4728***	0.5144***	0.3198	0.4182**	0.6242***	0.5885***
	[0.129]	[0.105]	[0.234]	[0.191]	[0.096]	[0.102]
$\Delta \frac{b_{it}}{K_{it}}$		-0.0569		-0.0583		0.0551
		[0.045]		[0.047]		[0.104]
$\Delta\left(\tau_{it}\frac{b_{it}}{K_{it}}\right)$		0.1675***		0.1604***		0.4404
		[0.045]		[0.047]		[0.336]
Constant	-0.1916***	-0.2053***	-0.2283***	-0.2426***	-0.1391	-0.1435
	[0.059]	[0.061]	[0.070]	[0.069]	[0.109]	[0.112]
Observations	2,012	1,908	797	770	1,173	1,138

Notes. *** p<0.01, ** p<0.05, * p<0.1. Regression equations are given by equations (7) and (9). The first difference is taken between 2002 and 2003. Robust standard errors are in brackets.

Table 7: Tax Credit Elasticity by percentiles of b_{it}/K_{it} ($t = 2003$)

	5%	10%	25%	50%	75%	90%	95%
$\frac{b_{it}}{K_{it}}$	0.1807	0.2301	0.3554	0.5236	0.7813	1.1780	1.7204
$\hat{\beta} + \hat{\theta}\frac{b_{it}}{K_{it}}$	2.0556	2.0766	2.0766	2.1048	2.1480	2.2144	2.3053

Notes. The row of b_{it}/K_{it} reports the value of debt-to-asset ratios at the 5th, 10th, ... , and 95th percentiles, and the last row reports the estimated tax credit elasticities at these percentiles using the estimates in column (2) of Table 6.

Table 8: Counterfactual Experiment ($t = 2003$)

	Change in RD_{it} (%)
Aggregate	-18.40%
Average	-18.06%
Average ($b_{it}/K_{it} \leq p10$)	-17.91%
Average ($b_{it}/K_{it} \geq p90$)	-19.33%

Notes. The row designated by "Aggregate" reports a percentage change between the sum of the predicted value of RD_{it} based on the actual data and the sum of the predicted value of RD_{it} based on the counterfactual data on τ_{it} without the 2003 tax credit reform for the sample used in column (2) of Table 6. The rows designated by "Average," "Average ($b_{it}/K_{it} \leq p10$)," and "Average ($b_{it}/K_{it} \geq p90$)" report the average percentage change in predicted RD_{it} for the sample used in column (2) of Table 6, that for the subsample with b_{it}/K_{it} smaller than its 10th percentile value, and that for the subsample with b_{it}/K_{it} greater than its 90th percentile.

Table 9: Heckman Two-Step Estimation ($t = 2003$)

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	$\Delta \ln RD_{it}$	$\Delta \ln RD_{it}$	$\Delta \ln RD_{it}$	$\Delta \ln RD_{it}$	$\Delta \ln RD_{it}$	$\Delta \ln RD_{it}$
SAMPLE	Benchmark	Benchmark	Small K	Small K	Large K	Large K
$\Delta \tau_{it}$	2.6094***	2.6673***	3.4225***	3.3120***	1.6148**	1.8045**
	[0.499]	[0.525]	[0.817]	[0.824]	[0.649]	[0.724]
$\Delta \ln Y_{it}$	0.4778***	0.5199***	0.3239**	0.4246***	0.6343***	0.6015***
	[0.084]	[0.090]	[0.146]	[0.155]	[0.101]	[0.106]
$\Delta \frac{b_{it}}{K_{it}}$		-0.0564***		-0.0577***		0.0450
		[0.015]		[0.018]		[0.149]
$\Delta\left(\tau_{it}\frac{b_{it}}{K_{it}}\right)$		0.1675***		0.1614***		0.4227
		[0.034]		[0.041]		[0.446]
$\hat{\lambda}_{it}$	0.1220**	0.1367***	0.1043	0.1025	0.1254*	0.2011***
	[0.048]	[0.052]	[0.079]	[0.079]	[0.071]	[0.075]
Constant	-0.2722***	-0.2964***	-0.3046***	-0.3187***	-0.2047***	-0.2552***
	[0.054]	[0.057]	[0.090]	[0.091]	[0.070]	[0.073]
Observations	3,052	2,876	1,490	1,446	1,479	1,430

Notes. *** p<0.01, ** p<0.05, * p<0.1. The first difference is taken between 2002 and 2003.

Table 10: GMM Estimation ($t = 2003$)

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	$\Delta \ln RD_{it}$	$\Delta \ln RD_{it}$	$\Delta \ln RD_{it}$	$\Delta \ln RD_{it}$	$\Delta \ln RD_{it}$	$\Delta \ln RD_{it}$
SAMPLE	Benchmark	Benchmark	Small K	Small K	Large K	Large K
$\Delta\tau_{it}$	2.0202	0.6009	4.4285	1.7168	0.6153	1.3098
	[1.9711]	[1.8934]	[3.5305]	[3.3123]	[1.8601]	[1.7374]
$\Delta \ln Y_{it}$	0.6087***	0.5698***	0.6353***	0.5499***	0.5871***	0.5914***
	[0.1045]	[0.1019]	[0.2074]	[0.1977]	[0.0953]	[0.0985]
$\Delta \frac{b_{it}}{K_{it}}$		-0.0375		-0.0556		0.0628
		[0.0449]		[0.0500]		[0.1079]
$\Delta\left(\tau_{it}\frac{b_{it}}{K_{it}}\right)$		0.2034***		0.1815***		-0.5036
		[0.0439]		[0.0517]		[0.5715]
Constant	-0.2038	-0.0822	-0.3943	-0.1630	-0.0877	-0.1301
	[0.1900]	[0.1822]	[0.3285]	[0.3072]	[0.1840]	[0.1674]
p-value of the test of over-identifying restriction	0.7127	0.1916	0.3692	0.1365	0.3064	0.5957
Observations	1725	1722	671	670	1052	1052

Notes. *** p<0.01, ** p<0.05, * p<0.1. Instruments are: col.(1), col.(3), col.(5): $\Delta \ln Y_{it}$, τ_{it-2}, τ_{it-3}, $\frac{\overline{RD}_{it-2}}{K_{it-2}}$, constant; col.(2), col.(4), col.(6): $\Delta \ln Y_{it}$, , $\Delta\frac{b_{it}}{K_{it}}$, τ_{it-2}, τ_{it-3}, $\frac{\overline{RD}_{it-2}}{K_{it-2}}$, $\tau_{it-2}\frac{b_{it-2}}{K_{it-2}}$, $\frac{\overline{RD}_{it-2}}{K_{it-2}}\frac{b_{it-2}}{K_{it-2}}$, constant. Robust standard errors are in brackets.

Table 11: GMM Estimation ($t = 2000 - 2003$)

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	$\Delta \ln RD_{it}$	$\Delta \ln RD_{it}$	$\Delta \ln RD_{it}$	$\Delta \ln RD_{it}$	$\Delta \ln RD_{it}$	$\Delta \ln RD_{it}$
SAMPLE	Benchmark	Benchmark	Small K	Small K	Large K	Large K
$\Delta\tau_{it}$	$3.3583**$	$2.6282*$	3.3319	3.3309	1.8649	2.0539
	[1.5405]	[1.4954]	[2.4418]	[2.3279]	[1.7938]	[1.8017]
$\Delta \ln Y_{it}$	$0.4398***$	$0.4359***$	$0.4075***$	$0.3890***$	$0.4847***$	$0.4839***$
	[0.0555]	[0.0556]	[0.0903]	[0.0890]	[0.0610]	[0.0614]
$\Delta \frac{b_{it}}{K_{it}}$		-0.0061		-0.0089		0.0396
		[0.0119]		[0.0130]		[0.0570]
$\Delta\left(\tau_{it}\frac{b_{it}}{K_{it}}\right)$		$0.2260***$		$0.2208***$		-1.0320
		[0.0137]		[0.0156]		[0.6347]
$Year2001$	$0.0357*$	$0.0391*$	0.0140	0.0146	$0.0551**$	0.0425
	[0.0197]	[0.0205]	[0.0393]	[0.0412]	[0.0216]	[0.0278]
$Year2002$	-0.0238	-0.0214	-0.0503	-0.0505	-0.0023	-0.0041
	[0.0204]	[0.0205]	[0.0416]	[0.0416]	[0.0212]	[0.0213]
$Year2003$	$-0.3054**$	$-0.2523*$	-0.2769	-0.3008	-0.1774	-0.1429
	[0.1510]	[0.1467]	[0.2333]	[0.2225]	[0.1786]	[0.1777]
Constant	-0.0203	-0.0213	-0.0089	-0.0081	$-0.0302**$	$-0.0289*$
	[0.0138]	[0.0140]	[0.0284]	[0.0284]	[0.0149]	[0.0150]
p-value of the test of over-identifying restriction	0.0997	0.1181	0.1744	0.2102	0.4539	0.6836
Observations	7057	7040	2694	2691	4350	4349

Notes. *** p<0.01, ** p<0.05, * p<0.1. Instruments are: col.(1), col.(3), col.(5): $Year2001$, $Year2002$, $Year2003$, $\Delta \ln Y_{it}$, τ_{it-2}, τ_{it-3}, $\frac{\overline{RD}_{it-2}}{K_{it-2}}$, constant; col.(2), col.(4), col.(6): $Year2001$, $Year2002$, $Year2003$, $\Delta \ln Y_{it}$, , $\Delta \frac{b_{it}}{K_{it}}$, τ_{it-2}, τ_{it-3}, $\frac{\overline{RD}_{it-2}}{K_{it-2}}$, $\tau_{it-2}\frac{b_{it-2}}{K_{it-2}}$, $\frac{\overline{RD}_{it-2}}{K_{it-2}}\frac{b_{it-2}}{K_{it-2}}$, constant. Robust standard errors are in brackets.

Table 12: Regression Results ($t = 2003$, with cap and deferred tax credit)

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	$\Delta \ln RD_{it}$	$\Delta \ln RD_{it}$	$\Delta \ln RD_{it}$	$\Delta \ln RD_{it}$	$\Delta \ln RD_{it}$	$\Delta \ln RD_{it}$
SAMPLE	Benchmark	Benchmark	Small K	Small K	Large K	Large K
$\Delta \tau_{it}$	-0.0465	-0.0850	0.6857	0.5646	-0.6338	-0.8896
	[0.461]	[0.475]	[0.598]	[0.586]	[0.716]	[0.797]
$\Delta \ln Y_{it}$	0.4606***	0.4958***	0.3010	0.3716*	0.6277***	0.5930***
	[0.124]	[0.106]	[0.224]	[0.194]	[0.093]	[0.101]
$\Delta \frac{b_{it}}{K_{it}}$		-0.0636		-0.0666		0.0566
		[0.040]		[0.041]		[0.103]
$\Delta\left(\tau_{it} \frac{b_{it}}{K_{it}}\right)$		0.1702***		0.1638***		0.6297
		[0.037]		[0.039]		[0.462]
Constant	0.0008	-0.0103	-0.0254	-0.0364	0.0219	0.0177
	[0.039]	[0.040]	[0.048]	[0.047]	[0.062]	[0.063]
Observations	2,012	1,908	797	770	1,173	1,138

Notes. *** p<0.01, ** p<0.05, * p<0.1. Regression equations are given by equations (7) and (9). The first difference is taken between 2002 and 2003. Robust standard errors are in brackets.

Table 13: Heckman Two-Step Estimation ($t = 2003$, with cap and deferred tax credit)

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	$\Delta \ln RD_{it}$	$\Delta \ln RD_{it}$	$\Delta \ln RD_{it}$	$\Delta \ln RD_{it}$	$\Delta \ln RD_{it}$	$\Delta \ln RD_{it}$
SAMPLE	Benchmark	Benchmark	Small K	Small K	Large K	Large K
$\Delta \tau_{it}$	-0.0316	-0.0803	0.6125	0.4714	-0.5926	-0.7843
	[0.358]	[0.366]	[0.638]	[0.638]	[0.413]	[0.504]
$\Delta \ln Y_{it}$	0.4605***	0.4957***	0.3011**	0.3722**	0.6292***	0.5952***
	[0.085]	[0.090]	[0.147]	[0.156]	[0.100]	[0.106]
$\Delta \frac{b_{it}}{K_{it}}$		-0.0636***		-0.0664***		0.0517
		[0.015]		[0.018]		[0.147]
$\Delta\left(\tau_{it} \frac{b_{it}}{K_{it}}\right)$		0.1702***		0.1637***		0.6330
		[0.034]		[0.040]		[0.535]
$\hat{\lambda}_{it}$	0.0085	0.0026	-0.0325	-0.0402	0.0375	0.0818
	[0.045]	[0.048]	[0.073]	[0.073]	[0.067]	[0.070]
Constant	-0.0024	-0.0113	-0.0098	-0.0170	0.0120	-0.0047
	[0.035]	[0.036]	[0.064]	[0.064]	[0.040]	[0.041]
Observations	3,052	2,876	1,490	1,446	1,479	1,430

Notes. *** p<0.01, ** p<0.05, * p<0.1. The first difference is taken between 2002 and 2003. The tax credit cap is imposed using the proxy for corporate tax paid.

Table 14: GMM Estimation ($t = 2003$, with cap and deferred tax credit)

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	$\Delta \ln RD_{it}$	$\Delta \ln RD_{it}$	$\Delta \ln RD_{it}$	$\Delta \ln RD_{it}$	$\Delta \ln RD_{it}$	$\Delta \ln RD_{it}$
SAMPLE	Benchmark	Benchmark	Small K	Small K	Large K	Large K
$\Delta\tau_{it}$	0.5442	1.9591	5.0555	4.8976	0.9940	0.9574
	[2.4861]	[1.9866]	[6.3352]	[5.8363]	[1.1786]	[1.1699]
$\Delta \ln Y_{it}$	$0.5873***$	$0.5330***$	$0.5188**$	$0.4777**$	$0.5839***$	$0.5956***$
	[0.1149]	[0.1079]	[0.2272]	[0.2164]	[0.0959]	[0.1022]
$\Delta \frac{b_{it}}{K_{it}}$		-0.0370		-0.0716		0.0935
		[0.0494]		[0.0636]		[0.1139]
$\Delta\left(\tau_{it}\frac{b_{it}}{K_{it}}\right)$		$0.2010***$		$0.1599**$		-0.7742
		[0.0495]		[0.0709]		[1.1685]
Constant	-0.0543	-0.1779	-0.3820	-0.3815	-0.1074	-0.0727
	[0.2002]	[0.1583]	[0.5006]	[0.4569]	[0.0944]	[0.1031]
p-value of the test of over-identifying restriction	0.5614	0.3803	0.2209	0.1695	0.5861	0.8066
Observations	1725	1722	671	670	1052	1052

Notes. *** p<0.01, ** p<0.05, * p<0.1. Instruments are: col.(1), col.(3), col.(5): $\Delta \ln Y_{it}$, τ_{it-2}, τ_{it-3}, $\frac{\overline{RD}_{it-2}}{K_{it-2}}$, constant; col.(2), col.(4), col.(6): $\Delta \ln Y_{it}$, , $\Delta\frac{b_{it}}{K_{it}}$, τ_{it-2}, τ_{it-3}, $\frac{\overline{RD}_{it-2}}{K_{it-2}}$, $\tau_{it-2}\frac{b_{it-2}}{K_{it-2}}$, $\frac{\overline{RD}_{it-2}}{K_{it-2}}\frac{b_{it-2}}{K_{it-2}}$, constant. Robust standard errors are in brackets.

Table 15: GMM Estimation ($t = 2000 - 2003$, with cap and deferred tax credit)

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	$\Delta \ln RD_{it}$	$\Delta \ln RD_{it}$	$\Delta \ln RD_{it}$	$\Delta \ln RD_{it}$	$\Delta \ln RD_{it}$	$\Delta \ln RD_{it}$
SAMPLE	Benchmark	Benchmark	Small K	Small K	Large K	Large K
$\Delta\tau_{it}$	1.7380	1.3179	1.4121	1.5991	0.6800	0.8619
	[2.1067]	[2.0788]	[3.4716]	[3.4165]	[1.7779]	[1.6581]
$\Delta \ln Y_{it}$	$0.4458***$	$0.4371***$	$0.4296***$	$0.4023***$	$0.4928***$	$0.5053***$
	[0.0659]	[0.0651]	[0.1097]	[0.1076]	[0.0651]	[0.0701]
$\Delta \frac{b_{it}}{K_{it}}$		-0.0069		-0.0098		0.0389
		[0.0125]		[0.0141]		[0.0608]
$\Delta\left(\tau_{it}\frac{b_{it}}{K_{it}}\right)$		$0.2323***$		$0.2278***$		-2.1246
		[0.0146]		[0.0180]		[2.2805]
$Year2001$	$0.0399*$	$0.0421**$	0.0177	0.0188	$0.0559**$	0.0469
	[0.0204]	[0.0213]	[0.0411]	[0.0432]	[0.0223]	[0.0293]
$Year2002$	-0.0232	-0.0217	-0.0525	-0.0533	-0.0015	-0.0019
	[0.0213]	[0.0213]	[0.0439]	[0.0437]	[0.0218]	[0.0220]
$Year2003$	-0.1198	-0.1001	-0.0751	-0.1098	-0.0494	0.0256
	[0.1713]	[0.1687]	[0.2777]	[0.2724]	[0.1471]	[0.2009]
Constant	$-0.0255*$	$-0.0251*$	-0.0146	-0.0136	$-0.0313**$	$-0.0315**$
	[0.0143]	[0.0143]	[0.0296]	[0.0295]	[0.0154]	[0.0155]
p-value of the test of over-identifying restriction	0.1319	0.1769	0.4552	0.3372	0.2690	0.4248
Observations	7057	7040	2694	2691	4350	4349

Notes. *** p<0.01, ** p<0.05, * p<0.1. Instruments are: col.(1), col.(3), col.(5): $Year2001$, $Year2002$, $Year2003$, $\Delta \ln Y_{it}$, τ_{it-2}, τ_{it-3}, $\frac{\overline{RD}_{it-2}}{K_{it-2}}$, constant; col.(2), col.(4), col.(6): $Year2001$, $Year2002$, $Year2003$, $\Delta \ln Y_{it}$, , $\Delta \frac{b_{it}}{K_{it}}$, τ_{it-2}, τ_{it-3}, $\frac{\overline{RD}_{it-2}}{K_{it-2}}$, $\tau_{it-2}\frac{b_{it-2}}{K_{it-2}}$, $\frac{\overline{RD}_{it-2}}{K_{it-2}}\frac{b_{it-2}}{K_{it-2}}$, constant. Robust standard errors are in brackets.

Figure 1: Level (2002)

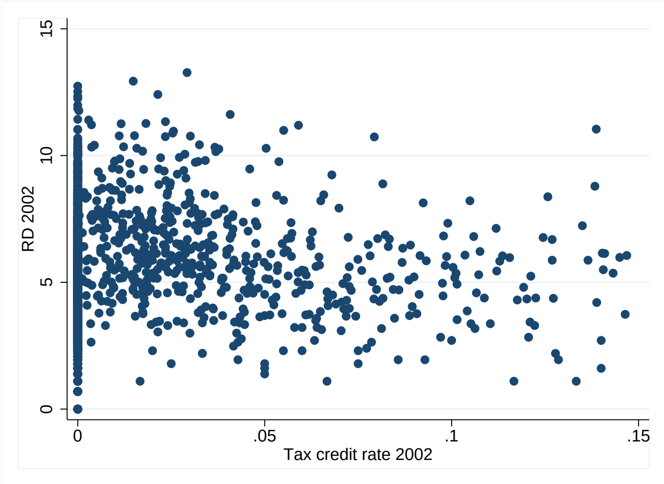


Figure 2: Level (2003)

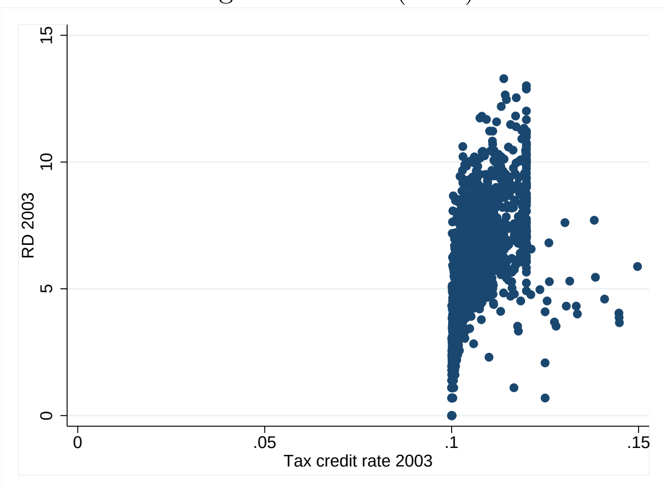


Figure 3: Difference (2002-2003, All)

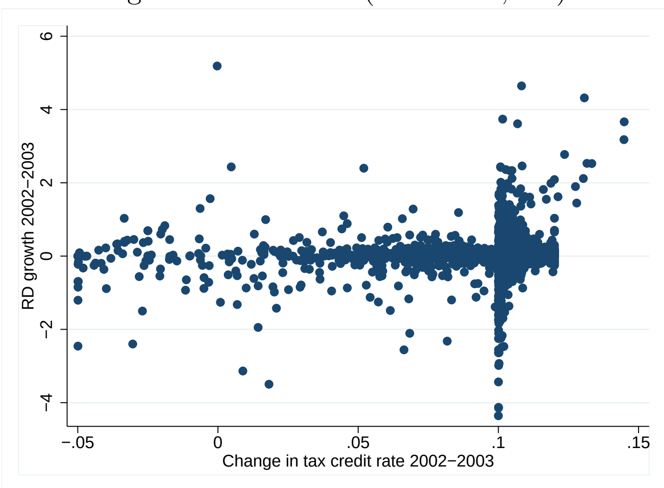


Figure 4: R&D Investment Decision for Low Value of I_{t-1}

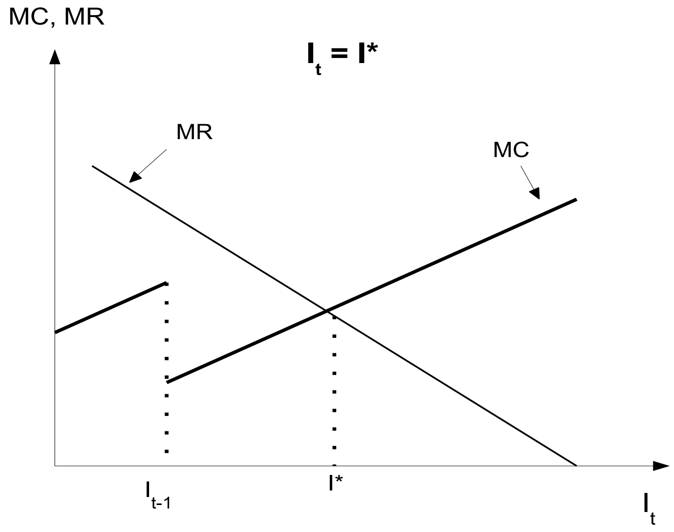


Figure 5: R&D Investment Decision for High Value of I_{t-1}

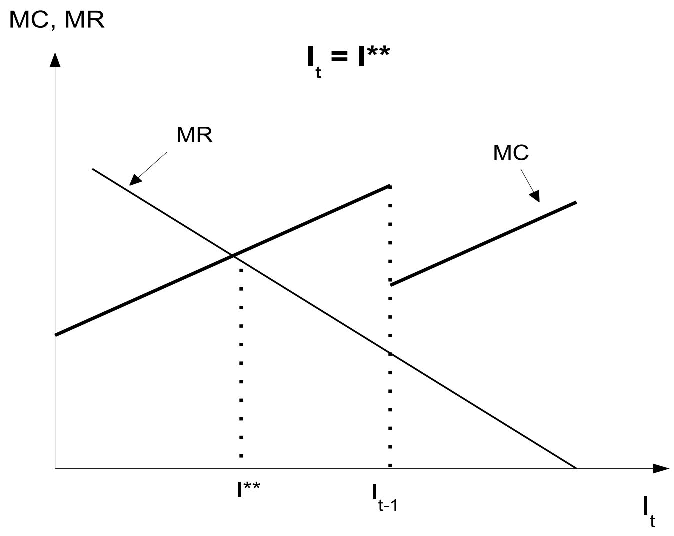
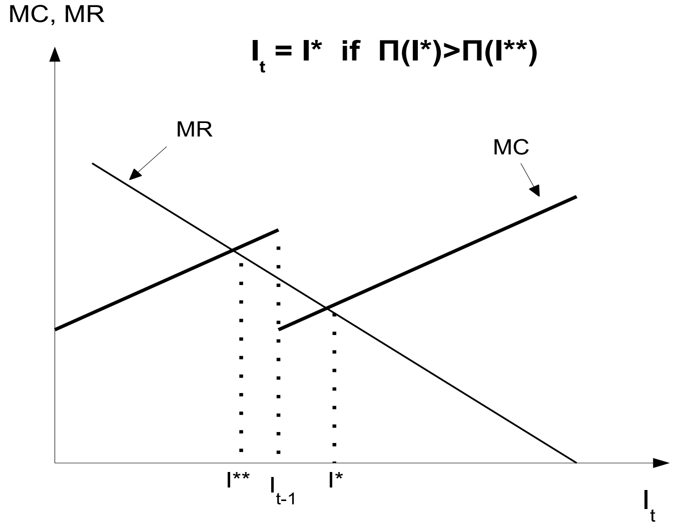


Figure 6: R&D Investment Decision when $I^{**} < I_{t-1} < I^{*}$



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

Our measure of R&D expenditure is the sum of own and outsourced research and development expenses.

A.2 Effective tax credit rate

Following the tax credit formulas described in Section 3, we construct a measure for the effective tax credit rate, τ_{it}, defined by (1) using the BSJ data on R&D expenditure and sales. For the benchmark analysis, we do not consider that the credit is capped by a certain fraction (12 to 20 percent) of the corporate tax, because the data on corporate tax are not available in the BSJ data set. We compute the tax credit under the incremental tax credit system (for, as an example, 2002 (X_{i2002})) as follows.

$$X_{i2002} = 0.15 \max\{RD^{net}_{i2002} - \overline{RD}^{net}_{i2002}, 0\}\mathbb{I}(RD^{net}_{i2002} > \max\{RD^{net}_{i2001}, RD^{net}_{i2000}\}) \tag{11}$$

where RD^{net}_{i2002} represents firm i's net R&D expenditure defined by the sum of own and outsourced R&D expenditure net of the amount received in commissioned R&D projects, and $\overline{RD}^{net}_{i2002}$ represents the average of firm i's three largest yearly net R&D expenditures over previous five years (1997 to 2001).[16] Then, the effective tax credit rate is

$$\tau_{i2002} = X_{i2002}/RD^{net}_{i2002}. \tag{12}$$

We compute the effective tax credit rate under the total tax credit system, for 2003 as an example, as follows.

$$\tau_{i2003} = \kappa(RD^{net}_{i2003}/\overline{Y}_{i2003}), \tag{13}$$

where $\kappa(x) = (0.2x + 0.1)\mathbb{I}(x < 0.1) + 0.12\mathbb{I}(x \geq 0.1)$ and $\overline{Y}_{it}$ denotes the average sales over the previous 4 years including the current fiscal year (2000 to 2003). Note that, from 2003 to 2005, firms were able to choose between the old incremental tax credit system and the new total tax credit system. 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

[16] Note that newly established firms cannot apply for the R&D tax credit under the incremental tax credit system in their first year because data on past R&D expenditures are not available.

tax credit in 2003. Therefore, the effective tax credit rate in 2003 is as follows.

$$\tau_{i2003} = \max\{\tau_{i2003}^{inc}, \tau_{i2003}^{total}\},$$

where τ_{i2003}^{inc} represents the tax credit under the incremental tax credit system with the tax credit given by the formula (12) with (11) and τ_{i2003}^{total} represents the tax credit under the total tax credit system, which is given by (13).

We use an alternative measure of tax credit with the cap and the deferred tax credit in Tables 12 to 15. To construct an alternative measure of tax credit from 2000 to 2002, we use the difference between ordinary and net profits as a proxy for corporate tax paid in the BSJ data and re-compute the effective tax credit rate following the formula described in Section 3. Note that this measure is likely to contain substantial measurement errors because, for example, it contains accounting depreciation and gains and losses from sales/revaluation of liquid and fixed assets in addition to corporate tax paid.

For the total tax credit system introduced in 2003, we construct an alternative measure of tax credit as in the case of the 2000 to 2002 period, except that we take into account the deferred tax credit that was introduced together with the total tax credit system. If a firm's tax credit exceeds 20% of the corporate tax paid in 2003, it can collect a tax credit only up to the capped amount in 2003, but 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 this rule into account by computing the tax credit in 2003 under perfect foresight using the realized value of corporate tax paid and R&D expenditure in 2004 as

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

where $X_{i2003}^* = \kappa(RD_{i2003}^{net}/\overline{Y}_{i2003})RD_{i2003}^{net}$ with $\kappa(x)$ defined as above. As before, for 2003, we take into account that firms can choose between the incremental and total tax credit system by taking the maximum value between the tax credits under the two systems.

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 (K_{it})

We construct data on the nominal value of the beginning-of-period capital stock (K_{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 $I_{it} = K_{it}^{book} - K_{it-1}^{book} + AD_{it}$, where K_{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 $K_{it}^{real} = (1-\delta)K_{it-1}^{real} + I_{it}^{real}$, where δ represents the depreciation rate and I_{it}^{real} and K_{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).[17] 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).[18] Finally, we compute the nominal value of 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 the inflation in the 1980s, 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 K_{it}, the mean and median debt-asset ratios (b_{it}/K_{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}/K_{it} are 2.76 and 1.37 in the BSJ data, while they are 1.20 and 0.36 in the DBJ data, respectively. Note that the DBJ dataset provides a more reliable estimate of the capital stock because it starts in 1969.[19] 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 0.91 and 0.45, respectively.

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

[18] The DBJ dataset provides detailed balance sheet information for Japanese firms listed on the Tokyo Stock Exchange.

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

Appendix B: Selection equation

Consider a selection indicator s_i that is equal to one if $RD_{it} > 0$ for both $t = 2002$ and $t = 2003$ and is equal to zero otherwise. We collect the regressors and their coefficients into vectors as $\Delta X_{it} = (1, \Delta\tau'_{it}, \Delta \ln Y_{it}, \Delta(b_{it}/K_{it}), \Delta(\tau_{it}(b_{it}/K_{it})))'$ and $\alpha = (\Delta\eta_t, \beta, \gamma, \delta, \theta)'$, respectively, so that we write equation (7) as $\Delta \ln RD_{it} = \Delta X'_{it}\alpha + \Delta\epsilon_{it}$. The OLS estimator using the selected sample with $s_i = 1$ is inconsistent when $E[\Delta\epsilon_{it}\Delta X_{it}|s_i = 1] \neq 0$. To control for selection bias, we consider a probit selection equation (10). We assume that (i) $(\Delta\epsilon_i, v_i)$ is independent of Z_i and ΔX_{it} with mean zero, (ii) $v_i \sim N(0, 1)$, and (iii) $E[\Delta\epsilon_i|v_i] = \rho v_i$. Under these assumptions, we can consistently estimate (ψ, α, ρ) by first obtaining an estimate of ψ by estimating a probit equation (10) and then estimating $\Delta \ln RD_{it} = \Delta X'_{it}\alpha + \rho\hat{\lambda}_i + \xi_{it}$ by the OLS. The standard errors for α and ρ can be computed while taking into account the sampling errors from the first step estimator $\hat{\psi}$.

Because the selection indicator s_i reflects a firm's decision to participate in R&D activity in 2002 and 2003, we choose the observed variables that may affect a firm's participation decision for R&D activity in 2002 and 2003. Specifically, when we estimate (9) with the selection equation (10), we choose $Z_i = (1, \ln Y_{i2002}, \ln Y_{i2003}, b_{i2002}/K_{i2002}, b_{i2003}/K_{i2003}, \mathbb{I}(RD_{i2000} > 0), \mathbb{I}(RD_{i2001} > 0))'$. The variables $\ln Y_{it}$ and b_{it}/K_{it} for $t = 2002$ and 2003 capture the firm's ability to conduct R&D activity and the firm's ability to finance R&D activity, respectively, in 2002 and 2003, while the dummy variables $\mathbb{I}(RD_{i2000} > 0)$ and $\mathbb{I}(RD_{i2001} > 0)$ may affect a firm's decision to participate in R&D activity in 2002 and 2003, especially if there exists a start-up cost of R&D activity. Note that the level variables $\ln Y_{it}$ and b_{it}/K_{it} for $t = 2002$ and 2003 contain additional information that is not contained in the first-difference variables $\Delta \ln Y_{i2003}$ and $\Delta(b_{i2003}/K_{i2003})$ in (8) because taking the first difference eliminates the permanent component contained in the level variables, providing exclusion restrictions for identifying the selection equation.