RIETI Discussion Paper Series 11-E-072

How Much Do R&D Tax Credits Affect R&D Expenditures? Japanese tax credit reform in 2003

KASAHARA Hiroyuki
University of British Columbia

SHIMOTSU Katsumi
Hitotsubashi University

SUZUKI Michio
University of Tokyo

RIETI
Research Institute of Economy, Trade & Industry, IAA

The Research Institute of Economy, Trade and Industry
http://www.rieti.go.jp/en/

RIETI Discussion Paper Series 11-E-072
November 2011

How Much Do R&D Tax Credits Affect R&D Expenditures? Japanese tax credit reform in 2003

KASAHARA Hiroyuki
Department of Economics, University of British Columbia
SHIMOTSU Katsumi
Department of Economics, Hitotsubashi University
SUZUKI Michio
Department of Economics, the University of Tokyo

Abstract

How much do tax credits affect firms' R&D activities? What are the mechanisms? Few empirical studies directly examine the effect of tax credit policies on firms' R&D investments and the importance of financial constraints on the policy effects on R&D. This paper examines the effect of the Japanese tax credit reform in 2003 on firms' R&D investments by exploiting cross-firm variation in the changes in the effective tax credit rate between 2002 and 2003. Regression results suggest a significantly positive effect of the change in the effective tax credit rate on corporate R&D investments. Across different specifications, the estimated (semi-) elasticity of R&D investments with respect to the effective tax credit rate is 2.3 with an approximate standard error of 0.6. We also examine the policy implications of financial constraints on R&D investments and find that the effect of tax credits is significantly larger for firms with relatively large outstanding debt.

Key words: R&D; tax credits; financial constraint; Japan.
JEL classification: D22; H25; H32; K34; O31; O38

1 Introduction

How much does tax credit affect firm's R&D activity? What are mechanisms? Since R&D has some characteristics of a public good, government subsidy to R&D investment could be justifiable to bridge the gap between the private and social rate of return. Further, R&D investment plays an important role for long-run economic growth (Romer (1986); Aghion and Howitt (1997)). Therefore, understanding the mechanisms through which tax policies affect R&D investment is a prerequisite for designing effective growth-promoting tax policies.

R&D investment may be difficult to finance through external funds due to proprietary information, highly uncertain returns, and lack of collateral value for R&D capital (see Arrow (1962)).[1] When firms do not hold sufficient internal funds, R&D investment may be restricted due to financial constraint. From this viewpoint, tax credit may promote R&D investment not only through increasing the private return from R&D investment but also through relaxing the financial constraint for R&D expenditure. While a small number of empirical studies provide micro-level evidence for financial constraint for R&D investment (see Hall (2002) and Brown et al. (2009)), few empirical studies directly examine the effect of tax credit policy change on firm's R&D investment and quantify the importance of financial constraints in explaining the policy effect on R&D. This paper fills this gap by carefully examining the effect of Japanese tax credit reform in 2003 on firm's R&D expenditure.

In the tax reform of 2003, Japanese government introduced a total tax credit system which substantially increased the amount of aggregate tax credit from the incremental tax credit system that were in effect until 2002. In the incremental system, firms can apply tax credit only if R&D expenditure in the current accounting year is greater than the base level which is roughly the average of R&D expenditure over the last 5 years.[2] Tax credit before 2002 is only a fraction of the increment in R&D expenditure, approximately equal to 15 percent of the difference between the current year's R&D expenditure and the average of the last 5 years. In the total tax credit system, tax credit is on total expenditure. Because tax credit depends on previous R&D expenditure under the incremental system, changes in the effective rate of tax credits due to the 2003 reform vary across firms. The firms with high R&D expenditure prior to 2002 experienced a large increase in the effect rate of tax credits in 2003. On the other hand, the effective rate of tax credits remain the same between 2002 and 2003 for those without any R&D expenditure prior to 2002.

To understand how the 2003 tax credit reform affect firm's R&D investment, we also develop a simple model of R&D investment and examine the optimal investment policy. First, even though the shift from the incremental to 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

[1] See also Brown, Fazzari, and Petersen (2009) and Ogawa (2007).
[2] See Section 3 for details.

level defined in the incremental system. This is because investment is determined by equating marginal benefit and marginal cost, and the tax credit reform does not change either of them in such a case. However, once we take into account the possibility of financial constraint, the tax reform may potentially have a large effect on R&D investment. When financial constraint is binding without being able to raise external funds for R&D, an increase in tax credit may increase the available internal funds one-to-one and, as a result, it could increase R&D investment substantially.

By using the variation across firms in the changes in the effective rate of tax credits between 2002 and 2003, we estimate the elasticity of R&D expenditure with respect to the effective rate of tax credit and examine 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 specify a linear model of R&D investment with possible interaction terms between the effective rate of tax credit and the measure of financial constraint. 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 rate of tax credit under Japanese tax credit system.

Regression results suggest the significantly positive effect of the change in the effective rate of tax credit on corporate R&D investment. Our OLS estimate for the elasticities of the effective rate of tax credit on R&D investment is 2.3 percent with the standard errors of around 0.6. These results imply that the tax reform of 2003 had substantial impact on firm's R&D investment. We also examine the policy implications of financial constraint on R&D investment, and the regression results provide some evidence that the effect of tax credit is significantly larger for firms with relatively large outstanding debt, consistent with the financial constraint channel stated above.

The remainder of this paper is organized as follows. Section 2 reviews related literature. Section 3 explains the 2003 tax credit reform in detail. Section 4 explains our data source and present summary statistics. Section 5 develops a simple model of R&D expenditure featuring tax credit and examine how tax credit affects R&D investment. Section 6 explains our empirical framework and report estimation results.

2 Literature Review

The effectiveness of R&D tax credit has attracted increasing recent attention and been studied extensively. Overall results suggest that the elasticity of R&D with respect to price is around 1. In other words, one yen in tax credit for R&D stimulates around one yen of additional R&D. Hall and Van Reenen (2000) survey 10 U.S. studies and 10 international studies on the econometric evidence on the effectiveness of fiscal incentives for R&D. Based on 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 γ is -0.144, implying a short-run and long-run elasticity of -0.144 and -1.088, respectively. This estimate suggests that a 10% fall in the cost of R&D stimulates a 1.44% rise in R&D in the short-run, and around 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 during 1994-1996 and 1997-1999. The estimates by Paff (2005) are substantially higher than unity, 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-level panel dataset from 2001 to 2005. Propensity score matching reveals that, on average, recipients of R&D tax credits have 93.53% higher R&D expenditures and a 14.47% higher growth rate for R&D expenditures than non-recipients with similar characteristics. Huang and Yang (2009) estimate a panel fixed effect model by a generalized method of moments (GMM) and report that the estimated (short-run) elasticity of R&D with respect to R&D tax credits 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 R&D tax credits using data on 904 Japanese manufacturing firms over 10 years (1989-1998). 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 kenkyu 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 $\log(\text{user cost of R\&D})$, 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 R&D tax credit reform in 2003 using a dataset on 485 firms from Report on the Survey of Research and Development (*Kagaku gijutu kenkyu chousa*) by the Ministry of Internal Affairs and Communications. Using the propensity score matching, Ohnishi and Nagata (2010) compare the change in the R&D expenditure from 2002 to 2003 between those firms who use the new total (*Sougaku gata*) tax credit system and those firms who do not use the new tax credit system. It is found that those who use the new *Sougaku gata* tax credit system increased their R&D expenditure by 1.2% while those who do not use the new tax credit system decreased their R&D expenditure by 0.9%. Ohnishi and Nagata (2010) conclude there is virtually no difference in increase in the R&D expenditure between those two groups of firms. The dataset of Ohnishi and Nagata (2010) is somewhat peculiar. The firms are restricted to the respondents of Kagaku Gijyutu Kenkyuu Tyosa, which may induce sample-selection bias. Further, 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 10% between 2002 and 2003.

Motohashi (2010) combines firm-level panel data for 1983-2005 from Report on the Survey of Research and Development (Kagaku gijutu kenkyu chousa) and 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 unit R&D cost reduction ($= \beta_1 + \beta_2$) is around -0.5.

Cash flow constraint has been documented to have a significant effect on firms' R&D activity. Because tax system affects after-tax cash flow, cash flow is a potentially important channel through which business tax policies affect firms' R&D activity. 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 while the effect of the debt-asset ratio on R&D investment was insignificant in the late 1980s.

Brown, Fazzari, and Petersen (2009) examine the role of cash flow and stock issues in financing R&D expenditures. R&D is difficult to finance through debt because of problems associated with proprietary information, highly uncertain returns, and lack of collateral value for R&D

capital. Brown et al. (2009) found significant effects of cash flow and external equity on R&D expenditures of young high-tech firms. 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 explains a reform of Japanese R&D tax credit system in 2003.[3] We measure the effective rate of tax credit for firm i in period t, denoted by τ_{it}, as

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

where RD_{it} denotes R&D expenditure of firm i in period t while X_{it} denotes the amount of tax credit[4]. The tax reform of 2003 substantially change the amount of tax credit X_{it} each firm is eligible to. Below we explain how to compute X_{it} before and after the tax reform.

We first explain the tax credit prior to 2002, i.e., before the reform. Prior to 2002, Japanese R&D tax policy is characterized by the *incremental tax credit system*. Denote the average of firm i's R&D expenditure over the three years of the largest R&D expenditure in the last five years by $\overline{RD}_{it}$, and denote firm i's "special experimental research expenses" (*Tokubetsu Shiken Kenkyu Hi* in Japanese) in year t by SRD_{it}.[5] 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, denoted by X_{i2002}, is computed as

$$X_{i2002} = \begin{cases} X^*_{i2002} & \text{if } 0.12T_{i2002} \geq X^*_{i2002} \text{ and } SRD_{i2002} = 0 \\ X^*_{i2002} & \text{if } 0.14T_{i2002} \geq X^*_{i2002} \text{ and } SRD_{i2002} > 0 \\ 0.12T_{i2002} & \text{if } 0.12T_{i2002} < X^*_{i2002} \text{ and } SRD_{i2002} = 0 \\ 0.12T_{i2002} & \text{if } 0.14T_{i2002} < X^*_{i2002} \text{ and } SRD_{i2002} > 0. \end{cases} \tag{2}$$

where

$$X^*_{i2002} = 0.15 \max\{RD_{i2002} - \overline{RD}_{i2002}, 0\}\mathbb{I}(RD_{i2002} > \max\{RD_{i2001}, RD_{i2000}\}) + 0.06SRD_{i2002},$$

whereas $\mathbb{I}(x > y)$ represents an indicator function. When $RD_{i2002} \leq \overline{RD}_{i2002}$ or the R&D expenditure in 2002 is smaller than the last two year's R&D expenditure, a firm receives no

[3]We do not cover 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 *Chusho kigyou gijutsu kiban kyouka zeisei* 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 by (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.

[4]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 the given firm receives for commissioned R&D projects. We follow this definition of R&D expenditure to compute tax credit in our data.

[5][Need to add an explanation of Tokubetsu Shiken Kenkyu Hi here.]

tax credit. Further, the amount of tax credit is roughly proportional to the difference between the current R&D expenditure and the past R&D expenditure ($RD_{i2002} - \overline{RD}_{i2002}$). Thus, 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 years while a new R&D firm with no past R&D experiences may receive up to 15 percent of the total amount of R&D expenditure as tax credit. Under this incremental tax credit system, the larger the past R&D expenditure is, the smaller the amount of tax credit a firm is eligible to.

In contrast, Japanese R&D tax policy after 2003 is characterized by the *total tax credit system*, where a firm is potentially eligible to the amount of tax credit equal to 10–15 percent of the R&D expenditure, regardless of the past R&D expenditure. Specifically, the R&D tax credit after 2003, denoted by X_{i2003}, is computed as[6]

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

where

$$X^*_{i2003} = \begin{cases} \kappa(RD_{i2003}/\overline{Y}_{i2003})RD_{i2003} & \text{if } RD_{i2003} \text{ is not classified as industry-university cooperation} \\ 0.15RD_{i2003} & \text{if } RD_{i2003} \text{ is classified as industry-university cooperation.} \end{cases}$$

with $\kappa(x) = (0.2x + 0.1)\mathbb{I}(x < 0.1) + 0.12\mathbb{I}(x \geq 0.1)$.

Table 1 reports the mean and the standard deviations for the changes in the effective rate of tax credit, $\Delta\tau_{it} = \tau_{it} - \tau_{it-1}$, across firms for each year from 2000 to 2005. Looking at the year 2002-2003, we notice that the average effective rate of tax credit was increased by 9.27 percent between 2002 and 2003, indicating the substantial impact of the 2003 tax credit reform on the average effective rate of tax credit.[7] In contrast, the average change in the effective rate of tax credit is close to zero for years other than 2002-2003.

Moreover, because tax credit crucially depended on past R&D expenditures in the incremental tax system, and past R&D expenditures before 2002 were substantially different across firms, the introduction of the total tax credit system induces heterogeneous changes in the effective rate of tax credit across firms. Those firms who conduct large R&D investment before 2002 gain a large benefit from the 2003 tax reform while those who did not conduct R&D investment before 2002 gain little. In fact, as Table 2 reports, comparing across different quantiles of R&D

[6]From 2003 to 2005, firms were able to choose between the old incremental tax credit system and the new total tax credit system. In the empirical analysis where we construct a proxy for the rate of tax credit, τ, we take this aspect into account by taking the maximum of the tax credit in the incremental system and that in the total system as the tax credit after 2003. However, the effect should be limited because the new total tax credit system introduced in 2003 provides larger credit than the incremental system in most cases.

[7]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 6–11 times as large as that before the reform.

expenditures in 2002, we find that the increase in the effective rate of tax credits between 2002 and 2003 is larger for the firms with the higher value of R&D expenditure in 2002. It is this cross-sectional variation of changes in the effective rate of tax credit before and after the tax reform that enables us to identify the effect of tax credit on R&D expenditure.

As shown in Table 1, the standard deviations of $\Delta\tau_{it}$ before the year 2002 are much larger than after the year 2003. For the period of 1999-2002, the standard deviations of $\Delta\tau_{it}$ are relatively high at 0.0304-0.0349, indicating that some firms experienced a substantial change in the effective rate of tax credit while other firms did not when the incremental tax system was in effect.

To understand the source of this cross-sectional variation in $\Delta\tau_{it}$, as an example, consider a firm which started R&D activity in 2000 for the first time. Since this firm's past R&D expenditure before 2000 is equal to zero, this firm is eligible for tax credit of 15 percent of R&D expenditure in 2000 as long as it is below the corporate tax the firm owes. Next year in 2001, this firm faces the lower effective rate of tax credit than 15 percent because past R&D expenditure in 2001 is not zero anymore. Thus, under the incremental tax system, the effective rate of tax credit tends to decrease over time for a first three years of R&D activity. On the other hand, the effective rate of tax credit would be close to zero for the firms with more than three years of R&D experience if they do not change the amount of R&D expenditures much across years.

Accordingly, the firm's past R&D experience is an important determinant of the effective rate of tax credit before 2002. Table 3 shows the average effective rate of tax credit across four groups of firms with positive R&D expenditure in 2002 classified according to their past R&D experience over the last 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 rate of tax credit decreases with the years of R&D experience from 0.15 to 0.01.

On the other hand, after the introduction of the total tax credit system in 2003, most firms experienced little change in the effective rate of tax credit, and there is little cross-sectional variation in the values of $\Delta\tau_{it}$ for 2003-2005.

4 Data

4.1 Data Source

We use data from the *Basic Survey of Japanese Business Structure and Activities* (BSJBSA) 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 operation is classified as the mining, manufacturing, and wholesale and retail trade, and eating and drinking places. It collects basic corporate finance data as well as detailed data on various business activities such as exports/imports and R&D activities. This survey started 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.[8] Response rates have been high and thus the size of the cross-section sample has been large, consisting of 25,000–30,000 firms each year.[9]

4.2 Sample Selection and Summary Statistics

We focus our attention on manufacturing firms. Further, we select a benchmark sample as follows. First, we exclude observations of firms with capital smaller than or equal to 100 million yen to focus on large firms. This is primarily because small or medium firms can choose between the R&D tax credit system for small or medium enterprises and that for all firms and, thus, including small or medium firms into the sample complicates our analysis substantially. [What is a fraction of aggregate R&D investment explained by these small/medium firms?]

Second, we only keep observations of firms of which accounting year closes in March. The new total tax credit system has become available for the accounting year that started after January 2003. Because the BSJBSA survey was conducted in June until 2007, in the 2004 BSJBSA survey, any firm of which 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 of which 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 keeping observations of which accounting year closes in March, we essentially keep the former groups of the firms in the sample in the benchmark analysis; a majority of Japanese firms close their accounting year in March.

Third, because tax credit under the incremental system crucially depends on firm's R&D expenditure over the past 5 years as described in Section 3, we reject observations missing past R&D expenditure data. For the benchmark analysis, we exclude observations with more than two years of missing R&D expenditure in the past five years, because the incremental tax credit system sets the base level to the average R&D expenditure over the selected three years in the past five years.[10] Table 4 describes the benchmark sample selection in detail.

Table 5 reports summary statistics for the benchmark sample. 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,

[8] Survey questionnaires were sent out to firms in June until 2007 and the timing has been shifted to March since 2008.

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

[10] We also tried alternative sample selections with respect to data on past R&D expenditure to check robustness. [Robustness check]

respectively. For those rows, the sample is restricted to the observations with strictly positive R&D expenditure. '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 expenditure. [Need to include 'Debt/Asset']

5 A R&D Investment Model with Financial Constraint

To understand how tax credits affect 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 $t+1$.

- Consider profit function, $\pi_t = \pi(K_t, z_t)$, 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.

- R&D expenditure is denoted by I_t while the law of motion for R&D capital stock is given by $K_{t+1} = (1-\delta)K_t + I_t$, where δ is depreciation rate.

- We assume quadratic capital adjustment costs and define $\psi(I_t, K_t) = I_t + \frac{\gamma}{2}(I_t/K_t)^2 K_t$. The quadratic adjustment cost of the form $\frac{\gamma}{2}(I_t/K_t)^2 K_t$ captures the difficulty in adjusting the amount of R&D capital. Since a large portion of R&D spending is the wages and salaries of highly educated scientists and engineers (see Lach and Schangerman (1989)), the coefficient γ partly reflects the degree of difficulty in hiring and firing these knowledge workers in the short period of time.

- We consider the following simplified tax credit systems before 2002 and after 2003. We assume that the amount of tax credit for R&D expenditure is given by $\varphi_t(I_t, I_{t-1})$, where

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

  The total tax credit system after 2003 provides the larger amount of tax credits than the incremental tax credit system before 2002, especially for the firms with a large amount of past R&D expenditures.

- Firm's short term debt at the beginning of period t is denoted by b_t. Here, b_t refers to the amount that the firm is supposed to repay in period t. The real interest rate is given by r.

5.1 A R&D investment model without financial friction

To examine the effect of tax credit on R&D investment decision, consider a simple two period investment model without financial constraint:

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

where $p < 1-\delta$ is the resale value of R&D capital.

To analyze the optimal investment decisions, 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 while MC^* and MC^{**} represent the marginal cost 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 $I_t = I^*$. On the other hand, 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 1-3 illustrate how the amount of R&D expenditure is determined under the incremental tax credit system. In Figure 1, when the past R&D expenditure is sufficiently low so that $I_{t-1} < I^{**}$, a firm benefits from the tax credit by choosing this year's R&D expenditure above 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 2, the past R&D expenditure is sufficiently high so that a firm's optimal choice of R&D expenditure is lower than the past R&D expenditure; in this case, a firm receives no tax credit. Figure 3 illustrates the intermediate case that $I^{**} \leq I_{t-1} < I^*$, where a firm chooses $I_t = I^*$ only if it leads to a higher profit than a profit from choosing $I_t = I^{**}$. In sum, 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. For example, consider a firm whose previous year's R&D expenditure is sufficiently lower than this year's "optimal" amount of 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. 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 does not affect neither the marginal cost nor the marginal return as long as this year's investment is larger than the last year's.

On the other hand, if a firm's optimal level of R&D expenditure is sufficiently lower than the previous year's R&D expenditure, then the tax credit reform in 2003 may positively affect the R&D expenditure. When a firm invests less than the previous year's in R&D (i.e., $I_t < I_{t-1}$), a firm is not eligible to any tax credit under the incremental tax credit system. On the other hand, under the total tax credit system, such a firm is eligible for 15 percent of tax credit. Thus, the change from the incremental to the total tax credit system will decrease the marginal cost of R&D investment by 15 percent and, as a result, the 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 depends on the past R&D expenditures before 2002. The firms with the large amount of R&D expenditures in 1997-2001 may experience a substantial change in the effective rate of tax credit in 2003. In contrast, the effective rate of tax credit does not change before and after the 2003 tax reform (given at 15 percent) for the firms without any R&D investment in 1997-2001. We exploit this variation of the effective rate of tax credit across firms in our empirical analysis.

5.2 A R&D investment model with financial constraint

R&D is difficult to finance through debt because of problems associated with proprietary information, highly uncertain returns, and lack of collateral value for R&D capital. Because the tax reform of 2003 may have a substantial impact on after-tax cash flow, the change from the incremental to the total tax credit system may have had an impact on R&D expenditure through relaxing firm's financial constraint. To examine this issue, we extend a two period investment model by incorporating financial constraint. See the analysis by Almeida, Campello, and Weisbach (2004).

Consider a firm with state (b_t, K_t, z_t, I_{t-1}) in the first period, where b_t represents the outstanding debt at the beginning of period t. We assume that, 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

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

where r denotes the real interest rate. 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 requires that the maximum amount of borrowing has to be less than the worst possible profit plus the resale value of firm in the second period:

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

Further, we assume that a firm cannot raise funds by issuing equity: $d_t \geq 0$.[11] Then, firm's investment problem in the first period t is given by

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

When there exists such financial constraint, the tax credit reform of 2003 may positively affect the R&D investment by relaxing the financial constraint. This can be seen from the budget constraint in 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 in the previous year (i.e., $I_{t-1} > 0$), the tax credit $\varphi_t(I_t, I_{t-1})$ would be higher after tax reform than before tax reform. As a result, the tax reform increases the R&D investment by increasing the internal fund 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 an 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 get zero profit with some positive probability while $p = 0$ 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 there is no possibility of borrowing. Since equity financing is also assumed to be restricted, as a result, 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

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

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

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 $\bar{I}(z_t, K_t, I_{t-1}, b_t)$, then the financial constraint is binding and the R&D expenditure under financial constraint is $\bar{I}(z_t, K_t, I_{t-1}, b_t)$. Since $\bar{I}(z_t, K_t, I_{t-1}, b_t)$ is decreasing in the amount of debt b_t and the past 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 tax credit reform in 2003 increases the internal cash flow by $0.15I_{t-1}$ and, as a result, the reform may increase the R&D expenditure of financially constrained firms as much as by $0.15I_{t-1}$. The model implies that, the larger amount of debt b_t a firm has, 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-capital ratio and the effective tax credit rate in our specifications.

6 Empirical Analysis

To examine the effect of tax credit on R&D investment, we estimate linear investment models using the BSJBSA data. Our base model is as follows.[12]

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

where RD_{it} is firm i's R&D expenditure in year t, τ_{it} is the effective rate of R&D tax credit for firm i's R&D expenditure in year t, Y_{it} is the sales of firm i in year t. The term μ_i captures firm fixed effects, η_t is time effects, and ϵ_{it} is the unobservable shocks that affect firm i's decision of 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 rate of tax credit, τ_{it}, defined by (1) using the BSJBSA data on R&D expenditure and sales. There are two omissions because of lack of information in the BSJBSA data. First, we do not take into account the fact that the credit is capped by a certain fraction (12–20 percent) of the corporate tax, because the data on corporate tax is not available in the BSJBSA data set. Second, we do not distinguish *Tokubetsu Shiken Kenkyu Hi* from other types of R&D expenditures.

Since we are interested in the effect of the change in the tax credit policies between 2002 and 2003, and to control for endogeneity due to the firm-specific effects μ_i, we take the first

[12] Our specification is similar to that in Bloom, Griffith, and Van Reenen (2002).

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 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 matters for R&D investment or not, we incorporate a debt to asset ratio that partially account for the cross-sectional variation in firm's internal funds into the above model. Specifically, we include the level of a debt to asset ratio as a proxy for financial constraint as well as its interaction with the effective rate of tax credit in equation (6) as

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

where b_{it} and K_{it} represent firm i's outstanding debt and fixed asset in the beginning of year t, respectively. We use the sum of liquid and fixed debt for b_{it} and the stock of fixed asset for K_{it}.[13] We also 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 tax credit reform in 2003 is especially large for the firms with a higher debt to asset ratio. To the extent that the higher debt to asset ratio leads to a tighter financial constraint, the positive value of θ can be interpreted as evidence that the 2003 tax credit reform promoted R&D expenditures of financially constrained firms.

Columns (1) and (2) in Table 6 report the results from the first difference regressions (7) and (9), respectively. In column (1), the estimated coefficient of $\Delta\tau_{it}$ is significantly positive at 2.33, indicating that the elasticity of R&D expenditure with respect to the effective rate of tax credit is 2.33 percent. Column (2) reports the estimates of the first-differenced equation with debt-to-asset ratio (9). The coefficient of $\Delta\tau_{it}$ is close to that in column (1). The estimated coefficient of $\Delta b_{it}/K_{it}$ is significantly negative, suggesting that an increase in the debt-to-asset ratio is correlated with a decline in the R&D expenditure between 2002 and 2003. One possible interpretation of this result is that a firm with the higher debt-to-asset ratio may face a tighter financial constraint for R&D investment. On the other hand, 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 that faces financial

[13] Data on K_{it} are constructed by the perpetual inventory method with the depreciation rate of 0.08. We multiply by 4 the book value of the fixed asset and use it for the initial value in the perpetual inventory method.

constraint. The median, 75 percentile, and 90 percentile of b_{it}/K_{it} are 0.6, 1.0, 1.6, respectively.

Columns (3)-(6) of Table 6 compares the effect of the effective tax credit rate on small and large firms. Because smaller firms are more likely to face a tighter financial constraint, it is expected that the effect of tax credit is larger for smaller firms than larger firms. To this end, we split the sample at the median of the fixed asset and estimate equations (7) and (9) separately for each sample. Columns (3)-(4) report the results for small firms, and columns (5)-(6) report the results for large firms. The coefficient of $\Delta\tau_{it}$ is larger in columns (3)-(4) than in columns in (5)-(6). Further, the estimated coefficient of the terms $\Delta b_{it}/K_{it}$ and $\Delta\tau_{it}b_{it}/K_{it}$ are significant in columns (3)-(4) but not in columns in (5)-(6). There results corroborate our theoretical prediction in Section 5, and suggests that the 2003 tax credit reform promoted R&D expenditures of small and financially constrained firms.

References

[1] Almeida, H., M. Campello, and M. Weisbach (2004) "The Cash Flow Sensitivity of Cash," *Journal of Finance*, 59: 1777-1804.

[2] Arrow, K. (1962) "Economic Welfare and the Allocation of Resources for Invention," NBER Chapters, in: The Rate and Direction of Inventive Activity: Economic and Social Factors, 609–626, National Bureau of Economic Research, Inc.

[3] Arellano, M., and S. Bond (1991) "Some Tests of Specification for Panel Data: Monte Carlo Evidence and an Application to Employment Equations," *Review of Economic Studies*, 58: 277-297.

[4] Bloom, N., Griffith R., Van Reenen, J. (2002) "Do R&D tax credits work? Evidence from a panel of countries 1979-1997," *Journal of Public Economics*, 85, 1-31.

[5] Bond, S. and C. Meghir (1994) "Dynamic Investment Models and the Firm's Financial Policy," *Review of Economic Studies*, 61(2): 197-222.

[6] Bond, S., Harhoff, D., and Van Reenen, J. (1999) "Investment, R&D, and Financial Constraints in Britain and Germany," London, IFS Working Paper No. 99/5.

[7] Brown, J.R., S.M. Fazzari, and B.C. Petersen (2009) "Financing Innovation and Growth: Cash Flow, External Equity, and the 1990s R&D Boom," *Journal of Finance*, 64(1): 151-185.

[8] Fazzari, S.M. Hubbard, R.G., and Petersen, B.C. (1988) "Financing Constraints and Corporate Investment," *Brookings Papers on Economic Activity*, 1: 141-205.

[9] Hall, B.H., (1993) "R&D tax policy during the eighties: success or failure?," *Tax Policy and the Economy*, 7, 1-36.

[10] Hall, B. H. (2002) "The Financing of Resrach and Development," *Oxford Review of Economic Policy*, 18(1): 35-51.

[11] Hall, B., Van Reenen, J. (2000) "How effective are fiscal incentives for R&D? A review of the evidence," *Research Policy*, 29, 449-469.

[12] Himmelberg, C.P., and B.C. Petersen (1994) "R&D and Internal Fiance: A Panel Study of Small Firms in High-Tech Industries," *Review of Economics and Statistics*, 76(1): 38-51.

[13] Howitt, P. and P. Aghion (1998) "Capital Accumulation and Innovation as Complementary Factors in Long-Run Growth," *Journal of Economic Growth*, 3(2), 111-30.

[14] Huang, C-H, Yang, C-H. (2009) "Tax Incentives and R&D Activity: Firm-Level Evidence from Taiwan," *Hi-Stat Discussion Paper*.

[15] Koga, T. (2003) "Firm size and R&D tax incentives," *Technovation*, 23, 643-648.

[16] Motohashi, K. (2010) "An empirical analysis of accumulation of R&D capital and performance of Japanese companies [in Japanese]," in: Macro Economy and Industrial Structure (ed. Fukao, K.), Keio University Press. 251-288.

[17] Ogawa, K. (2007) "Debt, R&D investment and technological progress: A panel study of Japanese manufacturing firms' behavior during the 1990s," *Journal of Japanese and International Economies*, 21, 403-423.

[18] Ohnishi, K., Nagata, A. (2010) "Does Tax Credit for R&D Induce Additional R&D Investment?: Analysis on the effects of gross R&D credit in Japan [in Japanese]," *Journal of Science Policy and Research Management*, 24, 400-412.

[19] Paff, L. A. (2005) "State-Level R&D Tax Credits: A Firm-Level Analysis," *Topics in Economic Analysis & Policy*, 5, Article 17.

[20] Romer, P. M. (1986): "Increasing Returns and Long Run Growth," *Journal of Political Economy*, 94, 1002–37.

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 $\Delta\tau_{it}$	-0.0019	-0.0050	-0.0024	0.0921	-0.0005	-0.0006
S.D. of $\Delta\tau_{it}$	0.0334	0.0349	0.0304	0.0303	0.0060	0.0061
No. of Observations	2124	2139	2111	1915	1897	1929
Year	2000	2001	2002	2003	2004	2005
Mean of τ_{it}	0.0167	0.0143	0.0134	0.1061	0.1063	0.1062
S.D. of τ_{it}	0.0349	0.0322	0.0311	0.0079	0.0083	0.0081
No. of Observations	2352	2384	2301	2060	2143	2098

Notes. The benchmark sample is used. (Source: Basic Survey of Japanese Business Structure and Activities)

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

$\overline{RD}_{i2002}$	$<= p25$	$(p25, p50]$	$(p50, p75]$	$> p75$
Mean of $\Delta\tau_{i2003}$	0.0744	0.0935	0.0977	0.1028
	(0.0021)	(0.0010)	(0.0009)	(0.0007)

Notes. Row designated by Mean of $\Delta\tau_{i2003}$ reports the sample average of the change in the effective rate of tax credit 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. (Source: Basic Survey of Japanese Business Structure and Activities)

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	0.0694	0.0352	0.0099
S.D. of τ_{it}	0.0000	0.0621	0.0493	0.0233
No. of Observations	31	27	67	1811

Notes. The benchmark sample is used. (Source: Basic Survey of Japanese Business Structure and Activities)

Table 4: Benchmark Sample Selection

	Observations deleted	Remaining observations
Original sample (manufacturing)		204091
Small or medium firms	126800	77291
Accounting year closed not in March	26003	51288
Missing past R&D	11772	39516

Notes. 'Small or medium firms' excludes 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 expenditure in the past five years prior to the given year. (Source: Basic Survey of Japanese Business Structure and Activities)

Table 5: Mean Characteristics of Benchmark Sample

	2001	2002	2003	2004
Sales (Y)	51477.40	53206.35	56266.52	58242.46
Net Profit	-133.53	685.04	1254.95	1533.89
# Employee (N)	903.37	878.58	907.91	897.50
Fixed Asset (K)	55920.41	52052.67	50065.44	47428.68
Debt (b)	36721.37	35111.96	35389.48	35094.14
b/K	1.0315	1.2258	1.3676	1.3194
R&D Expenditure	2334.37	2316.04	2436.00	2461.01
R&D Exp./Y	0.0281	0.0272	0.0266	0.0260
R&D Exp./N	1.1597	1.1918	1.2258	1.2574
Positive R&D	0.7010	0.6941	0.6915	0.7000
Observation	3438	3348	3287	3390

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 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 strictly positive R&D expenditure. All monetary values are nominal and in units of million yen. (Source: Basic Survey of Japanese Business Structure and Activities)

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

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
$\Delta\tau_{it}$	2.3304***	1.9616***	3.3205***	2.7608***	1.2380	1.1424
	[0.619]	[0.624]	[0.776]	[0.731]	[1.139]	[1.163]
$\Delta \ln Y_{it}$	0.5518***	0.5191***	0.5051**	0.3898**	0.6455***	0.6193***
	[0.110]	[0.109]	[0.200]	[0.194]	[0.104]	[0.110]
$\Delta \frac{b_{it}}{K_{it}}$		-0.0091***		-0.0079***		0.1609
		[0.003]		[0.003]		[0.122]
$\Delta\left(\tau_{it}\frac{b_{it}}{K_{it}}\right)$		0.2037***		0.2058***		0.0670
		[0.017]		[0.018]		[0.273]
Constant	-0.2235***	-0.2078***	-0.2764***	-0.2521***	-0.1431	-0.1426
	[0.060]	[0.061]	[0.069]	[0.066]	[0.116]	[0.116]
Observations	1,915	1,860	776	768	1,103	1,092

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. (Source: Basic Survey of Japanese Business Structure and Activities)

Appendix

Table 7: 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
$\Delta\tau_{it}$	1.6806	0.8829	5.5706∗	3.4898	−2.1821	−1.4140
	[2.0140]	[1.7374]	[3.2351]	[2.3219]	[2.4421]	[2.1050]
$\Delta \ln Y_{it}$	0.6043∗∗∗	0.5566∗∗∗	0.6253∗∗∗	0.4791∗∗	0.6299∗∗∗	0.6104∗∗∗
	[0.1038]	[0.1030]	[0.2000]	[0.1901]	[0.0960]	[0.1051]
$\Delta \frac{b_{it}}{K_{it}}$		−0.0126∗∗∗		−0.0085∗∗		0.1915
		[0.0034]		[0.0042]		[0.1177]
$\Delta\left(\tau_{it} \frac{b_{it}}{K_{it}}\right)$		0.2073∗∗∗		0.2172∗∗∗		−0.4715
		[0.0140]		[0.0165]		[0.3332]
Constant	−0.1710	−0.1138	−0.4958∗	−0.3314	0.1841	0.1383
	[0.1940]	[0.1694]	[0.3007]	[0.2192]	[0.2420]	[0.2142]
p-value of the test of overidentifying restriction	0.8787	0.2327	0.9180	0.3181	0.7564	0.9743
Observations	1716	1676	676	670	1014	1006

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. (Source: Basic Survey of Japanese Business Structure and Activities)

Table 8: Regression Results ($t = 2003$, with cap)

VARIABLES SAMPLE	$\Delta \ln RD_{it}$ Benchmark	$\Delta \ln RD_{it}$ Benchmark	$\Delta \ln RD_{it}$ Small K	$\Delta \ln RD_{it}$ Small K	$\Delta \ln RD_{it}$ Large K	$\Delta \ln RD_{it}$ Large K
$\Delta \tau_{it}$	0.1891	-0.1312	0.5904	0.1182	-0.1583	-0.3451
	[0.320]	[0.319]	[0.556]	[0.539]	[0.379]	[0.488]
$\Delta \ln Y_{it}$	0.5311***	0.5105***	0.4598***	0.3673**	0.6436***	0.6176***
	[0.092]	[0.092]	[0.158]	[0.154]	[0.109]	[0.112]
$\Delta \frac{b_{it}}{K_{it}}$		-0.0142**		-0.0139**		0.1547
		[0.006]		[0.007]		[0.126]
$\Delta \left(\tau_{it} \frac{b_{it}}{K_{it}} \right)$		0.1851***		0.1863***		0.2200
		[0.033]		[0.039]		[0.444]
Constant	-0.0213	-0.0112	-0.0230	-0.0088	-0.0135	-0.0149
	[0.027]	[0.026]	[0.046]	[0.044]	[0.032]	[0.032]
Observations	1,915	1,860	776	768	1,103	1,092

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. (Source: Basic Survey of Japanese Business Structure and Activities)

Table 9: Regression Results ($t = 2003$, Positive Profit)

VARIABLES SAMPLE	$\Delta \ln RD_{it}$ Benchmark	$\Delta \ln RD_{it}$ Benchmark	$\Delta \ln RD_{it}$ Small K	$\Delta \ln RD_{it}$ Small K	$\Delta \ln RD_{it}$ Large K	$\Delta \ln RD_{it}$ Large K
$\Delta \tau_{it}$	2.5501***	2.6835***	3.8545***	4.3465***	1.1386	0.8413
	[0.728]	[0.807]	[0.932]	[1.030]	[1.257]	[1.280]
$\Delta \ln Y_{it}$	0.5740***	0.5642***	0.5561*	0.4866*	0.6593***	0.6150***
	[0.159]	[0.164]	[0.286]	[0.289]	[0.157]	[0.170]
$\Delta \frac{b_{it}}{K_{it}}$		0.0175		0.0316		0.2103
		[0.024]		[0.026]		[0.162]
$\Delta \left(\tau_{it} \frac{b_{it}}{K_{it}} \right)$		-0.0139		-0.1155		0.4622
		[0.202]		[0.219]		[0.363]
Constant	-0.2202***	-0.2342***	-0.3140***	-0.3474***	-0.1054	-0.1111
	[0.072]	[0.076]	[0.084]	[0.088]	[0.128]	[0.128]
Observations	1,353	1,312	536	532	790	780

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. (Source: Basic Survey of Japanese Business Structure and Activities)

Table 10: 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
$\Delta\tau_{it}$	3.3848 **	3.1210 **	4.7624 **	4.6577 **	1.2837	1.5742
	[1.5614]	[1.4341]	[2.1478]	[1.9110]	[2.3539]	[2.3423]
$\Delta \ln Y_{it}$	0.4392 ***	0.4258 ***	0.4035 ***	0.3715 ***	0.4814 ***	0.4819 ***
	[0.0555]	[0.0551]	[0.0853]	[0.0838]	[0.0653]	[0.0660]
$\Delta \frac{b_{it}}{K_{it}}$		-0.0062		-0.0053		0.0421
		[0.0042]		[0.0038]		[0.0588]
$\Delta\left(\tau_{it}\frac{b_{it}}{K_{it}}\right)$		0.2284 ***		0.2270 ***		-0.8287*
		[0.0187]		[0.0172]		[0.4430]
$Year2001$	0.0361*	0.0391 **	0.0223	0.0181	0.0492 **	0.0311
	[0.0196]	[0.0199]	[0.0384]	[0.0390]	[0.0219]	[0.0336]
$Year2002$	-0.0238	-0.0247	-0.0677*	-0.0653	0.0041	0.0043
	[0.0204]	[0.0205]	[0.0398]	[0.0400]	[0.0226]	[0.0228]
$Year2003$	-0.3075 **	-0.3061 **	-0.4130 **	-0.4383 **	-0.1176	-0.0916
	[0.1528]	[0.1414]	[0.2055]	[0.1846]	[0.2344]	[0.2325]
Constant	-0.0208	-0.0208	-0.0038	-0.0023	-0.0337 **	-0.0327 **
	[0.0138]	[0.0138]	[0.0272]	[0.0272]	[0.0153]	[0.0154]
p-value of the test of overidentifying restriction	0.1287	0.1280	0.4151	0.3933	0.2011	0.3799
Observations	7049	6938	2687	2668	4283	4270

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. (Source: Basic Survey of Japanese Business Structure and Activities)

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

	(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
$\Delta\tau_{it}$	1.7895	2.0482	3.5311	3.3992	0.7663	1.0004
	[2.2416]	[2.2507]	[2.9905]	[2.9905]	[2.4594]	[2.3694]
$\Delta \ln Y_{it}$	0.4417 * **	0.4162 * **	0.3936 * **	0.3605 * **	0.4807 * **	0.4910 * **
	[0.0697]	[0.0689]	[0.1052]	[0.1048]	[0.0701]	[0.0768]
$\Delta \frac{b_{it}}{K_{it}}$		−0.0075		−0.0078*		0.0493
		[0.0047]		[0.0040]		[0.0681]
$\Delta\left(\tau_{it}\frac{b_{it}}{K_{it}}\right)$		0.2289 * **		0.2221 * **		−1.4582
		[0.0205]		[0.0171]		[1.5981]
$Year2001$	0.0392*	0.0426 * *	0.0279	0.0263	0.0481 * *	0.0293
	[0.0204]	[0.0205]	[0.0401]	[0.0407]	[0.0223]	[0.0366]
$Year2002$	−0.0238	−0.0263	−0.0716*	−0.0703*	0.0036	0.0054
	[0.0212]	[0.0212]	[0.0419]	[0.0421]	[0.0227]	[0.0230]
$Year2003$	−0.1099	−0.1462	−0.2142	−0.2313	−0.0516	0.0040
	[0.1643]	[0.1653]	[0.2145]	[0.2155]	[0.1835]	[0.2362]
Constant	−0.0251*	−0.0240*	−0.0093	−0.0075	−0.0329 * *	−0.0335 * *
	[0.0143]	[0.0142]	[0.0284]	[0.0284]	[0.0156]	[0.0157]
p-value of the test of overidentifying restriction	0.1687	0.2160	0.6800	0.4925	0.0894	0.1931
Observations	7049	6938	2687	2668	4283	4270

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. (Source: Basic Survey of Japanese Business Structure and Activities)

Table 12: GMM Estimation ($t = 2000 - 2003$, Positive Profit)

	(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
$\Delta\tau_{it}$	2.8898	3.1598*	4.7682*	5.2439**	1.8498	1.9804
	[1.8578]	[1.6175]	[2.5623]	[2.1783]	[2.2458]	[2.3506]
$\Delta \ln Y_{it}$	0.4837***	0.4554***	0.3683***	0.3304***	0.5929***	0.5901***
	[0.0880]	[0.0864]	[0.1308]	[0.1248]	[0.0957]	[0.0974]
$\Delta \frac{b_{it}}{K_{it}}$		-0.0127		-0.0050		0.0868
		[0.0197]		[0.0202]		[0.0799]
$\Delta\left(\tau_{it}\frac{b_{it}}{K_{it}}\right)$		0.2753*		0.2152		-0.4464
		[0.1664]		[0.1677]		[0.4016]
$Year2001$	0.0303	0.0326	-0.0183	-0.0238	0.0562**	0.0165
	[0.0258]	[0.0282]	[0.0509]	[0.0540]	[0.0267]	[0.0425]
$Year2002$	0.0216	0.0217	-0.0120	-0.0119	0.0427	0.0425
	[0.0258]	[0.0256]	[0.0513]	[0.0511]	[0.0259]	[0.0261]
$Year2003$	-0.2525	-0.3030*	-0.4248*	-0.4959**	-0.1577	-0.1449
	[0.1807]	[0.1579]	[0.2448]	[0.2076]	[0.2232]	[0.2228]
Constant	-0.0022	-0.0003	0.0393	0.0429	-0.0271	-0.0272
	[0.0182]	[0.0181]	[0.0368]	[0.0363]	[0.0186]	[0.0184]
p-value of the test of overidentifying restriction	0.1551	0.2262	0.7106	0.7645	0.0846	0.1795
Observations	4324	4258	1653	1641	2627	2617

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. (Source: Basic Survey of Japanese Business Structure and Activities)

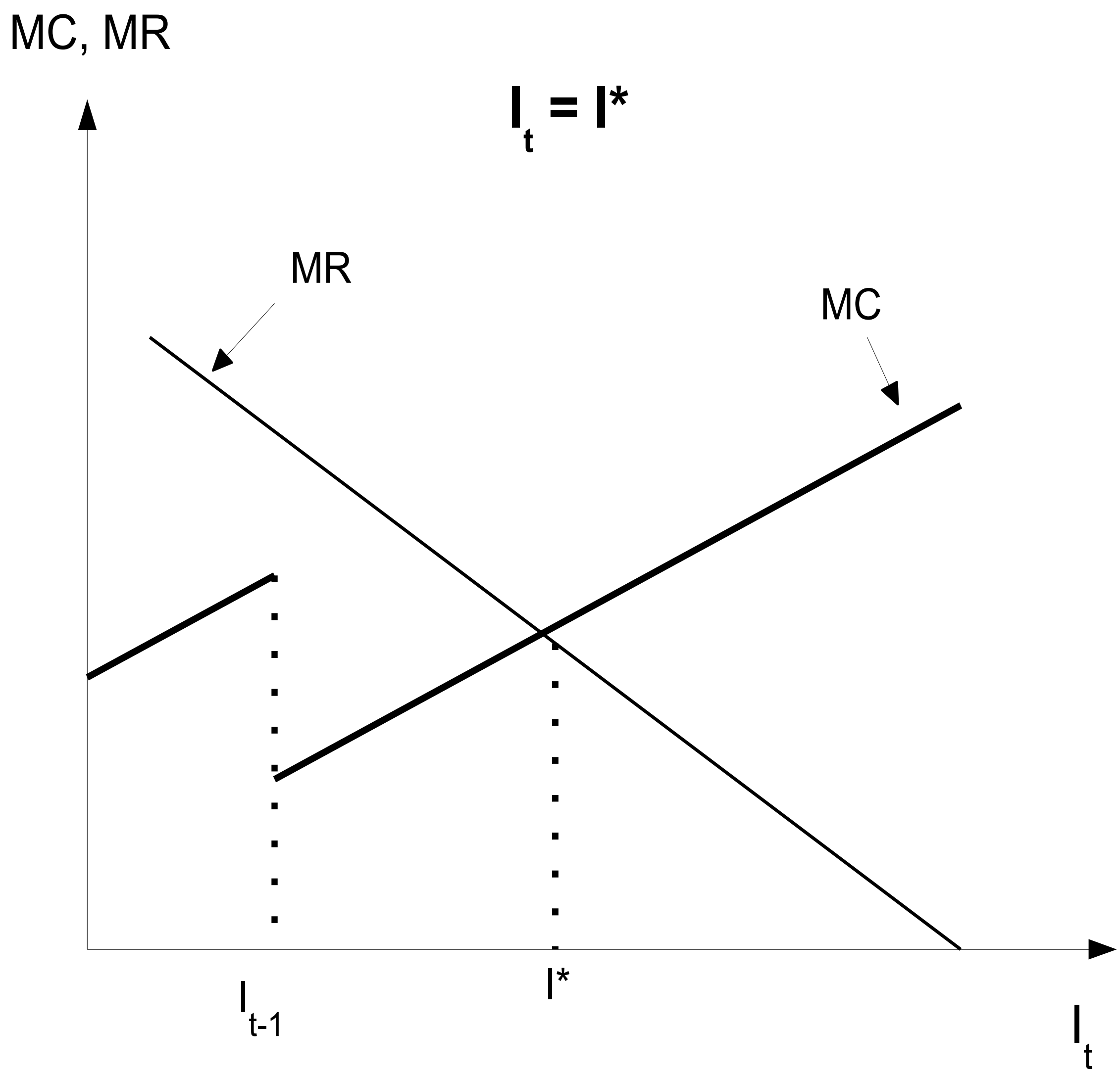

Figure 1: R&D Investment Decision for Low Value of I_{t-1}

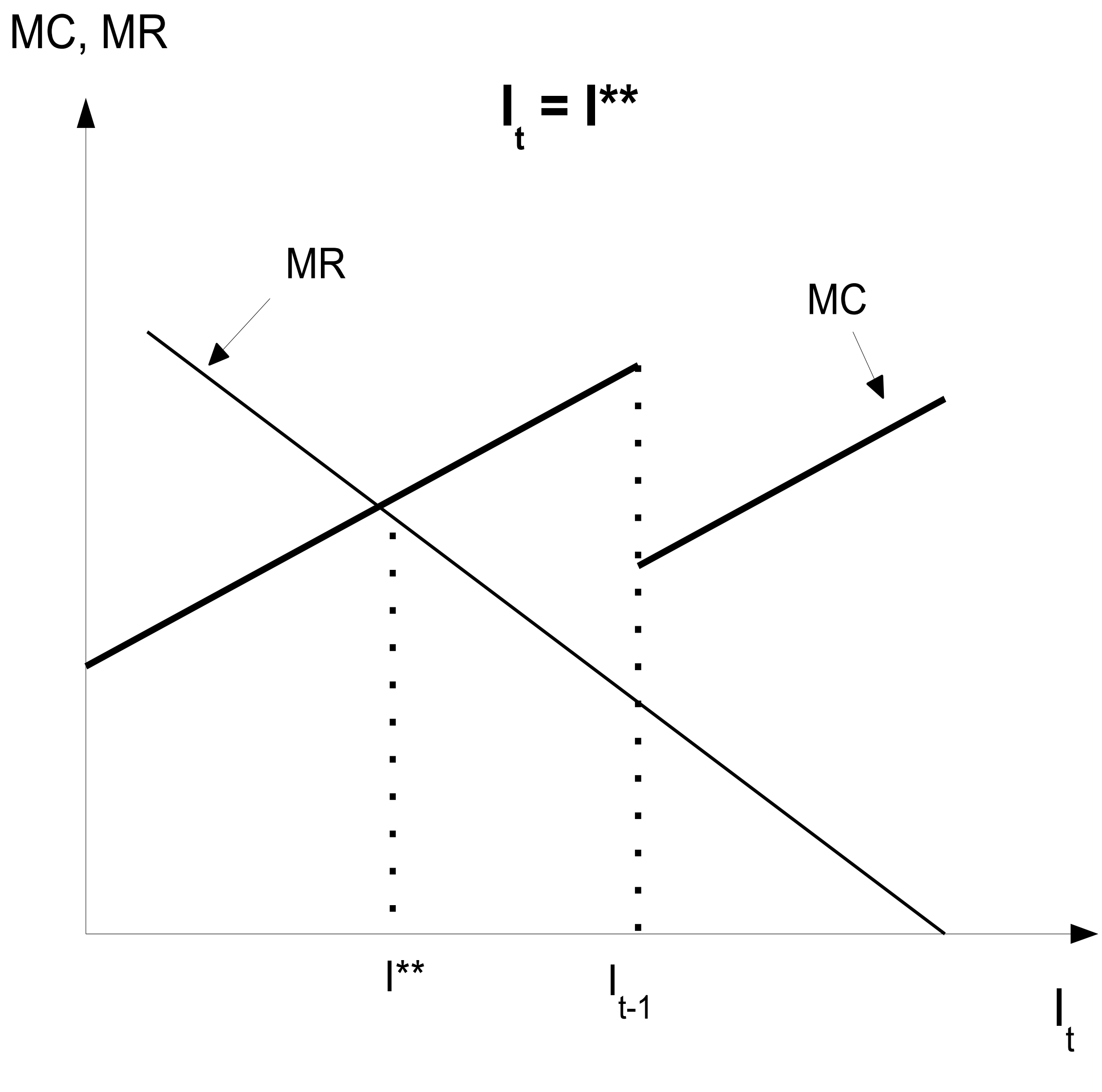

Figure 2: R&D Investment Decision for High Value of I_{t-1}

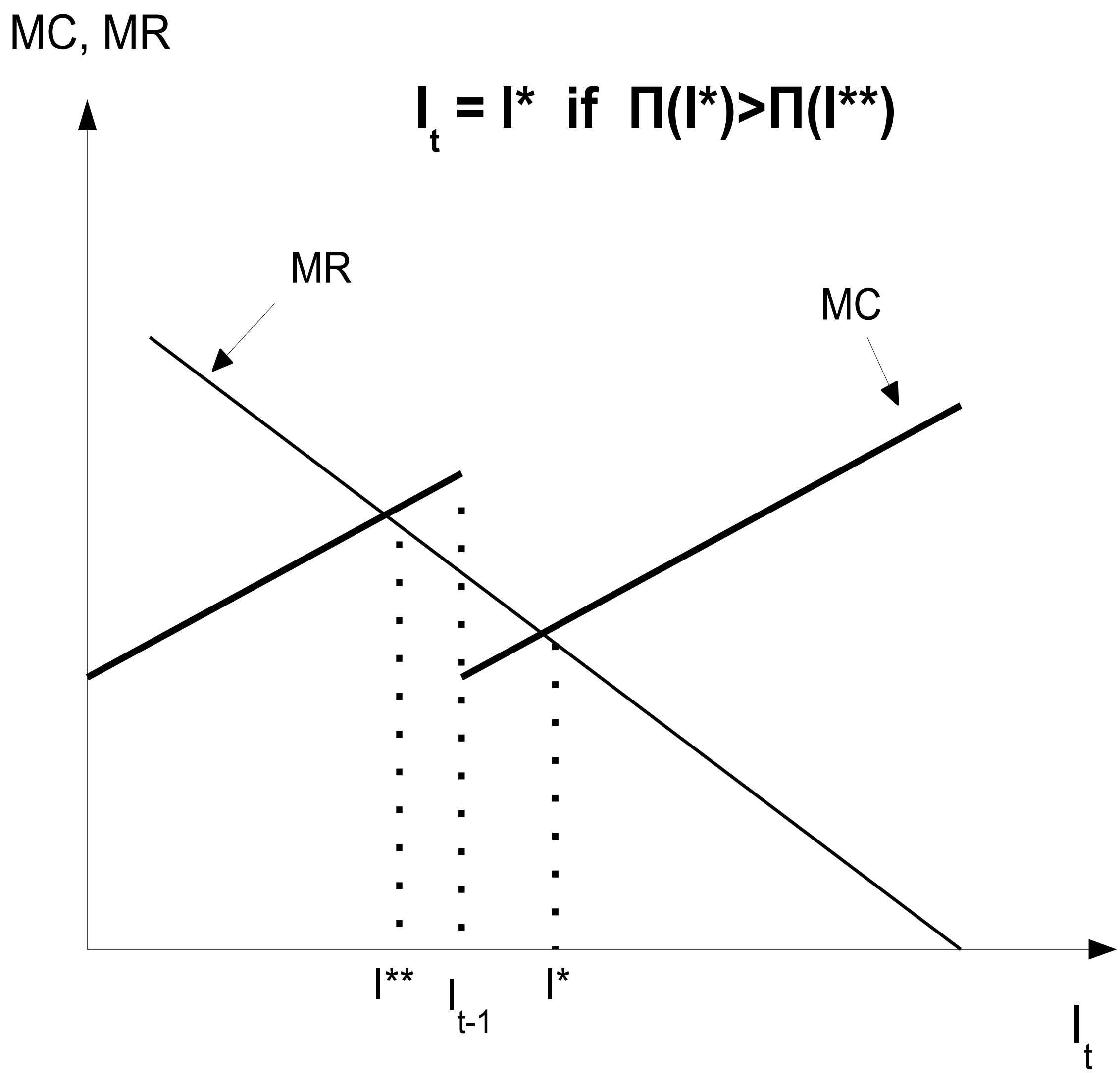

Figure 3: R&D Investment Decision when $I^{**}<I_{t-1}<I^{*}$