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Impact of Tax Credit Reforms on R&D Investments: A GMM Analysis of Japanese Firms

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Abstract

This study examines the effectiveness of research and development (R&D) tax credits in promoting R&D investment by focusing on the design of incentives and using publicly available financial data. Recognizing the vital role of R&D in economic growth, the Japanese government has implemented tax credit systems since 1967, with significant changes reflecting national economic policies. This study emphasizes the revisions introduced under the Japan Revitalization Strategy by the Abe Cabinet in 2014 and calculates eligible R&D tax credits for corporations listed on the Tokyo Prime Stock Exchange. To assess the changes in R&D expenditure levels before and after these revisions, this study employs a one-step generalized method of moments (GMM) estimation using balanced panel data from FY 2006 to 2022. The analysis reveals two key findings: First, while the R&D tax credit generally encourages firms to increase R&D investments, the post-2014 system is less effective than earlier versions, suggesting that the amendments have not fully achieved their intended goals. Second, the significance and magnitude of previous R&D spending highlight the importance of ongoing R&D strategies and tax credit policies as critical determinants of investment decisions. This study contributes to the literature by estimating eligible R&D tax credits through historical analysis, validating the effectiveness of the tax credits using publicly available data, and providing insights into corporate R&D behavior.

Keywords: Research and development (R&D), tax credits, general method of moments (GMM) analysis, Japanese firms

1. INTRODUCTION

Tax credits and subsidies for research and development (R&D) expenditures are often justified by the existence of technology or product market spillovers[1] (Arrow 1962; Boolm et al. 2013; Czarnitzki et al. 2011; Grossman & Helpman 1993; Hall 2002). Arrow (1962, p.618) characterizes technological spillovers as “commodities” integral to the growth process by facilitating further innovation, thereby emphasizing their pivotal role in generating additional knowledge. However, the discrepancy between the returns from R&D and the expenditures—due to the public goods-like characteristics of R&D spending and the resultant knowledge spillovers—may deter firms from investing in R&D, potentially undermining both national competitiveness and the firm’s own prospects (Agrawal et al. 2020; Bloom et al. 2013). Such dynamics underscore the societal value of R&D investment, which often exceeds the direct returns on investing firms, making a compelling case for public support to bridge the gap (Arrow 1962; Atkinson 2007; Morotomi & Kawakatsu 2015).
Governments, including those in Japan, recognize the vital role of R&D activities in economic growth and the necessity of encouraging companies to engage in R&D. Corporate tax credits and subsidies are offered to

[1] Grossman & Helpman (1993. P.335) explain that the most industrial R&D generates two main types of outputs: product-specific information that allows a firm to develop a new product and broader technical knowledge that supports future innovations. Bloom et al. (2013) refer to these as the product market rivalry effect and technology (or knowledge) spillovers, respectively. Technological spillovers, defined as externalities, occur when firms access information created by others without a market transaction and without legal recourse for the original creators if this information is used by other firms (Grossman & Helpman, 1993, p.16). For further detailed definitions, see Dumont & Meeusen (2000).

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compensate for the inherent losses[2] when knowledge becomes a public good. These measures are supported by a substantial body of research confirming the effectiveness of tax policy in significantly influencing the level and timing of investment expenditures (Agrawal et al. 2020; Bloom et al. 2002; Hall & Jorgenson 1967; Hall 1993; Rao 2016).

Since 1967, the Japanese government has promoted R&D investments through tax credits legislated by the Special Measures Concerning Taxation Act (hereafter, the Special Measures Act) and its subsequent amendments. These policies have been deemed successful[3], as evidenced by the increase in Japan's cumulative research expenses from JPY 11.8539 trillion in 1994 to JPY 19.4725 trillion in 2019, positioning Japan third in the world after the United States and China. However, the growth rate in Japan's research expenditures, at a 1.6-fold increase, is relatively modest compared with the growth rates observed in countries like the United States (2.4-fold), Germany (2.1-fold), China (30.8-fold), and South Korea (6.5-fold) (Nagata et al. 2022, p.2). Japan's struggle to increase R&D investment in the private sector is illustrated in Figure 1. Based on the Survey of Research and Development conducted by the Ministry of Internal Affairs and Communications (MIC), R&D expenditures increased only 23.2% from JPY 16.8 trillion in 2003 to JPY 20.7 trillion in 2022.

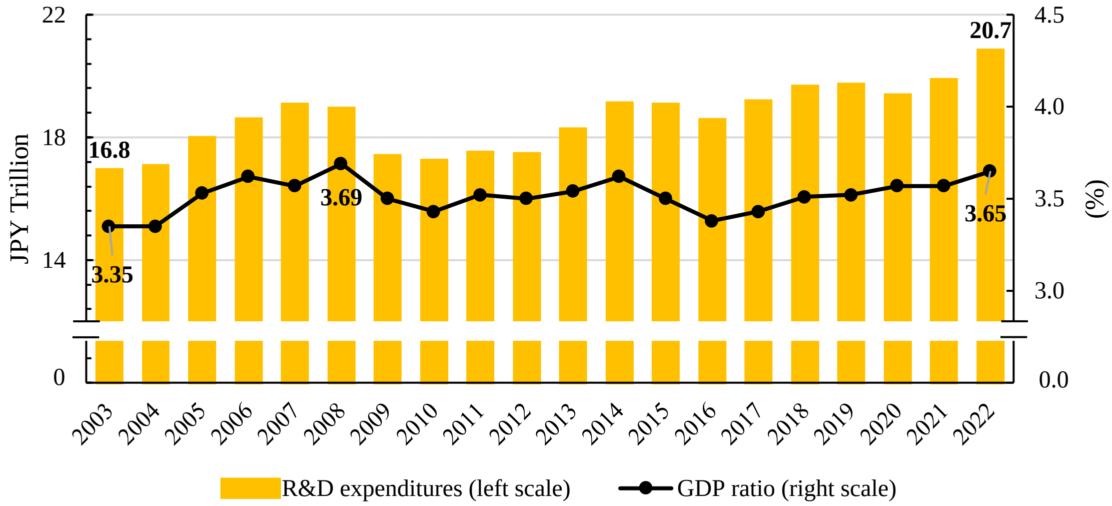

Figure 1. Growth of R&D expenditures and gross domestic product (GDP) ratio
Source: This figure is based on the research and development survey conducted by the Ministry of Internal Affairs and Communications (MIC). The latest survey coverage classification includes approximately 13,500 business enterprises, 1,100 non-profit institutions and public organizations, and 4,000 universities and colleges (MIC, 2004-2023).

The discrepancy between Japan and other countries becomes even more pronounced when examining intangible asset market value (IAMV). A 2020 study by Ocean Tomo highlights significant trends in IAMV across major global indexes, reflecting shifts in the economic landscape and their implications for competitiveness and R&D investments. For instance, IAMV accounted for 90% of the total market value of the S&P 500 companies, a notable increase from 68% in 1995. By contrast, Japan's IAMV represented only 32% of the total value of Nikkei-225 companies, rising from 15% in 2010 but declining from a peak of 52% in 2005. South Korea's IAMV in the KOSDAQ Composite Index stood at 57%, whereas China's in the Shanghai Shenzhen CSI 300 Index was 44%[4]. These figures underscore the challenges faced in Japan's competitive position.

[2] Nagata et al. (2022, p.9) report that the effectiveness of appropriability mechanisms has considerably declined over the years, making it increasingly difficult for companies to derive adequate profits from their innovations. This conclusion is based on an analysis of the Innovation Survey on Industrial Technology conducted by the Science and Technology Policy Bureau of the Science and Technology Agency in 1994 and by the National Institute of Science and Technology Policy in 2020.
[3] Revisions on the Special Measures Act have played a crucial role in shaping Japan's R&D landscape, as demonstrated by existing research. The 2003 revision, for instance, introduced a tax credit system based on total R&D expenses, raising the effective R&D tax credit rate from 1% or less to 10% or more (Motohashi, 2009, p.273). Kasahara et al. (2014, p.74) report that this revision increased aggregate R&D expenditure by 0.3–0.6% by easing financial constraints on firms with outstanding debts. Hosono et al. (2015) find that it significantly facilitated investment by reducing the cost of capital, especially for firms in industries with low dependence on external funding.
[4] Japan's Nikkei-225 Stock Average is a price-weighted index of 225 top-rated companies listed on the Tokyo Stock Exchange. Korea's KOSDAQ Index is a capitalization-weighted index that measures the performance of equities on the South Korean KOSDAQ market. China's Shanghai Shenzhen SCI 300 Index is a free-float weighted index comprising 300 A-share stocks listed on the Shanghai or Shenzhen Stock Exchanges (Ocean Tomo, 2020, p.3).

The Tax Commission (2014, p.4) emphasizes that the R&D tax credit policy is the largest taxation measure and the most significant tax credit system. However, based on the evidence above, tax policy and implementations did not appear to achieve the intended purpose of the tax credit system, thus accelerating R&D investments by Japan's leading corporations. To examine these discrepancies between the aim of tax credit policy and the substance of R&D investment among leading corporations, this study critically evaluates the effectiveness of tax credit policies on corporate R&D expenditures, focusing on corporations listed on the Tokyo Prime Stock Exchange[5].

Section 2 examines the amendments to the Special Measures Act, detailing the conditions and calculations for eligible R&D tax credits in response to the nation's economic policy to boost information and technology. It also traces the evolution of these amendments, highlighting major changes. Section 3 reviews the relevant literature to establish the foundation for the research questions. Section 4 outlines the model, variables, and method used in the analysis. Section 5 discusses the sample selection and provides a descriptive analysis. Section 6 analyzes the relationship between R&D expenditures and tax credits in listed corporations before and after significant policy changes and assesses the effectiveness of the tax credit measures. Robustness tests and further discussion are conducted to validate the findings. Finally, the conclusions and limitations are presented in Section 7.

2. DEVELOPMENT OF THE R&D TAX CREDIT SYSTEM[6]

The evolution of Japan's Tax Credit System for R&D expenditure can be divided into three distinct phases: the introduction and adjustment period for the incremental tax credit system (1967[7] to 2002), the introduction and expansion of the system for the total tax credit system under the Structural Reforms of the Koizumi Cabinet (2003 to 2013), and the bifurcation of two tax credit systems under the economic policies of Abenomics and the Japan Revitalizing Plan (2014 to 2021). As the R&D tax credit system is regulated by the Special Measures Act, which aims to achieve national economic policy objectives through policy-driven tax reduction (Narimichi & Sakamoto 2021), this division based on Japan's broader economic strategies is appropriate for examining the development of the R&D tax credit system. Owing to page limitations and to clarify the main measures, the introduction and adjustment periods for the incremental tax credit system are illustrated in the Appendix A.

This section focuses on the revisions from FY 2003 to 2022, covering the scope of the empirical estimation. This study explores how strategic adjustments have shaped the system's current framework, reflecting Japan's approach to fostering innovation in alignment with changing economic conditions and policies. Generally, the system consists of four dimensions: (1) the general measure, which is the fundamental one applied to any corporation filing blue tax returns; (2) the special measure, applied to corporations conducting specialized experimentation and research, such as in cooperation with national research institutions or universities; (3) the small and medium-sized enterprises (SME) measure, applied to SMEs to strengthen their technology base; and (4) the additional measure, applied to corporations with significant R&D expenditure. This study focuses on prime market-listed firms and uses publicly available information that does not provide detailed data on R&D activities; thus, this section emphasizes general and additional measures.

2.1 Introduction and expansion of total tax credit system

In the second phase, spanning the fiscal years from 2003 to 2013, new measures were introduced and expanded as part of the Koizumi cabinet's structural reforms. To enhance industry competitiveness, the "Tax Credit System for Total Experimentation and Research Expenditures" (hereafter referred to as the "Total Credit Type") was introduced, replacing the "Incremental Experimentation and Research Expenditure Tax Credit System" (hereafter referred to as the 'Incremental Credit Type' (refer to the Appendix for details). Total Credit Type measures allow deductions from corporate tax liabilities based on total R&D expenditures, regardless of any increase or decrease in R&D expenditures from the previous year (ESRI, 2002). By allowing companies to choose the most beneficial option between the Incremental Credit Type and the Total Credit Type, the scope of R&D tax credits was significantly broadened (Hosono et al., 2015; Kasahara et al., 2014). Furthermore, these reforms made the previous temporary preferential tax system permanent, enabling companies to strategize their

[5] Another reason the study focuses on firms listed on the Tokyo Prim Stock Exchange is that young firms seldom generate sufficient profits in their earlier stages, making it almost impossible for them to benefit from the tax credit policy (Appelt et al., 2023, p.45).
[6] The intricacies of the tax credit systems draw extensively from the literature of Onishi & Nagata 2009 and Morotomi & Kawakatsu (2015) and publications by National Tax Agency (NTA) (2003, 2015, 2019). The formulation's structure is predominantly based on Kasahara et al. (2014) and Hosono et al. (2015).
[7] Onishi & Nagata (2009) and Morotomi & Kawakatu (2015) state the incremental type was initiated in 1968. However, NTA (2003, p.12) suggests that the incremental type system was implemented in June 1967.

R&D investments from a long-term tax perspective. Consequently, tax deductions substantially increased under the Total Credit Type after 2003, rising 6 to 11 times, as reported by Onishi & Nagata (2009, pp.401-402).

The eligible tax credit amount under the Total Credit Type (T_X_{it}) is determined as illustrated in Equation (1), which is divided into two parts based on the R&D ratio (x_{it}), which is the ratio of R&D expenditure (RD_{it}) to average of sales revenue over the preceding four years ($\frac{1}{4}\sum_{k=0}^{3} S_{it-k}$) . A firm with an R&D ratio (x_{it}) of 10% or greater may be eligible for a potential tax credit (X_{it}^{*}) of 10% of its R&D expenditures. This potential tax credit (X_{it}^{*}) is capped at 20% of corporate tax paid (T_{it}). For firms where the R&D ratio (x_{it}) is less than 10%, the potential tax credit is determined by multiplying the R&D expenditure by R&D ratio (x_{it}) times 0.2 and adding 8% to this figure. This potential R&D credit (X_{it}^{*}) is also subject to the 20% cap on the corporate tax paid.

$$T\_X_{it}^{2003-2016} = \begin{cases} X_{it}^{*} & if\ Cap_t T_{it} \geq X_{it}^{*} \\ Cap_t T_{it} & if\ Cap_t T_{it} < X_{it}^{*} \end{cases} \quad where\ X_{it}^{*} \begin{cases} 0.1(*)RD_{it} & if\ x_{it} = \frac{RD_{it}}{\frac{1}{4}\sum_{k=0}^{3} S_{it-k}} \geq 0.1 \\ RD_{it}(0.08\ (**) + 0.2x_{it}) & if\ x_{it} = \frac{RD_{it}}{\frac{1}{4}\sum_{k=0}^{3} S_{it-k}} < 0.1 \end{cases} \quad (1)$$

where (***) denotes $\mathrm{Cap_t} = 0.2$ if $\mathrm{t} =$ from 2003 to 2012, $\mathrm{Cap_t} = 0.3$ if $\mathrm{t} =$ from 2013 to 2014, and $\mathrm{Cap_t} = 0.25$ if $\mathrm{t} =$ from 2015 to 2016.
Notes: (*): The tax credit ratio was temporarily set at 12% until 2005, after which it decreased to 10%. (**): The additional ratio was temporarily set at 10% until 2005, after which it decreased to 8%. (***) Subsequent reforms in FY 2013 raised the tax credit limit for the total amount type from 20% to 30% of the corporate tax paid, applicable throughout FY 2014. In FY 2015, the system maintained a tax credit limit of 25% of the corporate tax paid.

In 2006, the Incremental Type was abolished, and a revised framework introduced an additional tax credit cap of 5% on incremental R&D expenditures, calculated as the differences between current R&D expenditures (RD_{it}) and average R&D expenditures over the preceding three years (comparative R&D expenditure $\mathrm{C}\_\overline{RD}_{it}$). To qualify for this additional credit measure (Add_X_{it}), a corporation's current R&D expenditure (RD_{it}) must exceed both the comparative R&D expenditure ($\mathrm{C}\_\overline{RD}_{it}$) and the highest amount of R&D expenditures recorded in the last two years (Equation (2)).

$$Add\_X_{it}^{2006-2007} = ((RD_{it} - C\_\overline{RD}_{it}) \times 0.05) \quad if\ RD_{it} > C\_\overline{RD}_{it}\ and\ RD_{it} > max\{RD_{it-1}, RD_{it-2}\} \quad (2)$$

In 2008, this additional credit measure (Add_X_{it}) was superseded, and a new top-up measure was introduced. This modification enables companies to opt for combinations of tax credits: either the Total Credit Type and Additional Incremental Type (AI_X_{it}) or the Total Credit Type and Additional High-level Credit Type (AH_X_{it}). These changes enhance the adaptability and effectiveness of the tax credit system, thereby supporting diverse R&D investment strategies across sectors. The credit types are described below.

- Additional Incremental Credit Type (AI_X_{it}): This allows eligible corporations an additional tax credit equivalent to 5% of their incremental R&D expenditures ($RD_{it} - \mathrm{C}\_\overline{RD}_{it}$) capped at 10% of the current year's corporate income tax. To apply this Additional Incremental Credit Type, a corporation's R&D expenditure must exceed both comparative R&D expenditure and the highest of R&D expenditure recorded in the last two years, as detailed in Equation (3).

- Additional High-level Credit Type (AH_X_{it}): This tax credit is granted when the current R&D expenditure exceeds 10% of the average revenue over the last four years ($\frac{1}{4}\sum_{k=0}^{3} S_{it-k}$). The calculation is based on the amount remaining after subtracting 10% of the average revenue from the current period's R&D expenditures, followed by the application of the excess tax credit ratio. This ratio is computed by subtracting 10% of the R&D ratio (x_{it}) of current R&D expenditure from the average revenue ($\frac{1}{4}\sum_{k=0}^{3} S_{it-k}$) and then multiplying by 0.2, as shown in Equation (4).

$$AI\_X_{it}^{2008-2013} = \begin{cases} AI\_X_{it}^{*} & if\ 0.1T_{it} > AI\_X_{it}^{*} \\ 0.1T_{it} & if\ 0.1T_{it} \leq AI\_X_{it}^{*} \end{cases}$$
$$where\ AI\_X_{it}^{*} = ((RD_{it} - C\_\overline{RD}_{it}) \times 0.05) \quad if\ RD_{it} > C\_\overline{RD}_{it}\ and\ RD_{it} > max\{RD_{it-1}, RD_{it-2}\} \quad (3)$$

$$AH\_X_{it}^{2008-2018} = \begin{cases} AH\_X_{it}^{*} & if\ 0.1T_{it} > AH\_X_{it}^{*} \\ 0.1T_{it} & if\ 0.1T_{it} \leq AH\_X_{it}^{*} \end{cases}$$
$$where\ AH\_X_{it}^{*} = \left(RD_{it} - 0.1 \times \frac{1}{4}\sum_{k=0}^{3} S_{it}\right) \times \left((x_{it} - 0.1) \times 0.2\right) \quad if\ RD_{it} > 0.1 \times \frac{1}{4}\sum_{k=0}^{3} S_{it-k} \tag{4}$$

2.2 Development of Japan's dual R&D tax credit system[8]

The last phase in the development of Japan's R&D tax credit system, beginning in 2014 and continuing to the present, is characterized by a bifurcation in the tax credit computation, encompassing both the Incremental and Total Credit Types. This period is also identified as the innovation promotion period under the Japan Revitalization Strategy, which commenced in 2014 (Cabinet Office, 2014). The Abe Cabinet set a target for total R&D investment by the public and private sectors to reach at least 4% of GDP (PMOJ 2014, p.76). To achieve this ambitious goal, the Additional Incremental Credit Type was updated by adjusting the tax credit ratio based on the increase in R&D expenditure, followed by significant revisions.

To benefit from the updated Additional Incremental Credit Type, a corporation's R&D expenditure must exceed the highest R&D expenditures in the last two years. Additionally, excess R&D expenditure ($ExcRD_{it}$)—calculated by subtracting the comparative R&D expenditure ($C\_\overline{RD}_{it}$) from the deductible R&D expenditure (RD_{it}) for the relevant fiscal year—must exceed 5% of the comparative R&D expenditure. The incremental R&D ratio (i_x_{it}) was introduced, which was determined by dividing excess R&D expenditure ($ExcRD_{it}$) by the comparative R&D expenditure ($C\_\overline{RD}_{it}$). If the incremental R&D ratio (i_x_{it}) is equal to or greater than 30%, 0.3 is multiplied by the excess R&D expenditure ($ExcRD_{it}$) amount to determine the potential additional tax credit ($AI\_X_{it}^{*}$). If the incremental R&D ratio is less than 30%, this ratio (i_x_{it}) is multiplied by the excess R&D expenditure ($ExcRD_{it}$) amount instead of the full 30% to calculate the potential additional tax credit ($AI\_X_{it}^{*}$). This potential additional tax credit is subject to a 10% cap on the corporate tax paid (Equation (5)).

$$AI\_X_{it}^{2014-2016} = \begin{cases} AI\_X_{it}^{*} & if\ 0.1T_{it} > AI\_X_{it}^{*} \\ 0.1T_{it} & if\ 0.1T_{it} \leq AI\_X_{it}^{*} \end{cases} \quad where\ AI\_X_{it}^{*} = \begin{cases} (ExcRD_{it}(*) \times 0.3) & if\ \ i\_x_{it} = \frac{ExcRD_{it}}{C\_\overline{RD}_{it}} \geq 0.3 \\ (ExcRD_{it} \times i\_x_{it}) & if\ \ i\_x_{it} = \frac{ExcRD_{it}}{C\_\overline{RD}_{it}} < 0.3 \end{cases}$$
$$if\ ExcRD_{it} > 0.05C\_\overline{RD}_{it}\ and\ \ RD_{it} > max\{RD_{it-1}, RD_{it-2}\} \tag{5}$$

Notes: (*): $ExcRD_{it} = \ RD_{it} - C\_\overline{RD}_{it}$

In 2017, a significant amendment was implemented as the existing Total Credit Type was criticized for lacking sufficient incentives to encourage R&D investment (MEIT, 2017). The government needed to revise the R&D tax credit system to accomplish the goal of raising the R&D investment rate to 4% of GDP by 2020 as part of broader tax measures aimed at overcoming deflation and revitalizing the economy (Cabinet Office, 2017). The Additional Incremental Credit Type was superseded, and its progressive incentivizing nature was incorporated into the Total Credit Type, creating the New Total Tax Credit Type (New Total Credit Type, NT_X_{it}).

The eligible tax credit ratio (eligible ratio, E_TC_{it}) was introduced in 2017. It is determined based on the incremental R&D ratio (i_x_{it}). If the incremental R&D ratio (i_x_{it}) exceeds 5%, the eligible ratio (E_TC_{it}) is determined by subtracting 5% from the incremental R&D ratio, multiplying the result by 0.3, and adding 9%. This ratio was capped at 10% (at 14% until 2018). If the incremental R&D ratio (i_x_{it}) is 5% or lower, the eligible ratio (E_TC_{it}) is calculated by subtracting the incremental R&D ratio from 5%, multiplying the difference by 0.1, and reducing 9% by this outcome. The minimum eligible ratio (E_TC_{it}) is set to 6%. This eligible tax credit ratio is then applied to R&D expenditures to determine the potential tax credit (X_{it}^{*}), which is subject to a 25% cap on the corporate tax paid (Equation (6)).

$$NT\_X_{it}^{2017-2018} = \begin{cases} X_{it}^{*} & if\ 0.25T_{it} \geq X_{it}^{*} \\ 0.25T_{it} & if\ 0.25T_{it} < X_{it}^{*} \end{cases}$$
$$where\ X_{it}^{*} =$$
$$\begin{cases} \begin{cases} E\_TC_{it}RD_{it} & if\ 0.14(*) > E\_TC_{it} \\ 0.14(*)RD_{it} & if\ 0.14(*) \leq E\_TC_{it} \end{cases} & where\ E\_TC_{it} = 0.09 + \left(\left(i_{x_{it}} - 5\%\right) \times 0.3\right) if\ i\_x_{it} = \frac{ExcRD_{it}}{C\_\overline{RD}_{i}} > 0.05 \\ \begin{cases} E\_TC_{it}RD_{it} & if\ E\_TC_{it} \geq 0.06 \\ 0.06RD_{it} & if\ E\_TC_{it} < 0.06 \end{cases} & where\ E\_TC_{it} = 0.09 - ((5\% - i\_x_{it}) \times 0.1)\ if\ i\_x_{it} = \frac{ExcRD_{it}}{C\_\overline{RD}_{i}} \leq 0.05 \end{cases} \tag{6}$$

Notes: (*): The upper limit was initially set at 10% but it was temporarily increased to 14% for FY 2017 to 2018.

[8] This subsection draws heavily on METI publications (METI, 2017, 2019, 2021).

$$AL\_X_{it}^{2017-2022} = \begin{cases} AL_{X_{it}^*} \; if \; 0.1T_{it} > AL\_X_{it}^* \\ 0.1T_{it} \; if \; 0.1T_{it} \leq AL\_X_{it}^* \end{cases} where \; AL\_X_{it}^* = T_{it} \times ((x_{it} - 0.1) \times 2) \; if \; x_{it} = \frac{RD_{it}}{\frac{1}{4}\sum_{k=0}^{3} S_{it-k}} \geq 0. \quad (7)$$

Moreover, regarding the upper limit of the tax deduction for each fiscal year from 2017 to 2018, if the R&D ratio (x_{it}) exceeds 10%, an additional upper limit (AL_X_{it}) is added to the standard tax deduction cap. This additional upper limit is computed by subtracting 10% from the R&D expenditure ratio (x_{it}) and multiplying the remainder by two, as defined in Equation (7). This does not exceed 10% of corporate taxes paid (T_{it}). Corporations applying an additional upper limit (AL_X_{it}) are not eligible for the Additional High-level Credit Type (Equation (4)).

Since the replacement of the New Total Credit Type, the government has periodically increased the tax credit ratio with minor adjustments, as captured in Equations (8) and (9). In the 2019 (2021) revision, when the incremental R&D ratio (i_x_{it}) exceeds 8% (9.4%), the eligible ratio (E_TC_{it}) is determined by subtracting 8% (9.4%) from the incremental R&D ratio (i_x_{it}), multiplying the result by 0.3 (0.35), and adding this to 9.9% (10.145%), with the ratio capped at 14% (10%). For excess ratios of 8% (9.4%) or lower, the eligible ratio is calculated by subtracting the excess ratio from 8% (9.4%), multiplying the difference by 0.175, and subtracting this result from 9.9% (10.145%). The minimum eligible tax credit ratio is established at 6% (2%), as delineated in Equation (8) (Equation (9)).

Additionally, if the R&D ratio (x_{it}) exceeds 10%, the eligible ratio (E_TC_{it}) is replaced with an additional tax credit (AE_TC_{it}). This additional tax credit is calculated by adding the result of the R&D expenditure ratio minus 0.1, then multiplying the result by 0.5 to obtain the eligible ratio $(E\_TC_{it}$; Equations (8) and (9)). The upper limit of the tax deduction (AL_X_{it}) is also added to the standard tax deduction cap, as in 2017 and 2018, up to 2022 (Equation (7)).

$$NT\_X_{it}^{2019-2020} = \begin{cases} X_{it}^* \quad if \; 0.25T_{it} \geq X_{it}^* \\ 0.25T_{it} \; if \; 0.25T_{it} < X_{it}^* \end{cases}$$

$$where \; X_{it}^* = \begin{cases} \begin{cases} AE\_TC_{it}RD_{it} \; if \; 0.14 > AE\_TC_{it}(*) \\ 0.14(**)RD_{it} \quad if \; 0.14 \leq AE\_TC_{it} \\ where \; E\_TC_{it} = 0.099 + \left(\left(i_{x_{it}} - 8\%\right) \times 0.3\right) \quad if \; i\_x_{it} = \frac{ExcRD_{it}}{C\_\overline{RD}_{it}} > 0.08 \end{cases} \\ \begin{cases} E\_TC_{it}RD_{it} \quad if \; E\_TC_{it} \geq 0.06 \\ 0.06RD_{it} \quad if \; E\_TC_{it} < 0.06 \\ where \; E\_TC_{it} = 0.099 - ((8\% - i\_x_{it}) \times 0.175) \; if \; i\_x_{it} = \frac{ExcRD_{it}}{C\_\overline{RD}_{it}} \leq 0.08 \end{cases} \end{cases} \quad (8)$$

Notes: (*): $AE\_TC_{it} = E\_TC_{it} + E\_TC_{it} \times ((x_{it} - 0.1) \times 0.5) \quad if \; x_{it} = \frac{RD_{it}}{\frac{1}{4}\sum_{k=0}^{3} S_{it-k}} \geq 0.1$, otherwise E_TC_{it}.
(**): The upper limit was initially set at 10% but was temporarily increased to 14% for FY 2019 to 2020.

$$NT\_X_{it}^{2021-2022} = \begin{cases} X_{it}^* \quad if \; 0.25T_{it} \geq X_{it}^* \\ 0.25T_{it} \; if \; 0.25T_{it} < X_{it}^* \end{cases}$$

$$where \; X_{it}^* = \begin{cases} \begin{cases} AE\_TC_{it}RD_{it} \; if \; 0.14 > AE\_TC_{it}(*) \\ 0.14(**)RD_{it} \; if \; 0.14 \leq AE\_TC_{it} \\ where \; E\_TC_{it} = 0.10145 + \left(\left(e_{x_{it}} - 9.4\%\right) \times 0.35\right) \; if \; e\_x_{it} = \frac{ExcRD_{it}}{C\_\overline{RD}_{it}} > 0.094 \end{cases} \\ \begin{cases} E\_TC_{it}RD_{it} \; if \; E\_TC_{it} \geq 0.02 \\ 0.02RD_{it} \; if \; E\_TC_{it} < 0.02 \\ where \; E\_TC_{it} = 0.10145 - \left((9.4\% - e\_x_{it}) \times 0.175\right) if \; e\_x_{it} = \frac{ExcRD_{it}}{C\_\overline{RD}_{it}} \leq 0.094 \end{cases} \end{cases}$$

$$where \; E\_TC_{it} = 8.5\%, \; if \; the \; age \; of \; a \; firm = 0 \; or \; C\_\overline{RD}_{it} = 0 \quad (9)$$

Notes: (*): $AE\_TC_{it} = E\_TC_{it} + E\_TC_{it} \times ((x_{it} - 0.1) \times 0.5) \quad if \; x_{it} = \frac{RD_{it}}{\frac{1}{4}\sum_{k=0}^{3} S_{it-k}} \geq 0.1$, otherwise E_TC_{it}.
(**): The upper limit was initially set at 10% but temporarily increased to 14% for FY 2021 to 2022.

With these amendments described above, eligible corporations had a tax credit limit of up to 45% of the corporate tax paid. The incremental R&D ratio (i_x_{it}) criterion was gradually adjusted, and the calculation of the eligible ratio (E_TC_{it}) was modified accordingly.

This section outlines the historical evolution of Japan's Tax Credit System for R&D expenditure. This investigation reveals the Japanese government's main goal is to sustain and enhance R&D investments by private-sector corporations across various economic phases. The recent expansion aligns with the National Economic Policy, which aims "to encourage medium- to long-term, innovative R&D to strengthen Japan's growth potential and international competitiveness" (METI, 2021, p.3). These efforts provide a valuable perspective on the influence of fiscal policies on technological R&D investments by assuming a portion of the R&D risks for corporations.

3. LITERATURE REVIEW

Research on the effects of R&D tax credits on R&D investment was pioneered by Hall & Jorgenson (1967), who combined information on tax rates, depreciation allowances, and income tax integration. This approach of examining R&D price elasticity, user cost, or R&D tax price related to tax policy has been extensively applied in related research (Boom et al., 2002, p.3). Another way to evaluate the effectiveness of tax policy is to use the R&D demand equation with a shift parameter for credit by adopting the Euler equation approach. Using firm-level data, this approach provides a dynamic perspective on how firms adjust their R&D investments by measuring the availability and usability of credit at the firm level (Hall & Van Reenen 2000, p.458).

Early studies in the United States (Berger, 1993; Hall, 1993; Hines, 1993) provide compelling evidence that the benefits of R&D tax credits exceed their associated costs. Hall (1993)[9] found that R&D tax credits significantly boosted R&D expenditures among U.S. manufacturing firms during the 1980s, demonstrating a notable response to tax price[10] and underscoring the effectiveness of these credits in increasing R&D spending beyond the cost of foregone tax revenue. Hines (1993) showed a higher tax price elasticity range of -1.2 to -1.6 for US multinationals, indicating a promotional effect on R&D investment. He concluded that although the tax treatment of R&D is unlikely to have an enormous impact on the overall level of R&D, an incentivizing measure such as 100% deductibility against US taxes could stimulate additional annual R&D spending between $1.4 billion and $2.2 billion. Berger (1993) tested the credit investment effect through a time-series R&D spending model incorporating an R&D credit usability variable to capture the tax credit incentive. He observed a significant increase in R&D investment following changes in the tax credit policy, specifically the Economic Recovery Tax Act of 1981, revealing the impact of the tax credit on the level of R&D investment and the magnitude of the implicit tax created by the tax credit.

Building upon these insights, Bloom et al. (2002) developed a user cost model for R&D capital employing a constant elasticity of substitution production function. They examined the sensitivity of R&D to changes in user cost in nine countries from 1979 to 1997. Their findings revealed that R&D investments were significantly affected by their associated costs, with a short (long)-run elasticity of the R&D use cost is over 0.14 (around unity in absolute magnitude). Wilson (2009) highlighted that most research on R&D tax incentives focuses on federal R&D credit, and R&D may be mobile across states. He estimated an augmented R&D factor demand model using a two-way fixed-effects estimator with state panel data from 1981 to 2004, finding that the long-run elasticity of in-state R&D concerning the in-state (out-of-state) user cost is about -2.5 (+2.5). Rao (2016)[11] further investigated the impact of the federal tax policy between 1981 and 1991 using IRS data from tax returns. He reported that a 10% reduction in the user cost of R&D led an average firm to increase its research intensity by 19.8% in the short run, with long-term adjustments slightly less than short-term increases.

To differentiate US Incremental Credit Type system with Canada's Total Credit Type system, Klassen et al. (2004) conducted a comparative analysis and found that Canadian tax credits yielded an additional $1.30 in R&D spending for each foregone tax dollar versus a $2.96 increase in the United States. Although both systems encourage R&D investments, the US system appears more efficient. Additionally, Klassen et al. (2004) undertook a unique investigation, focusing on differences in accounting standards, capitalization and expense. They discovered that differences in accounting standards induce disparities in R&D activities, as firms that capitalized on R&D costs in Canada spent, on average, 18% more on R&D than US firms. Klassen et al. (2004)

[9] Hall (1993)'s work is highly regarded for its pioneering contributions, as recognized by Hall & Van Reenen (2000), Koga (2005) and Matsuura (2021) in their research exploring the effectiveness of tax credit on R&D expenditure through the lens of investment utilization.
[10] Tax price represents the tax component of the use cost of R&D capital, which encompasses the total cost incurred by a firm for using R&D capital, including depreciation, opportunity cost of investment, and tax implications (Koga, 2005).
[11] Rao (2016) used IRS corporate tax return data and employed OLS and IV techniques, and a GMM approach for longitudinal analysis.

examined large listed corporations, while Agrawal et al. (2020) focused on Canadian SMEs. They found significant boosts in innovation and SMEs' R&D spending owing to R&D tax credits, especially for firms with no current tax liability. Czarnitzki et al. (2011) also studied Canadian firms but focused on the effect of R&D tax credits on innovation output rather than R&D expenditure. They revealed that R&D tax credits increased the innovation output of recipient firms, with those firms realizing a higher number of product innovations and increased sales.

In another international context, Appelt et al. (2023) conducted extensive comparative research across OECD countries to evaluate the effectiveness of R&D tax incentives and their impact on a firm's economic performance. Their cross-country analysis revealed that R&D tax incentives yielded a gross incrementality ratio (IR) of approximately 1.4, with the effects being more pronounced for small (IR:1.6) and medium-sized firms (IR:1.4) than for larger firms (IR:0.4). Additionally, their pilot firm-level analysis of economic returns from R&D indicated that social returns from R&D were, on average, twice as large as the private returns, primarily because of significant knowledge spillovers. Bloch & Graversen (2012) examined the effect of public funding, using Danish firms' R&D data from 1995 to 2005, and found significantly complementary effects, specifically, a 0.12% increase in privately funded R&D with a 1% increase in public funding.

The discussion transitions to Japan's distinct experience with R&D tax credits, highlighting the significant shift from the Incremental Credit Type to the Total Credit Type in 2003. Koga (2003) [12] examined the effectiveness of tax credits before the 2003 reform and reported that larger firms were more responsive to R&D tax incentives, with significantly negative tax price elasticity (-1.03) compared with medium-sized firms. Their results suggest that larger firms fore effectively leverage tax credits to enhance their R&D investments, underscoring the differential impact of tax credits across firm sizes.

However, further investigation into the effectiveness of the 2003 reform revealed mixed outcomes. Kasahara et al. (2014), focusing on larger manufacturing firms with capital greater than JPY 100 million, highlighted the positive association between the eligible tax credit rate and debt-to-asset ratio. They showed that the 2003 tax credit revision significantly impacted firms facing financial constraints, increasing R&D expenditures by 3.0 to 3.4%. In an additional analysis, they compared small and large firms and found that the estimated coefficients for small firms were positive and significant, suggesting that tax credits are particularly beneficial for SMEs with outstanding debt. This result emphasizes the importance of financial constraints in explaining the impact of tax credits on R&D expenditures and suggests that tax credits can provide vital support for financially constrained firms, particularly those with limited collateral.

Kobayashi (2014) [13] demonstrated that R&D tax credits significantly enhanced R&D spending among SMEs, particularly those facing financial constraints. His findings indicate that tax credits not only reduce the user cost of capital but also enable financially constrained firms to strengthen their internal funding. Kobayashi (2014) showed that tax credits positively influenced SMEs' R&D decisions, more than doubling R&D expenditures, on average, and were particularly effective for SMEs with liquidity constraints.

Studies have reported varying results regarding financial constraints. Maekawa (2013) found that large, highly leveraged firms (with over JPY 10 billion in equity capital) tended to suppress their R&D expenditures. By contrast, Hosono et al. (2015) revealed that firms in industries less reliant on external funds benefitted significantly from R&D tax credits, thus encouraging more investment in R&D activities. Those in industries highly dependent on external funds did not benefit as much from these tax credits. The authors suggested that factors other than tax incentives, such as sales growth and internationalization, may play more significant roles in driving R&D investments.

Onishi & Nagata (2009)[14] and Maekawa (2013) obtained contrasting findings. Onishi & Nagata (2009) observed no overall increase in R&D spending following the introduction of the new system in 2003 after comparing tax credit users and non-users through propensity score matching and difference-in-differences analysis of firms with capital of JPY 1 billion or more. Maekawa (2013) also observed no overall increase in R&D spending

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[12] Koga (2003) used data from the Research on R&D Activities in Private Firms conducted by the Science and Technology Agency, supplemented by the Nikkei Annual Corporation Reports by Nikkei Shinbun Inc.

[13] Kobayashi (2014) used firm-level data from the 2009 Basic Survey of Small and Medium Enterprises conducted by the Small and Medium Enterprise Agency of the Ministry of Economy, Trade and Industry (METI). The survey collects information about SMEs across various industries, including construction, manufacturing, information and communications, wholesale and retail trade. In manufacturing, SMEs are defined as companies with a capitalization of JPY 300 million or less or employing 300 or fewer persons.

[14] Onishi & Nagata (2009) employed data derived from three surveys: the Survey on R&D Activities of Private Firms, the Survey on Science and Technology Research, and the Basic Survey of Japanese Business Structure and Activities.

owing to tax credits after comparing the effectiveness of expanding tax credits with that of lowering the corporate income tax rate

These studies reveal the complex and multifaceted impact of fiscal policies on corporate R&D activities in Japan, underscoring the need for tailored policy measures to address the specific needs and challenges of different segments of the economy. Although the R&D tax credit system generally encourages investments in R&D activities, the outcomes are inconsistent and sometimes contradictory. Firm characteristics, particularly size and financial constraints, play a significant role in R&D investment decisions. Based on the historical investigation in Section 2 and the literature review in Section 3, two research questions were formulated.

- Research Question (1): How effective have the 2014 and 2015 revisions under the Japan Revitalization Strategy been in enhancing R&D investment among Japanese corporations?
- Research Question (2): To what extent has the bifurcation of the Incremental Credit and Total Credit Types influenced R&D investment?

4. RESEARCH DESIGN

Given the unavailability of the latter, this study employs publicly available financial information as a substitute for highly confidential corporate tax return data. This approach is justified by the alignment between financial reporting practices and tax reporting practices and by a substantial body of research that employs public data.[15] Moreover, the implementation of new accounting standards for R&D ensures that financial information accurately reflects the economic substance of R&D investment.[16] Considering the nature of the data used in this analysis, this study adopts the estimation model outlined in Berger (1993), Klassen et al. (2004), and Finley et al. (2015), which also rely on publicly available data. Sensitivity analyses and robustness checks further validate the consistency and reliability of the proxy measures.

Firms tend to consider current-period R&D investment decisions in light of prior years' activities (Klassen et al., 2004, p.651). Additionally, firms identifying more potentially profitable innovation opportunities are expected to increase R&D spending annually compared with their counterparts (Berger, 1993). Incorporating a lagged R&D term ($RD_{i,t-1}$) into the specification is essential; however, autoregression results in a serial correlation in the error term within each firm. To address the autocorrelation in the residuals caused by non-stationarity in the time-series process of R&D expenditures (Roodman, 2009), we employ a generalized method of moments (GMM) approach. According to Finley et al. (2015, p.166), the GMM approach functions well for panel data, ensures that the potentially endogenous firm-specific variables are not correlated with the error term, and allows the lagged dependent variable to be instrumented with past levels.

Our simpler dynamic specification includes several factors, such as the R&D tax credit, financial constraint variables and controls, and a legged R&D (Model 1). Table 1 presents the definition of the variables in the model and their anticipated signs.

Because this study focuses on the effectiveness of revisions to the Special Measures Act since 2014, we introduce the *Post* indicator variable. It takes the value of 1 for years following the implementation of the Revitalization Policy (from 2014 to 2022), and 0 otherwise. The interaction of the post variable with the ratio of the eligible tax credit to R&D expenditures ($Post \times EliTCR$) allows the testing of our research questions. If the coefficient is positive, the revisions encourage corporations to invest more in R&D activities; otherwise, they do not.

The industry R&D (*IndRD*) variable is introduced to control for the impact of industry-level $R\&D$ expenditure levels on individual firms' R&D spending decisions, as suggested by Berger (1993), Bloom et al. (2002), and Finley et al. (2015). To account for financial constraints that may affect R&D spending, we incorporate the firm's leverage (*Debt*), following Kasahara et al. (2014). Evidence provided by Kasahara et al. (2014) and

[15] As Bloom et al. (2002, p.11) stated, estimating eligible tax credit using publicly available financial information and examining the relationship between tax credits and R&D is the approach taken by most studies. For example, Appelt et al. (2023) adopted business R&D survey microdata and patent microdata as alternative sources to compensate for the unavailability of relevant tax data. Hall (1995) re-estimated the equations from Table 6 of her 1993 study to assess the validity of Compustat data compared with restricted-access IRS data from an earlier period. The results showed a descriptive log-log regression of R&D on tax price, indicating that the tax price elasticity of R&D was either unity or slightly higher. This finding suggests that financial reporting information can serve as a substitute for tax return data, albeit with minor discrepancies between the two.

[16] Yoshizawa & Kobayashi (2003, p.35) stated that following the establishment of the Accounting Standard for Research and Development Costs (ASBJ Statement No. 23) in 1998, a discernible improvement in the representation of R&D expenditures in financial statements has been observed, with significantly fewer discrepancies between reported R&D data and R&D tax return data.

Maekawa (2013) suggests that highly leveraged corporations tend to suppress their R&D expenditures. Sales (*Rev*) are considered a source of budget for discretionary expenditures like R&D and an indicator of future sales expected from current R&D investments (Berger, 1993; Boom et al., 2002; Klassen et al., 2004; Kasahara et al., 2014). Hall (1993, p.28) noted that lagged sales growth could predict R&D growth even after considering lagged R&D growth, helping to address simultaneity issues (Koga, 2003; Maekawa, 2013).

Year dummies are included as Roodman (2009) emphasized that including time dummies is likely to satisfy the assumption that the autocorrelation test and the robust estimates of the coefficient standard errors assume no correlation across individuals in the idiosyncratic disturbances. The term u_i represents entity-specific fixed effects, capturing unobserved heterogeneity across firms, whereas $\varepsilon_{i,t}$ represents the idiosyncratic error term, accounting for random shocks specific to each firm and time period.

$$\ln(RD_{i,t}) = \delta \ln(RD_{i,t-1}) + \alpha_1 Post_t + \alpha_2 EliTCR_{i,t} + \alpha_3 Post_t \times EliTCR_{i,t} + \alpha_4 \ln(IndRD_{i,t}) + \alpha_5 Debt_{i,t-1} + \alpha_6 \ln(Rev_{i,t-1}) + \sum_{j=1}^{16} Year_j + \mu_i + \varepsilon_{i,t} \quad \text{(Model 1)}$$

Table 1 Variable definitions and anticipated signs

Variable	Anticipated sign	Definitions
$\ln(RD_{i,t})$		natural logarithm[17] of firm $i's$ $R\&D$ expenditure[18] in year t
$\ln(RD_{i,t-1})$	+	natural logarithm of the $R\&D$ expenditures of firm i lagged by one year
$Post_t$		indicator variable taking the value of 1 for years following the implementation of the Revitalization Policy (from 2014 to 2021), and 0 otherwise
$\ln(EliTCR_{i,t})$	+	rate of firm $i's$ eligible tax credit to R&D expenditures in year t, with the eligible tax credit amount calculated using the tax credit equations for the relevant year described in Section 2
$Post_t \times EliTCR_{i,t}$	+ / -	interaction of *Post* and $EliTCR$
$\ln(IndR\&D_{i,t})$	+	natural logarithm of the $R\&D$ level of all firms within the industry to which firm i belongs in year t, employing the industry classification code provided by Nihon Keizai Shimbun Inc.
$Debt_{it-1}$	-	proxy for firm i's leverage in year $t-1$, measured by dividing short-term and long-term debt in year $t-1$ by total assets in year $t-2$ (Finley et al. 2015)
$\ln(Rev_{i,t-1})$		a proxy for firm size, defined as the natural logarithm of firm i's sales in year $t-1$
$Year_j$		year dummy
u_i		entity-specific fixed effects
$\varepsilon_{i,t}$		error term

5. DATA AND DESCRIPTIVE ANALYSIS

5.1 Sample selection

This study focuses on corporations listed on the Tokyo Prime Stock Market from 2006 to 2021, a period encompassing the implementation and revisions of the Special Measures Act. The sample selection procedure is detailed in Table 2. The data were primarily sourced from the Nikkei-Needs Financial QUEST database and supplemented with hand-collected data from securities filings, beginning with 24,982 firm-year observations.

Several exclusions were applied to ensure data integrity and comparability. First, 2,864 firm-year observations from financial industries such as banking, securities, insurance and other financial sectors were excluded because of their distinct financial structures and income components. Additionally, 131 firm-year observations with reporting periods shorter than 12 months were excluded to maintain data consistency. To standardize accounting practices across the sample, 1,553 observations adhering to US Generally Accepted Accounting Principles (GAAP) or International Financial Reporting Standards (IFRS) were also excluded.

[17] Several studies (Ben-Zion, 1984; Klassen et al., 2004; Kasahara et al., 2014; Koga, 2005; Maekawa 2013) employed the natural logarithm as an alternative to deflating by sales or total assets (Berger, 1993). In line with this widely adopted approach, this study also uses the natural logarithm, except for the leverage ratio (total debts to total assets).
[18] According to Hall & Van Reenen (2000, p.460), the outcome of the regression estimation remains approximately consistent, irrespective of whether the log of the R&D stock or its flow serves as the dependent variable. Unless explicitly stated, this manuscript employs the flow amount of R&D as the dependent variable.

Table 2 Sample selection criteria and resulting sample sizes

Description	Firm-years	
Firm-year observations from Tokyo Prime Market Listed Corporates (2006 ~ 2021)		24,982
Financial industries (banks, securities, insurance)	(2,864)	22,118
Firm-year shorter than 12months	(131)	21,987
Firm-year applying US GAAP or IFRS	(1,553)	20,434
Outliers in all variables trimmed at the 0.25% level for both sides	(6,442)	13,992
Firm-year observations from firms not in the sample for all years in the period	(3,384)	10,608
Mid-industries with less than 1.0% firm-years of the sample	(656)	9,952

Furthermore, all variables were winsorized at the 0.25% level for both tails, eliminating 6,442 outlier firm-year observations to mitigate the influence of extreme values. To ensure a continuous dataset, we excluded 3,384 firm-year observations from firms that were inconsistently present throughout the 16-year study period. Finally, industries representing less than 1.0% of the sample, amounting to 656 firm-year observations, were excluded to minimize potential biases and noise introduced by underrepresented sectors, thereby ensuring that the dataset reflects more substantial industry trends. These rigorous selection criteria culminated in a robust and balanced panel dataset comprising 622 firms and 9,952 firm-year observations, providing a solid foundation for analyzing the effects of R&D tax credit revisions.

Table 3 presents the distribution of firm-year observations by industry, based on the Nikkei Industry Middle Codification. The dataset includes 17 industries, encompassing both manufacturing and non-manufacturing sectors. The chemicals industry has the highest representation, accounting for 13.58% of the sample with 1,360 firm-year observations, followed closely by the machinery industry at 13.26% with 1,328 firm-year observations. In contrast, the smallest industries are pulp & paper and electric power, each representing 1.45% of the sample with 144 firm-year observations. The textile products industry is the second smallest, comprising 2.09% of the sample with 208 firm-year observations.

Table 3 Industry classification*

Industry	Frequency	Percent	Industry	Frequency	Percent
01 Food Products	720	7.23	23 Electrical Machinery	1,184	11.90
03 Textile Products	208	2.09	27 Automobiles	368	3.70
05 Pulp & Paper	144	1.45	31 Precision Instruments	304	3.05
07 Chemicals	1,360	13.67	33 Other Manufacturing	432	4.34
09 Pharmaceutical	224	2.25	41 Construction	912	9.16
15 Ceramics Products	320	3.22	43 Trading	448	4.50
17 Iron & Steel	272	2.73	67 Electric Power	144	1.45
19 Non-ferrous Metals	640	6.43	71 Services	944	9.49
21 Machinery	1,328	13.34	Total	9,952	100.00

Notes: *: Based on Nikkei Industry Middle Codification

5.2 Descriptive statistics and correlation analysis

Panel A of Table 4 presents key descriptive statistics for the variables incorporated in the analysis, including the mean, median, maximum, minimum and standard deviation. Overall, the mean values of most variables are close to their median values, suggesting a generally symmetric distribution with some exceptions.

For example, R&D expenditures (RD) have a mean of 7.155 and a median of 7.183, suggesting a slightly positive skewness. By contrast, the interaction variable ‘Post × EliTCR’ has a mean of 0.051 and a median of 0.001, with a standard deviation of 0.059. This discrepancy suggests that while the interaction effect is present in the dataset, it is notably skewed towards higher values. This indicates that the interaction between the post-revision period and eligibility for tax credit is minimal for most firm-year observations. However, a smaller subset of observations exhibits a more pronounced interaction effect, contributing to higher mean relative to the median. This skewness may reflect the differing impacts of tax credit eligibility across firms during the post-revision period.

The variability across the dataset is evident from the range of values for each variable. For instance, RD ranges from 0.693 to 12.187, with a mean of 7.155, a median of 7.183 and a standard deviation of 1.694, indicating considerable variation in R&D expenditures among firms. Similarly, industry R&D expenditure (IndRD), with a mean of 12.827, median of 12.525, and standard deviation of 1.401, also shows substantial variability, reflecting differences in industry-level R&D activities. The revenue (Rev) variable also demonstrates a wide range of values, with a standard deviation of 1.280, indicating diverse revenue structures among firms. These substantial variances within certain underscore the underlying diversity within the dataset. This suggests that while averages provide a general sense of the data, significant disparities exist, posing caveats when interpreting the empirical results.

The "Post" variable, with a mean and median both at 0.500, accurately reflects that 50% of the observations fall within the post-revision period, ensuring a balanced temporal distribution in the sample. Additionally, the large sample size (N=9952) provides a robust analysis dataset, enhancing the reliability of the findings. However, the variability within the data emphasizes the importance of considering distribution shapes and potential outliers in further analyses. Skewed variables like "Post × EliTCR" suggest that some firms may experience markedly different effects of tax credit revisions, which could be explored further in the context of heterogeneous treatment effects.

Panel B of Table 4 shows the correlation between the variables in the sample. Pearson (Spearman) correlation coefficients are presented below (above) the diagonal. Based on the Pearson correlation analysis, all independent variables, except the ratio of eligible tax credit to R&D expenditure (EliTCR), were significantly correlated with the dependent variable (RD) at the 0.01 significance level. The Spearman correlation analysis further indicated that all independent variables were significantly correlated with the dependent variable, reinforcing the relevance of including these variables in the model. Notably, correlations are higher between RD and IndRD (0.410), Debt (0.106) and Rev (0.631), suggesting the appropriateness of these variables as control variables.

The correlations between most variables are relatively low, indicating that multicollinearity is unlikely to affect the estimation results adversely. However, the correlations between Post × EliTCR and EliTCR (0.701 Pearson, 0.534 Spearman) and between Post × EliTCR and Post (0.864 Pearson, 0.926 Spearman) are notably higher. This is expected given that Post × EliTCR is an interaction term involving these two variables. The next highest correlation is between Rev and Debt, with correlations of 0.376 (Pearson) and 0.381 (Spearman), which is moderate and does not raise concerns about multicollinearity.

The overall correlation analysis supported the inclusion of the selected variables in the model, as the correlations were generally moderate and did not suggest severe multicollinearity. This contributed to the robustness and reliability of the estimation results, ensuring that the variables could be effectively analyzed without bias. Additionally, the strong correlations between the dependent variable and key independent variables highlight their importance in explaining variations in R&D expenditures, confirming their role as essential predictors in the model.

Table 4 Descriptive statistics and correlation matrix

Panel A: Descriptive statistics							
	RD	Post	EliTCR	Post × EliTCR	IndRD	Debt	Rev
Mean	7.155	0.500	0.090	0.051	12.827	0.470	11.512
Max	12.187	1.000	0.265	0.265	15.347	2.010	15.293
Median	7.183	0.500	0.085	0.001	12.525	0.469	11.460
Min	0.693	0.000	0.000	0.000	9.925	0.042	6.221
SD	1.694	0.500	0.035	0.059	1.401	0.198	1.280
N	9952	9952	9952	9952	9952	9952	9952
Panel B: Correlation matrix							
	RD	Post	EliTCR	Post × EliTCR	IndRD	Debt	Rev
RD	1	**0.059**	**0.072**	**0.073**	**0.410**	**0.107**	**0.607**
Post	**0.058**	1	**0.272**	**0.926**	**0.095**	**-0.109**	**0.081**
EliTC	0.019	**0.331**	1	**0.534**	**0.045**	**-0.075**	0.011
Post × EliTCR	**0.074**	**0.864**	**0.701**	1	**0.087**	**-0.095**	**0.081**
IndRD	**0.410**	**0.068**	-0.014	**0.064**	1	**-0.189**	**-0.103**
Debt	**0.106**	**-0.109**	-0.021	**-0.076**	**-0.168**	1	**0.381**
Rev	**0.631**	**0.086**	0.034	**0.075**	**-0.068**	**0.376**	1

Notes: Bold fonts indicate significant correlation at $p < 0.01$. The Pearson (Spearman) correlation coefficients appear below (above) the diagonal.

6. ESTIMATED RESULTS AND ROBUSTNESS ANALYSIS

6.1 Estimated results

To determine the appropriate GMM approach[19]—whether difference GMM or system GMM—we followed the steps detailed by Roodman (2009, pp.99-119). As Table 5 shows, the coefficients of lagged R&D expenditures

[19] The GMM approach mitigates serial correlation in the error term caused by the autoregressive nature of R&D

in Ordinary Least Squares (OLS), fixed effects (FE) panel, and difference GMM estimations are 0.973 (p<0.01), 0.689 (p<0.01) and 0.443 (p<0.01), respectively. The coefficient on lagged R&D in the difference GMM is outside the credible range of 0.689-0.973, indicating that the difference GMM performs poorly due to the weak-instruments problems. This led us to employ a system GMM to enhance the efficiency and reliability of the estimation[20]. Additionally, we decided to use the one-step system GMM because of its simplicity and the fact that its standard errors are asymptotically robust to heteroskedasticity and more reliable in finite samples (Bond et al., 2001).

Table 5 also presents the diagnostic statistics from estimating Model (1) using a one-step GMM approach. The test for second-order autocorrelation (*AR*(2)) in the first-differenced errors failed to reject the null hypothesis (p=0.746), indicating the absence of second-order serial correlation. This result supports the specification of the system GMM, suggesting that the instrument strategy is appropriate. Additionally, the Hansen test result (p=0.138) indicated that the instrument set was valid and did not suffer from overidentification[21]. The number of instruments (126) is smaller than the number of groups (622) and observations (8708), which is desirable for maintaining the validity of the GMM estimation (Roodman, 2009, pp.98-99). Overall, these results indicate that the instruments in the model are valid and that the model is well-specified.

Table 5. Results of one-step general method of moment analysis

	OLS		**Fe. robust**		**Diff-GMM robust**		**Sys-GMM robust**	
	Coeff.	t-stat	Coeff.	t-stat	Coeff.	t-stat	Coeff.	t-stat
RD								
Lag 1 (t-1)	0.973***	367.91	0.689***	29.08	0.443***	4.38	0.982***	116.77
Post	0.002	0.11	-0.006	-0.25	0.145*	1.92	0.171*	1.90
Lag 1 (t-1)					0.321*	1.71	0.117	0.66
Lag 2 (t-2)					-0.197	-0.80	-0.382**	-2.42
EliTCR	2.769***	16.43	2.351***	8.50	4.689***	6.05	4.493***	6.31
Lag 1 (t-1)					3.649	1.57	-2.733	-1.33
Lag 2 (t-2)					0.184	0.10	-2.638	-1.54
Post × EliTCR	-0.553***	-2.93	0.013	0.05	-2.374***	-3.14	-1.918***	-2.74
Lag 1 (t-1)					-3.914*	-1.93	-0.385	-0.21
Lag 2 (t-2)					1.211	0.61	3.959**	2.16
IndRD	-0.002	-0.17	0.121***	3.69	-0.022	-0.13	0.228	0.37
Lag 1 (t-1)					0.074	0.11	-0.805	-0.86
Lag 2 (t-2)					0.969	1.39	0.590	0.95
Debt	0.028*	1.95	-0.005	-0.17	0.365	1.46	-0.289	-0.65
Lag 1 (t-1)					0.780	1.41	1.157*	1.90
Lag 2 (t-2)					0.190	0.37	-0.656	-1.31
Rev	0.024***	6.88	0.153***	6.30	-0.087	-0.72	0.019	0.05
Lag 1 (t-1)					-0.018	-0.03	-0.247	-0.32
Lag 2 (t-2)					0.344	0.78	0.230	0.50
Constant	-0.219	-1.45	-1.251***	-2.88			-0.109	-0.54
Year Dummies	Yes		Yes		Yes		Yes	
No. of Obs.	9330		9330		8086		8708	
Groups/ Instruments			622		622 / 110		622 / 126	
F Statistic	13237.07		274.69		35.57		12235.26	
R-squared	0.981		0.633					
AR (2)					0.521		0.746	
Hansen Statistic					0.197		0.138	

Notes: *** p<0.01, ** p<0.05, * p<0.1. The robust option is equivalent to cluster(id) in most other estimation commands, requiring that standard errors be robust to heteroskedasticity and arbitrary patterns of autocorrelation within individuals (Roodman, 2009). Diff-GMM (Sys-GMM) robust denotes a robust analysis using difference GMM (system GMM).

expenditures. This method is well-suited for panel data as it ensures that potentially endogenous firm-specific variables are not correlated with the error term and allows the lagged dependent variable to be instrumented with past levels (Finley et al., 2015, p.166).

[20] When the lagged dependent variable coefficient in the difference GMM falls outside the credible range, this may indicate a weak instruments problem. In such cases, system GMM can address the issue by using the lagged levels of the dependent variable as instruments for the first-differences equations, maintaining the initial orthogonality conditions. This approach enhances estimation efficiency and reliability by combining levels and differences, thereby mitigating the weak-instrument problem associated with difference GMM (Mammi, 2011; Roodman, 2009).

[21] As Roodman (2009, p.129) explained, a Hansen test p-value between 0.1 and 0.25 suggests the validity of the system GMM instruments, whereas values outside this range may indicate potential issues.

The coefficient of the lagged R&D expenditure, δ, is 0.982 at the 0.01 significance level in the system GMM estimation, suggesting that current R&D spending is strongly influenced by previous R&D spending. This result aligns with the findings from the difference GMM, where the coefficient, although lower at 0.443, also indicates significant persistence in R&D expenditures. The coefficient on Post, α_1, is positive and significant at 0.171 ($p<0.10$), indicating that R&D expenditures increased following the revision of the Special Measures Act. Similarly, the difference in the GMM estimation yielded a positive and significant coefficient of 0.145 ($p<0.10$), further supporting this conclusion. The coefficient of eligible tax credit (EliTCR) is 4.493 ($p<0.01$), suggesting that tax credit incentives have a substantial effect on R&D expenditure decisions, consistent with the difference in the GMM result of 4.689 ($p<0.01$).

The interaction term Post $\times$ EliTCR is the most important variable as it provides insights into whether revisions since 2014 have successfully incentivized corporations to invest more in R&D activities. The coefficient for the contemporaneous variable is significantly negative at -1.918 ($p<0.01$), the second lagged variable is significantly positive at 3.959 ($p<0.05$), and the first lagged variable is negative but not significant. The negative contemporaneous coefficient, α_3, indicates that introducing of the New Total Credit Type has not successfully induced additional R&D spending compared with the pre-revision period. Given the magnitude of -1.918 percentage points at the 1.0% significance level and the non-significant first-lagged variable, we conclude that tax credit incentives do not effectively facilitate R&D investments. This finding suggests that regulators should consider redesigning the R&D tax credit incentive system.

Most independent variables, except Debt in the first lagged variable (1.157, $p<0.1$), are not significant. The coefficients are positive for IndRD, negative for Debt, and positive for Rev in the contemporaneous year. Even though these results are not significant, the direction of the coefficients aligns with the findings of Finley et al. (2015), Kalassen et al. (2004), and Maekawa (2013), indicating that larger corporations tend to invest more in R&D activities, while corporations with higher debt levels tend to invest less. In addition, corporations in industries with higher R&D investments are more likely to spend more time on R&D.

6.2 Robustness analysis

To ensure the robustness of our findings, we conducted a sensitivity analysis by re-estimating the model using Instrumental Variables (IV), as well as the two-step difference and system GMM approaches (Table 6). The IV is a relevant method for dynamic panel data and provides an additional check on the robustness of the model. As Mammi (2011, p.27) suggested, significant differences between one- and two-step estimates may indicate the presence of a finite sample bias. Two-step GMM estimations offer an alternative specification that incorporates both level and differenced equations, potentially enhancing estimation efficiency and addressing weak-instrument problems associated with the one-step GMM. By comparing IV, one-step GMM and two-step GMM results, we can assess the consistency and reliability of our estimates.

The magnitudes and signs of the coefficients in the IV estimation are similar to those in the one-step system GMM. For instance, the coefficient of lagged R&D is 0.980 at the 0.01 significance level in the IV estimation compared with 0.982 at the same level in the one-step system GMM. Similarly, the coefficient for the eligible tax credit rate in the IV estimation is 3.391 ($p<0.01$), which is slightly smaller than the 4.493 ($p<0.01$) found in the one-step system GMM. Likewise, the magnitude and sign of the coefficient for the interaction term, Post $\times$ EliTCR are consistent, with -0.814 ($p<0.10$) in the IV estimation and -1.918 ($p<0.01$) in the one-step system GMM estimation.

In the IV estimation, more independent variables are statistically significant. The industry R&D (IndRD) variable is significant at 0.05, with a coefficient of 0.109, while the second lagged IndRD is negative at -0.088 ($p<0.05$). The contemporaneous and the first lagged coefficients of the revenue (Rev) are significant at the 0.01 level. Overall, the IV estimation results support the findings of the one-step system GMM.

Both two-step GMM estimations demonstrate robust results, with the Hansen test ($p=0.197$) and AR(2) test ($p=0.628$) in difference GMM, and the Hansen test ($p=0.138$) and AR(2) test ($p=0.899$) in the system GMM, supporting the validity of the instruments. In terms of the results of the two-step GMM estimations, while the system GMM results are very similar to those of the one-step system GMM, the difference GMM results show fewer significant variables: Post is no longer significant, and Post $\times$ EliTCR is only significant at 0.10 level in the two-step difference GMM. By contrast, the lagged RD, Post, EliTCR and Post $\times$ EliTCR in the two-step system GMM are significant at 0.01 level, with similar signs and magnitudes—0.990, 0.167, 3.519, and -1.545, respectively.

Table 6. Results of the Robustness Test

	IV		**Two-step Diff-GMM**		**Two-step Sys-GMM**	
	Coeff.	t-stat	Coeff.	t-stat	Coeff.	t-stat
RD						
Lag 1 (t-1)	0.980***	409.44	0.466***	3.92	0.990***	109.88
Post	0.017	0.71	0.075	1.34	0.167***	2.65
Lag 1 (t-1)	-0.018	-0.70	0.168	1.08	-0.084	-0.62
Lag 2 (t-2)	-0.018	-0.80	-0.153	-0.94	-0.188	-1.23
EliTCR	3.391***	16.17	2,840***	4.32	3.519***	5.88
Lag 1 (t-1)	-1.376***	-7.67	1.865	0.91	-3.648**	-2.17
Lag 2 (t-2)	0.110	0.58	-0.250	-0.17	-1.171	-0.82
Post × EliTCR	-0.814***	-3.61	-1.191*	-1.92	-1.545***	-2.62
Lag 1 (t-1)	0.481**	1.99	-2.115	-1.25	1.365	0.91
Lag 2 (t-2)	0.548***	2.60	0.983	0.64	1.968	1.26
IndRD	0.109**	2.43	0.065	0.48	0.318	0.41
Lag 1 (t-1)	-0.005	-0.09	0.215	0.36	-0.910	-0.81
Lag 2 (t-2)	-0.088**	-1.99	0.655	1.03	0.598	0.93
Debt	0.005	0.14	0.361	1.53	-0.220	-0.55
Lag 1 (t-1)	-0.023	-0.68	0.604	1.25	0.671	1.19
Lag 2 (t-2)	0.023	0.78	0.209	0.56	-0.259	-0.69
Rev	0.178***	8.17	-0.104	-0.95	0.022	0.08
Lag 1 (t-1)	0.182***	-4.96	0.096	0.22	0.012	0.02
Lag 2 (t-2)	-0.155	-0.42	0.228	0.60	-0.037	-0.12
Constant	-0.395***	-8.75			0.024	0.11
Year Dummies	Yes		Yes		Yes	
No. of Obs.	8708		8086		8708	
Groups/ Instruments			622 / 110		622 / 126	
Adj R-squared	0.9816					
F Statistic	16008.46		26.77		11764.30	
AR (2)			0.628		0.899	
Hansen Statistic			0.197		0.138	

Notes: *** p<0.01, ** p<0.05, * p<0.1. Two-step Diff-GMM (Sys-GMM) denotes an analysis using the two-step difference GMM (system GMM) approach.

Overall, these results strengthen the credibility of our analysis. Given the greater consistency, efficiency, and precision observed in the system GMM estimations, both one-step and two-step, compared with the difference GMM, we prefer the system GMM results for drawing our conclusions. The system GMM approach better handles the potential issues of weak instruments and finite sample bias, making it a more robust choice for this analysis.

7. CONCLUSIONS AND FUTURE OUTLOOK

Using publicly available financial information, this study explores how the effectiveness of R&D tax credits in encouraging R&D investment relates to the design of R&D tax incentives. This approach is based on the assumption (Klassen et al., 2004, p.668) that a firm's investment decisions are often constrained by financial reporting policies, which can influence its ability to leverage tax incentives effectively. This assumption provides a strong foundation for using financial information to sufficiently examine the association between a firm's R&D investments and R&D tax incentives despite discrepancies between the eligible tax credit amount claimed on tax returns and the estimated amount based on financial statements. Understanding this association is crucial for policymakers to design more effective R&D tax incentives and for firms to optimize their investment strategies.

Our results show that tax credit policies incentivize firms to invest more in R&D activities, as the coefficients of EliTCR are the largest and positive in every estimation. By contrast, the introduction of the New Total Credit Type since 2014 does not incentivize firms as much as it did before the revisions, as the magnitude of the interaction term variable (Post × EliTCR) is negative at a significance level (p<0.01) in all estimations, even though the coefficients of Post are positive at a small magnitude and low significant level (0.171, p<0.10) in the one-step system GMM. This suggests that, while the eligible tax credit measures to have an impact, the amendments to the R&D tax credit since 2014 were not as effective as intended. Additionally, previous R&D spending variable demonstrates greater magnitude after EliTCR at higher significance levels. Determinants of investment in R&D activities include continuing firms' R&D strategies and tax credit policies.

As Appelt et al. (2023, p.46) pointed out, policymakers may implement incremental incentives with the expectation of improving additionality; however, the effectiveness of such measures can be limited. This limitation arises because incremental tax incentives might lead to weaker elasticity as current R&D investments increase the base amount, thus reducing the proportion of R&D that qualifies for tax credits in the future. The key insights from our evidence are pivotal for regulators in future policy development concerning the appropriate design of R&D incentive systems to establish an advanced R&D nation. Policymakers should consider environmental incentives rather than merely adjusting the percentage eligible for tax credits to encourage corporations to invest rigorously in R&D activities.

This study has several limitations. First, it focuses on well-established larger corporations; however, extensive research suggests that the impact of R&D tax credit on SMEs is greater than on larger firms. Therefore, further research should compare these findings with those for Growth Market-listed corporations. Additionally, the study was limited to R&D expenditures under JP GAAP; however, as Klassen et al. (2004, p.664) stated, firms that capitalize on R&D costs undertake approximately 18% more R&D investments than those that do not. In our sample, after eliminating IFRS adopters, R&D expenditures were reduced by just under half[22], indicating higher R&D activity among these firms. Further research is needed to examine the behavior of Japanese IFRS adopters and their approach to capitalizing on R&D assets. Investigating this aspect could provide a more comprehensive understanding of how tax incentives influence firms' R&D spending behavior using different accounting standards.

Further research should incorporate data that includes information on firms using R&D tax credits. Many studies have compared tax credit users with non-users and identified differences in the extent of R&D expenditure increases between the two groups (e.g., Hosono et al., 2015; Onishi & Nagata, 2009). Incorporating more precise estimates in future studies would provide deeper insights into tax credit policies and firms' R&D behavior.

APPENDIX A. THE EARLIER TRANSITION OF THE R&D TAX CREDIT SYSTEM

The initial phase of the tax credit system spanned from 1967 to 1992. During the 1960s, various Special Measure Acts were revised or enacted based on economic policy objectives, including "promotion of exports," "improvement of corporate structure," and "technological development" (Wada, 1992, p.63). In alignment with these changes and to further encourage technological development (Wada, 1992, p.62), the R&D tax credit system was introduced in 1967 as a comprehensive tax incentive for R&D investment[23]. Under this system, a corporation was eligible for credit when its current R&D expenditure (RD_{it}) exceeded its previous maximum expenditure ($\max P\_RD_{i1967-1992}$). The eligible tax credit amount (X_{it}) was equivalent to 10% of the excess amount, as illustrated in Equation (A.1), which could be deducted from the corporate tax liability. This is known as the Incremental Experimentation and Research Expenditure Tax Credit System (Incremental Credit Type; Morotomi & Kawakatu, 2015, p.32; Onishi & Nagata, 2009, p.401).

$$X_{it}^{1967-1992} = 0.1(RD_{it} - \max P\_RD_{i1967\sim t-1}) \qquad if\ RD_{it} > \max P\_RD_{i1967\sim t-1} \qquad \text{(A. 1)}$$

Following its introduction, the Incremental Credit Type (I_X_{it}) was adjusted to address the economic turbulence from 1993 to 2002. In 1993, a significant paradigm shift occurred because of a substantial reduction in corporate R&D expenditure after the economic bubble burst, making many corporations ineligible for benefits under the existing system (Morotomi & Kawakatsu, 2015, p. 32). Consequently, the policy was revised from 1993 onward to allow a tax deduction equal to 10% of the excess amount when a corporation's annual R&D expenditure exceeded its historical maximum (Equation (A.2)).

$$X_{it}^{1993-1997} = 0.1(RD_{it} - \max P\_RD_{i1993\sim t-1}) \qquad if\ RD_{it} > \max P\_RD_{i1993\sim t-1} \qquad \text{(A. 2)}$$

Further modifications were made in the year 1998. According to these amendments, a corporation qualifies for tax credit if its R&D expenditure (RD_{it}) exceeded the average of the three highest-expenditure years within the preceding five-year period ($\max \overline{RD}_i$), including the current fiscal year, and if the current R&D expenditure was greater than the largest amount of R&D expenditure in the last two years. The eligible tax credit amount,

[22] After excluding US GAAP (294 firm-years) and IFRS (1,259 firm-years) adopters, the total amount of R&D expenditures decreased from JPY 209,440 billion to JPY 100,929 billion.
[23] Prior to the establishment of the R&D tax credit system, a special depreciation measure for test and research equipment had been implemented since 1961 as an incentive to further encourage technological innovation (Wada, 1992, pp.59-61).

calculated as 15% of the excess amount ($(RD_{it} - max\overline{RD}_i$), was then deducted up to the cap of 12% of the corporate tax paid (T_{it}) (Equation (A.3)).

$$I\_X_{it}^{1998-2005} = \begin{cases} X_{it}^{*} & if\ 0.12T_{it} \geq X_{it}^{*} \\ 0.12T_{it} & if\ 0.12T_{it} < X_{it}^{*} \end{cases} \quad where\ X_{it}^{*} = 0.15(RD_{it} - max\overline{RD}_i)$$
$$if\ RD_{it} > max\overline{RD}_i\ and\ RD_{it} > max\{RD_{it-1}, RD_{it-2}\} \quad (A.3)$$

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REFERENCES

Agrawal, A., Rosell, C., & Simcoe, T. (2020). Tax credits and small firm R&D spending. *American Economic Journal: Economic Policy*, 12(2), 1-21.

Appelt, S., Cabral, A. C. G., Hanappi, T., Galindo-Rueda, F., & O'Reilly, P. (2023). Cost and uptake of income-based tax incentives for R&D and innovation. *OECD Science, Technology and Industry Working Papers 2023/03*. https://www.oecd-ilibrary.org/docserver/4f531faf-en.pdf?expires=1724244118&id=id&accname=guest&checksum=5D7AFA96BBF497A4D1BA565DA0A569A8.

Arrow, K.J. (1962). Economic welfare and the allocation of resources for invention. In R. Nelson (Ed.), *The rate and direction of inventive activity* (pp. 609-626). Princeton, NJ: Princeton University Press.

Atkinson, R.D. (2007). Expanding the R&E tax credit to drive innovation, competitiveness and prosperity. *Journal of Technology Transfer*, 32, 617-628.

Ben-Zion, U. (1984). The R&D and investment decision and its relationship to the firm's market value: Some preliminary results. In Z. Griliches (Ed.), *R&D, patents, and productivity* (pp. 299-314). University of Chicago Press.

Berger, P.G. (1993). Explicit and implicit tax effects of the R&D tax credit. *Journal of Accounting Research*, 31(2), 131-171.

Bloch, C., & Graversen, E. K. (2012). Additionality of public R&D funding for business R&D—A dynamic panel data analysis. *World Review of Science, Technology and Sustainability Development*, 9(2/3/4), 204-220.

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.

Bloom, N., Griffith, R., & Van Reenen, J. (2013). Identifying technology spillovers and product market rivalry. *Econometrica*, 81(4), 1347-1393.

Bond, S., Roy, T., & Jonathan, R.W. (2001). GMM estimation of empirical growth models. *Centre for Economic Policy Research Discussion (CEPR) Discussion Papers*, 3048. ISSN 0265-8003.

Cabinet Office. (2014). *Basic policies for the economic and fiscal management and reform 2014: From deflation to an expanded economic virtuous cycle*. Cabinet Office, Government of Japan. Available at https://www5.cao.go.jp/keizai-shimon/kaigi/cabinet/honebuto/2014/2014_basicpolicies_02.pdf.

Cabinet Office. (2017). *Tax measures for overcoming deflation and economic revitalization (No. 9 Taxation Research Committee, 9–1 part 2)*. Available at https://www.cao.go.jp/zei-cho/gijiroku/zeicho/2016/28zen9kai4.pdf. [in Japanese].

Czarnitzki, D., Hanel, P., & Rosa, J. M. (2011). Evaluating the impact of R&D tax credits on innovation: A microeconomic study on Canadian firms. *Research Policy, 40*, 217–229.

Dumont, M., & Meeusen, W. (2000). Knowledge spillovers through R&D cooperation. *The workshop of the OECD-NIS focus group on innovative firms and networks*, Rome.

Economic and Social Research Institute (ESRI). (2002). *The results and progress of economic structural reforms 3: Policy objectives, Ministry of Finance, fundamental policy 2002 (Economic Revitalization Strategy)*. Cabinet Office. Available at https://www.esri.cao.go.jp/jp/esri/prj/sbubble/data_history/7/housin11_3_4.pdf [in Japanese].

Finley, A. R., Lusch, S. J., & Cook, K. A. (2015). The effectiveness of the R&D tax credit: Evidence from the alternative simplified credit. *Journal of the American Taxation Association*, *37*(1), 157–181.

Grossman, G. M., & Helpman, E. (1993). *Innovation and growth in the global economy*. MIT Press.

Hall, B. H. (1993). R&D tax policy during the 1980s: Success or failure? *Tax Policy and the Economy*, *7*, 1–35.

Hall, B. H. (1995). Effectiveness of research and experimentation tax credits: Critical literature review and research design. Report to Office of Technology Assessment, Congress of the United States.

Hall, B. H. (2002). The financing of research and development. *Oxford Review of Economic Policy*, *18*(1), 35–51.

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

Hall, R. E., & Jorgenson, D. W. (1967). Tax policy and investment behavior. *The American Economic Review*, *57*(3), 391–414.

Hines, J. R. (1993). On the sensitivity of R&D to decline tax changes: The behavior of U.S. multinationals in the 1980s. In G. Giovannini et al. (Eds.), *Studies in international taxation* (pp. 149–193). University of Chicago Press.

Hosono, K., Hotei, M., & Miyakawa, D. (2015). Does research and development tax credit promote research and development investment? —Verification of effects through cost of capital and internal financing. *RIETI Discussion Paper Series 15-J-030*. https://www.rieti.go.jp/jp/publications/dp/15j030.pdf. [in Japanese].

Kasahara, H., Shimotsu, K., & Suzuki, M. (2014). Does an R&D tax credit affect R&D expenditure? The Japanese R&D tax credit reform in 2003. *Journal of the Japanese and International Economies*, *31*, 72–97.

Klassen, K. J., Pittman, J. A., & Reed, M. P. (2004). A cross-national comparison of R&D expenditure decisions: Tax incentives and financial constraints. *Contemporary Accounting Research*, *21*(3), 639–680.

Kobayashi, Y. (2014). Effect of R&D tax credits for SMEs in Japan: A microeconometric analysis focused on liquidity constraints. *Small Business Economics*, *42*, 311–327.

Koga, T. (2003). Firm size and R&D tax incentives. *Technovation*, *23*, 643–648.

Koga, T. (2005). Research and development and taxation: An overview. *The Keizai Ronshu (The Economic Review of Kansai University)*, *55*(2), 255–271.

Maekawa, S. (2013). Effectiveness of tax incentives for R&D: Evidence from empirical analysis on Japanese data. *Public Finance Studies*, *9*(1), 267–282. [in Japanese].

Mammi, I. (2011). *Essays in GMM estimation of dynamic panel data models*. Ph.D. Dissertation in Economics, Markets, Institutions. IMT Institute for Advanced Studies.

Matsuura, S. (2021). Review on effects of the R&D promotion tax and current R&D investment. *The Ritsumeikan Business Review*, *60*(1), 91–109. [in Japanese].

Ministry of Economy, Trade and Industry (METI). (2017, 2019, 2021). *Overview of the research and development tax system and the tax reform*. Available at https://www.meti.go.jp/policy/tech_promotion/tax/about_tax.html. [in Japanese].

Ministry of Economy, Trade and Industry (METI). (2021). *Overview of R&D tax system and the FY 2021 tax reform*. METI Industrial Technology and Environment Bureau, Technology Promotion and University Collaboration Promotion Division. Available at https://www.meti.go.jp/policy/tech_promotion/tax/R4gaiyov2.pdf. [in Japanese].

Ministry of Internal Affairs and Communications (MIC). (2004–2023). *Survey of research and development*. Available at https://www.stat.go.jp/english/data/kagaku/index.html. [in Japanese].

Motohashi, K. (2009). An empirical analysis of accumulation of R&D capital and performance of Japanese companies. In K. Fukao (Ed.), *Macro economy and industrial structure* (pp. 251–288). Keio University Press. [in Japanese].

Nagata, A., Goto, A., & Ohnishi, K. (2022). Changing appropriability conditions and technological opportunities of innovation in Japan: 1994–2020. *NISTEP Discussion Paper, No. 210*. National Institute of Science and Technology Policy. https://doi.org/10.15108/dp210. [in Japanese].

Narimichi, H., & Sakamoto, M. (2021). *Tax Accounting* (4th ed.). Chuokeizai. [in Japanese].

National Tax Agency (NTA). (2003, 2006, 2014, 2017). *Overview of revisions to corporation tax related laws and regulations*. Available at https://www.nta.go.jp/publication/pamph/02.htm.

Ocean Tomo. (2020). *Intangible asset market value study, Annual Study*.

Onishi, K., & Nagata, A. (2009). Does tax credit for R&D induce additional R&D investment? Analysis on the effects of gross R&D credit in Japan. *Japan Society for Research Policy and Innovation Management*, *24*(4), 400–412. [in Japanese].

Prime Minister's Office of Japan (PMOJ). (2014). *Japan revitalization strategy, revised in 2014: Japan's challenge for the future*. Available at https://www.kantei.go.jp/jp/singi/keizaisaisei/pdf/honbunEN.pdf. [in Japanese].

Roodman, D. (2009). How to do xtabond2: An introduction to difference and system GMM in Stata. *The Stata Journal*, *9*(1), 86–136.

Tax Commission. (2014). *In terms of reform of corporation income tax*. Tax Commission. Available at https://www.cao.go.jp/zei-cho/shimon/26zen10kai7.pdf. [in Japanese].

Wada, Y. (1992). *Special tax measures: History and structure*. Yuhikaku. [in Japanese].

Wilson, D. J. (2009). Beggar thy neighbor? The in-state, out-of-state, and aggregate effects of R&D tax credits. *The Review of Economics and Statistics*, *92*(2), 431–436.

Yoshizawa, K., & Kobayashi, S. (2003). New accounting standards for research and development, and its impact on companies' behavior. *National Institute of Science and Technology Policy (NISTEP) Discussion Paper, 95*. [in Japanese].