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The After-tax Marginal Cost and B Index of the R&D Tax System in Japan

Toshiyuki UEMURA
(Kwansei Gakuin University)

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SCHOOL OF ECONOMICS

KWANSEI GAKUIN UNIVERSITY

1-155 Uegahara Ichiban-cho
Nishinomiya 662-8501, Japan

The After-tax Marginal Cost and B Index of the R&D Tax System in Japan ※

Toshiyuki UEMURA *

Abstract

As of the 2024 fiscal year, Japan's R&D tax credit amounted to 763.7 billion yen, which is equivalent to approximately 5% of corporate tax revenue and the largest loss of tax revenue among special tax measures. Nevertheless, the R&D tax credit is still necessary because there is a positive externality in firms' R&D activities; even if results are produced, there is a public goods-like characteristic wherein they are free-ridden. Thus, if left to the market mechanism, firms' R&D activities will be underestimated. Information asymmetry, uncertainty, and the need to secure funding for R&D activities might also arise. While it is possible to support R&D activities through subsidies or other policy measures, the R&D tax credit has a lower application cost than subsidies requiring advanced applications and post-event reporting of results, thus offering greater benefits to firms. However, as this causes a significant loss in tax revenue, there is a great deal of interest in the results of the R&D tax system, which has led to many empirical analyses on this topic. Subsequently, this study comprehensively surveys previous empirical analyses of Japan's R&D tax credit system and highlights the importance of analyzing the system from the cost of capital perspective. I then present a model of firm behavior that incorporates the R&D tax system, derives the cost of capital, and theoretically examines the after-tax marginal cost of R&D and the B index. Finally, the results obtained from estimating the after-tax marginal cost and B index based on Japan's R&D tax system demonstrate that Japan's system favors small and medium-sized enterprises

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* Professor, School of Economics, Kwansei Gakuin University

over large firms.

JEL: H25, H32

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1. Introduction

The corporate tax system provides preferential measures for firms' R&D activities. This is known as the R&D tax system, and in Japan it refers to the special deduction of corporate tax in the case of R&D expenditure, which is a special tax measure. Figure 1 shows the trend in tax deductions under the R&D tax system and the percentage of corporate tax revenue. Japan's R&D tax system provided a tax credit of 763.7 billion yen in FY2024, which is equivalent to about 5% of the national corporate tax revenue and is the largest loss of tax revenue among special tax measures. Why should we support firms' R&D activities through the tax system even if it results in such a significant loss of tax revenue?

There are positive externalities for households and firms in firms' R&D activities, with results having a public goods-like quality in that they are free-ridden, even when they are produced. Therefore, without support from the government, firms that conduct R&D activities are based on private rather than social benefits, and R&D activities are socially underutilized. Arrow (1962) was the first to show that government support is necessary to correct market failures. [1] Therefore, it is necessary to internalize externalities through government policy measures.

[1] For more information on the characteristics of firms' R&D activities, see Irie (1998), Iwasawa (2001), Koga (2005), Motohashi (2007), and Otsuka (2010).

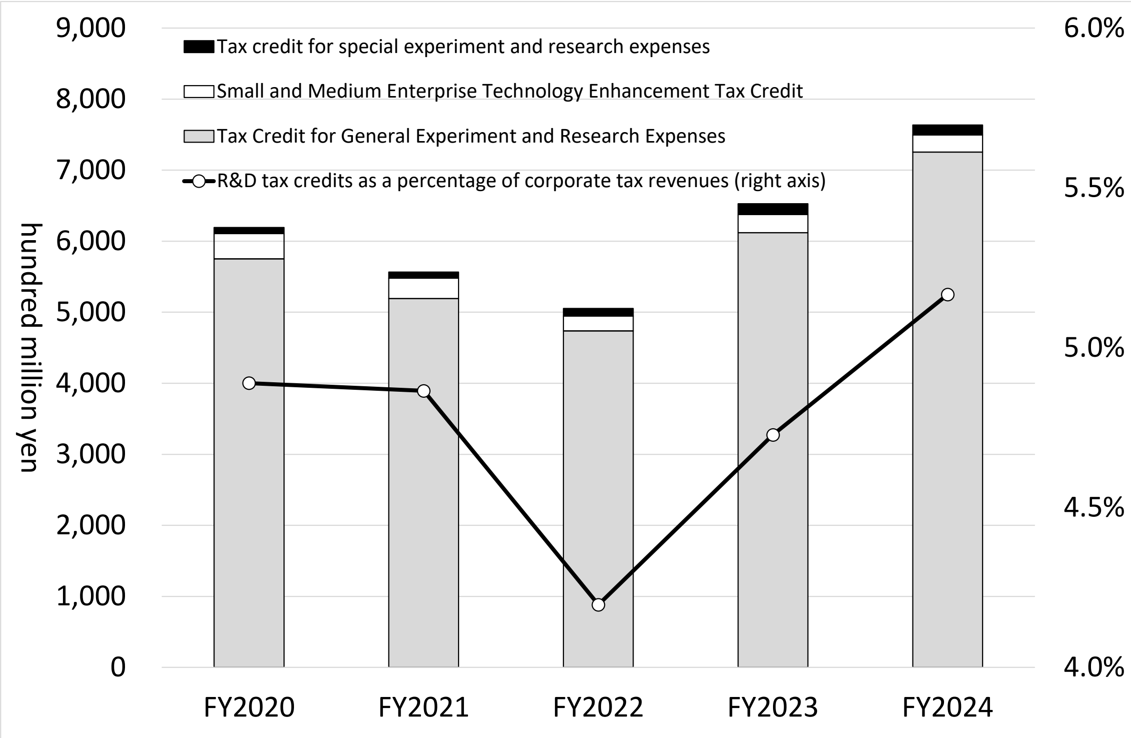

Figure 1: Trends in the amount of tax credits under Japan's R&D tax system and the ratio to corporate tax revenue

(Notes) Created from the Ministry of Finance's "Report on the Results of a Survey on the Application of Special Tax Measures" and the National Tax Agency's "Long-term Time Series Data."

Typical government policy measures include regulations, taxes, and subsidies. Of these, both taxation and subsidies require financial measures and are used to support R&D activities. The R&D tax system is a special tax measure that reduces the corporate tax burden when firms carry out R&D; therefore, only profitable firms that pay corporate tax can use the R&D tax system, but subsidies can support even loss-making firms. In addition, subsidies are included in the national budget, but R&D tax incentives are not included in the budget, making financial control difficult.

Nevertheless, in Japan and many other countries, R&D tax incentives are used in addition to subsidies. When obtaining a subsidy, firms must apply to the government in advance and report the results afterward. However, R&D is accompanied by uncertainty and risk, and it is not always possible to know in advance whether the results will be positive. There is also a risk that R&D ideas will be publicly revealed at the application stage. In addition, the government establishes subsidy systems only in areas where it wants to promote R&D; however, owing to information asymmetry, the government cannot know in advance which areas will develop in the future. R&D tax systems also have practical advantages over subsidies, such as lower application and government costs for firms. Because R&D sometimes requires large amounts of funding, R&D tax systems allow firms to secure cash flows. In addition, there is a higher possibility of rent-seeking by private firms with subsidies than with R&D tax credit. For the above various reasons, R&D tax credits were used. [2]

However, because the R&D tax credit is the largest source of tax revenue loss in special tax measures, it is only natural for there to be a great deal of interest in the results of R&D activities. For this reason, many empirical analyses have been conducted. This study presents a comprehensive survey of the empirical analyses of Japan's R&D tax system. It then highlights the importance of a theoretical analysis of the R&D tax system from the perspective of the cost of capital and presents a model. This study evaluates Japan's R&D tax system by examining the after-tax marginal cost and B index obtained from the model.

The remainder of this paper is structured as follows. In Section 2, I

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[2] For more information on the role and problems of the R&D tax credit, see Koga (1998a), Iwasawa (2001), Director General for Economic and Fiscal Management, Cabinet Office (2002), Nishino (2003), European Commission (2014), Morotomi and Kawakatsu (2015), Ambe (2017), Seko (2017), Khoyama (2018), Taniguchi (2018), Sato (2108), Sato (2020), and Hamada (2021).

conduct a comprehensive survey of previous empirical analyses of Japan's R&D tax credit system and highlight the importance of analyzing the system from the perspective of the cost of capital. In Section 3, I present a firm's behavior model that incorporates the R&D tax credit system and provides the derivation of the cost of capital. In Section 4, the after-tax marginal cost of R&D is examined. In Section 5, the B index is examined theoretically. Section 6 estimates the after-tax marginal cost of R&D and the B index based on Japan's R&D tax system. Finally, Section 7 summarizes and concludes the paper.

2. Comprehensive Survey of Empirical Analyses of R&D Tax Credit in Japan

In this section, I conduct a comprehensive survey of previous studies that empirically analyzed Japan's R&D tax credit.[3] These include studies that conducted model-based analyses from the 1990s to the 2020s, divided into 10-year or 5-year periods.[4]

Tamada (1998a,b) analyzed the effects of tax credits for increased R&D based on a survey of firms and proposed changes to the calculation method for R&D tax credits at the time. Koga (1998a) estimated the cost of capital for R&D tax credits derived from a firm's behavior model using corporate financial data and examined the effect of R&D tax credits on reducing the cost of capital by industry.

[3] As in this section, previous studies that introduce empirical analyses of the R&D tax credit include Irie (1998), European Commission (2014), Sato (2018), Sato (2000), Koga (1998 b, 2005), Kato and Saito (2013), Matsuura (2021), Ikeda and Ijichi (2023), and Deloitte Tohmatsu Consulting LLC (2023).

[4] Prior studies that have not conducted model analysis but have conducted data-based verification include Ijichi (2007), Hirai (2013a,b), Okada (2014), and Kakihara, Yoneda, Tamura, Yamaguchi, and Ma (2015).

Koga (2003) estimated the price elasticity of taxes using corporate financial data. Kometani and Matsuura (2007) measured the cost of capital for an R&D tax system using corporate financial data and examined its relationship with risk premiums. Ogawa (2007) analyzed the relationship between R&D taxation and total factor productivity using panel data on manufacturing industries. Motohashi (2009) analyzes the impact of the R&D tax system on R&D expenditure through taxation costs using an econometric model. Onishi and Nagata (2009) analyzed the effects of R&D tax credits using a difference-in-differences (DID) analysis based on propensity score matching (PSM). Kawaguchi (2009) analyzed the effects of R&D tax credits on firms' effective tax rates.

Koga (2012) estimated production functions using financial data from small and medium-sized enterprises (SMEs) and analyzed the impact of the R&D tax credit on productivity. Kawaguchi (2012) analyzed the relationship between firms' cash flows and R&D tax credits. Maekawa (2013) analyzed the impact of the revision of the R&D tax credit and the reduction in the corporate tax rate on R&D expenditures. Kasahara, Shimotsu, and Suzuki (2014) and Kobayashi (2011, 2014) analyzed the effect of R&D tax credits on R&D using corporate financial data.

Hosono et al. (2015) analyzed the impact of capital costs and retained earnings on R&D investment. Using corporate financial data, Yamazaki (2017) analyzed the impact of R&D tax credits on R&D investment, and Koga (2019) estimated the effective tax rate of R&D tax credits. Kawaguchi (2019) analyzed the relationship between R&D investment, retained earnings, and R&D tax credit. Mitsubishi UFJ Research and Consulting (2019, 2020) analyzed the effects of R&D expenditures on SMEs.

Deloitte Touche Tohmatsu LLC (2022) and Deloitte Tohmatsu Consulting LCC (2023) analyzed the policy effects of R&D tax credits using a questionnaire survey. Ikeuchi (2022) analyzed the impact of tax system reforms on R&D tax credits, such as the abolition of the carry-forward deduction system. Kawase (2023) empirically analyzed the relationship between R&D tax credits and R&D in the textile industry.

As mentioned above, many studies have analyzed the R&D tax credit system from the 1990s to the 2020s. The analysis methods and results vary, but in this study I focus on the analysis using the cost of capital, incorporating the R&D tax system derived from the firm's behavioral model. This is because, as I discuss later, the OECD places importance on the index of the R&D tax system derived from the cost of capital. In the next section, I present the firm's behavioral model as an analysis tool for the R&D tax system.

3. A Model of Firms' Behavior incorporating the R&D Tax System

In this section, I present a firm behavior model incorporating the R&D tax system. I introduce the R&D tax system into the traditional model of firm behavior developed by Jorgenson and Hall (1971), who analyzed the corporate tax system.[5] For simplicity, the prices of goods and R&D are normalized to 1, and F is defined as a production function in which R&D capital stock G is a production factor. R is R&D expenditure, and T is the amount of corporate tax. The corporate profit Π and firms' value V are as follows:

$$V_t = \int_{t=0}^{\infty} \{F(G) - R - T\} e^{-\rho t} dt = \int_{t=0}^{\infty} \Pi_t e^{-\rho t} dt \qquad (1)$$

ρ is the discount rate held by shareholders, and t is the subscript for time. For simplicity, we assume that R&D expenditure is paid for by the firm's retained earnings.

[5] This section is based on Koga (1998a, 2005) and Cabral, Appelt and Hanappi (2021).

Next, when the corporate tax rate is $\tau(0 \leq \tau \leq 1)$, the amount of corporate tax T is as follows.

$$T = \tau\{F(G) - \alpha R - \varphi(G)\} - J(R, G) \quad (2)$$

Let $\alpha(0 \leq \alpha \leq 1)$ denote the share of current expenditures that are allowed as deductible expenses under the tax law among R&D expenditures R in the current period. Let φ denote depreciation on R&D capital stock G, and let J denote the tax credit for R&D expenditures. These are the R&D tax credits used in this model.

In Japan, a firm to which the R&D taxation system applies must be profitable with a sufficiently large corporate tax amount T. In this section, I assume that the firm satisfies this condition. [6] In this case, the firm's profit Π is as follows:

$$\Pi = F(G) - R - \tau\{F(G) - \alpha R - \varphi(G)\} + J(R, G) \quad (3)$$

Let $\beta(0 \leq \beta \leq 1,\ 0 \leq \alpha + \beta \leq 1)$ be the share of capital expenditure on R&D capital stock G among R&D expenditures R and let $\delta_{R\&D}$ be the economic depletion rate of R&D capital stock; the accumulation equation for R&D capital stock is

$$\dot{G} = \beta R - \delta_{R\&D} G \quad (4)$$

Maximizing firm value V under the accumulation equation yields the R&D tax capital cost $\tilde{p}_{R\&D}$. For simplicity, the discount rate is set equal to the interest rate $(\rho = r)$.

$$\tilde{p}_{R\&D} = (r + \delta_{R\&D})\frac{(1 - A_{R\&D})}{1 - \tau} - \delta_{R\&D} = (r + \delta_{R\&D})\frac{C}{1 - \tau} - \delta_{R\&D} = (r + \delta_{R\&D})B\ index - \delta_{R\&D} \quad (5)$$

Here, the R&D tax savings (discounted present value) are $A_{R\&D}$ and the after-tax marginal cost of R&D is C. These are reflected by depreciation φ and tax credits J. The $B\ index$ is discussed later in this paper.

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[6] The specifics of Japan's R&D tax system will be explained later.

To compare the cost of capital, I can obtain the cost of capital $\tilde{p}_{TAX}$ for the corporate tax system by using a firm's behavior model with physical capital stock K as the production function and incorporates national corporate income tax and local corporate taxation.

$$\tilde{p}_{TAX} = (r + \delta_{TAX})\frac{(1-A_{TAX})}{1-\tau} - \delta_{TAX} \tag{6}$$

where A_{TAX} is the present discounted value of the tax savings and δ_{TAX} is the economic depletion rate of the physical capital stock K.

Now, the cost of capital $\tilde{p}$ in the case of no taxation $(A_{R\&D} = A_{TAX} = \delta_{R\&D} = \delta_{TAX} = 0)$ equals the interest rate r $(\tilde{p} = r)$. Given that the capital cost $\tilde{p}_{TAX}$ of the corporate tax system is expected to be higher, and the capital cost $\tilde{p}_{R\&D}$ of the R&D tax system is expected to be lower than the capital cost $\tilde{p}$ of the no-tax system, the relationship between these three capital costs is usually as follows:

$$\tilde{p}_{R\&D} \leq \tilde{p} \leq \tilde{p}_{TAX} \tag{7}$$

Figure 2 illustrates these relationships. The horizontal axis represents R&D capital stock G or physical capital stock K, and the vertical axis represents the marginal rate of return and cost from these capital stocks. The marginal return curve for capital is depicted as a declining right-hand curve. For simplicity, we assume that the marginal return curves for R&D capital stock G and physical capital stock K are identical.

For the cost of capital $\tilde{p}$ without taxation, R&D capital stock G^* or physical capital stock K^* is optimal at the intersection point B with the marginal revenue curve. Physical capital stock K** is optimal at intersection C for the cost of capital $\tilde{p}_{TAX}$ in the corporate tax system and the physical capital stock K^{**} is optimal at intersection C. In this case, tax revenue is the quadrilateral ECIF, and the excess burden is the triangle CBI. In this case, the marginal effective tax rate $EMTR_{TAX}$ is defined as where the numerator $(\tilde{p}_{TAX} - \tilde{p})$ is the "tax wedge."

$$EMTR_{TAX} = \frac{\tilde{p}_{TAX} - \tilde{p}}{\tilde{p}} \quad (8)$$

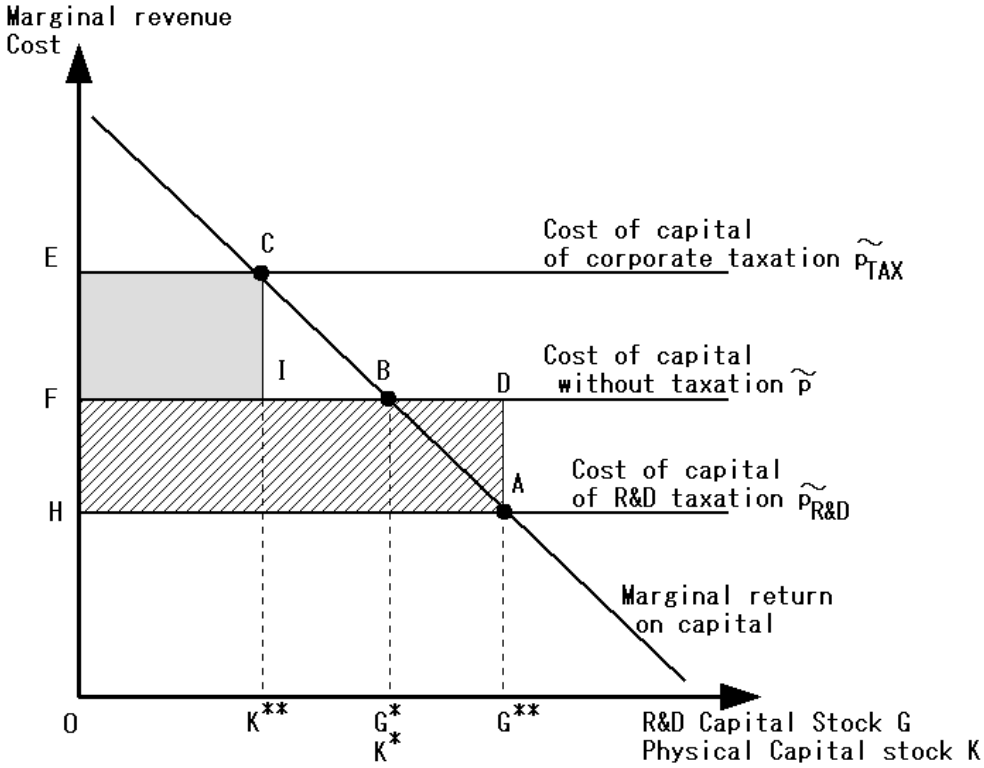

Figure 2 Cost of Capital and Marginal Rate of Return for R&D Tax and Corporate Tax

Similar considerations can be made for the R&D tax system. At intersection A, R&D capital stock G^{**} is optimal for the cost of capital $\tilde{p}_{R\&D}$ in the R&D tax system. At this point, the square FDAH is the "hidden subsidy," and the excess burden is the triangle BDA. Then, the marginal effective tax rate $EMTR_{R\&D}$ can be defined as follows:

$$EMTR_{R\&D} = \frac{\tilde{p}_{R\&D} - \tilde{p}}{\tilde{p}} \quad (9)$$

Figure 2 assumes that the marginal revenue curves of R&D capital stock G and physical capital stock K are equal, but the reality is different. As a firm, it is thought that investment will be made by choosing the one with the higher marginal profit from R&D stock and physical capital stock while considering the capital costs of the corporate tax system and the R&D tax system.

4. Theoretical Investigation of the After-tax Marginal Cost of R&D Taxation

In the R&D taxation cost of capital $\tilde{p}_{R\&D}$, after-tax marginal cost C is an important component of the cost of capital. When the marginal pre-tax cost of R&D is JPY 1, the after-tax marginal cost C is obtained by subtracting the tax savings on JPY 1 $A_{R\&D}$.

$$C = 1 - A_{R\&D} \tag{10}$$

In this section, I theoretically examine how various R&D tax systems change the after-tax marginal cost (the discounted present value of) C.[7]

In Case (1), R&D expenditures are not deductible as tax-deductible expenses and cannot be deducted from a firm's current income. This case is unlikely to be considered in a normal taxation system; however, it provides a basis for considering the after-tax marginal cost of R&D expenditure. When 1 yen of R&D expenditure is not recognized as a deductible expense, the after-tax marginal cost C is JPY 1.

Case (2) includes current expenditures. R&D expenditure can be divided into current and capital expenditure. Current expenditure is deductible as a loss. The after-tax marginal cost C of R&D expenditure of 1 yen for current expenditure is $(1-\tau)$ yen. When the corporate tax rate $\tau = 0.2$, the after-tax marginal cost is (1-0.2)=0.8 yen.

Case (3) is a case of depreciation using the declining-balance method for capital expenditures. Tax savings are postponed by recording 1 yen of

[7] The contents of this and the next section are based on McFetrige and Warda (1983).

R&D expenditure as a fixed asset as capital expenditure and then depreciating the fixed asset to expense over a number of years. Typical depreciation systems include the declining-balance and straight-line methods. Assuming the statutory depreciation rate $a (0 \leq a \leq 1)$ for the declining-balance method, the tax savings from depreciation $A_{R\&D}$ is as follows, where e is the base of the natural logarithm.

$$A_{R\&D} = \tau \int_0^{\infty} a e^{-(a+r)t} \, dt = \frac{\tau a}{a+r} \quad (11)$$

In this case, the discounted present value C of the after-tax marginal cost is $\{1 - \tau a/(a+r)\}$ yen. When the interest rate $r = 0.05$ and the statutory depreciation rate $a = 0.3$, the after-tax marginal cost is {1 − 0.2×0.3/(0.3+0.05)} = 0.8286 yen.

Case (4) shows the depreciation in capital expenditure using the straight-line method. Assuming the statutory useful life of the straight-line method $L (> 0)$, the tax savings $A_{R\&D}$ from depreciation using the straight-line method for capital expenditure of 1 yen would be as follows:

$$A_{R\&D} = \tau \sum_{t=0}^{L-1} \frac{1}{(1+r)^t} \quad (12)$$

The discounted present value C of the after-tax marginal cost of R&D is $[1 - \tau \sum_{t=0}^{L-1} \{1/(1+r)^t\}]$ yen. Assume a case in which the R&D cost of 1 yen is capital expenditure and depreciates using the straight-line method over its statutory useful life L of five years. One year of depreciation is 1/5=0.2 yen. Therefore, the after-tax marginal cost C is [1 − 0.2*× {0.2 + 0.2/(1+0.05) + $0.2/(1+0.05)^2$ + $0.2/(1+0.05)^3$ + $0.2/(1+0.05)^4$}] =0.8182 yen.

There is an immediate write-off that is fully deductible for capital expenditures; this treatment is the same as that for current expenditures in Case (2). Comparing the after-tax marginal costs C of immediate depreciation and depreciation, immediate depreciation has a lower after-tax marginal cost than depreciation, which is advantageous for a firm. The magnitude of the after-tax marginal cost of the declining-balance method versus the straight-line method depends on the statutory depreciation rate a and statutory useful life L.

Case (5) presents a simple and special deduction. Assuming a special deduction rate $k(k > 0)$, when R&D expenditures of 1 yen are made, $(1 + k)$ yen can be deducted from the current year's income. In this case, the after-tax marginal cost C is $\{1 - \tau(1 + k)\}$ yen. When the special deduction rate $k = 0.1$, the after-tax marginal cost is ｛1－0.2×(1+0.1)=0.78 yen.

Case (6) outlines the increase in R&D expenditure between the previous and current years, which can be deducted from the income for the current year. Let us assume that R&D expenditures for the current year exceed those for the previous year by 1 yen. In this case, a special deduction can be applied to the excess amount in the current period; however, if R&D expenditures in the next period do not increase, the special deduction cannot be applied, and a loss is incurred because of the excess amount. Since the discounted present value of the loss is $1/(1 + r)$ yen, the after-tax marginal cost C is $[1 - \tau\{1 - 1/(1 + r)\}]$ yen. The after-tax marginal cost of the numerical example is [1－0.2×{1－1/(1+0.05)}]=0.99 yen.

Case (7) generalizes Case (6) and considers the case in which the excess current-year R&D expenditures over the average past years' R&D expenditures can be deducted from current-year income. Let us assume that the current year's R&D expenditures exceed the average R&D expenditure for the past m years by JPY 1. In this case, the discounted present value of the loss associated with the excess in the current period is $\sum_{n=0}^{m-1}(1 + r)^{-n}/m$ yen. Therefore, the after-tax marginal cost C is $[1 - \tau\{1 - \sum_{n=0}^{m-1}(1 + r)^{-n}/m\}]$ yen. Assuming the past three years ($m = 3$), the after-tax marginal cost is 〔1－0.2×[1－1/{(1+(1+0.05)$^{-1}$＋(1+0.05)$^{-2}$)/3}]=0.8699 yen.

Case (8) is the tax credit case: for a tax credit rate $c(0 \leq c \leq 1)$ for

R&D expenditures of 1 yen, I consider a simple tax credit that can reduce a firm's tax burden. In this case, the marginal after-tax cost C is $(1-\tau-c)$ yen. When the tax credit rate $c=0.1$, the after-tax marginal cost is (1 − 0.2 − 0.1) = 0.7 yen.

Case (9) considers the case in which the firm spends 1 yen on nominal R&D expenditures to keep the real stock of R&D assets constant; in this case, the tax credit rate c for R&D expenditures can be applied. Under an inflation rate π, nominal R&D expenditures increase at an incremental rate of π. In this case, the after-tax marginal cost C is $[1-\{\tau+(1+\pi)c\}]$ yen. When the inflation rate π=0.03, the after-tax marginal cost C is [1 − {0.2 + (1 + 0.03)×0.1}] = 0.697 yen.

As described above, various R&D tax systems can be assumed, and the after-tax marginal cost C differs according to the tax system. In the following, a combination of cases (2) and (4) is assumed.

Case (10) considers the current expenditure ratio $b(0\leq b\leq 1)$ and the capital expenditure ratio $(1-b)$ out of R&D expenditure of 1 yen, where the full amount of current expenditure is deductible, and the depreciation of capital expenditure is calculated by the straight-line method over the statutory useful life of L years. Since the tax savings on current expenditures are τb yen and the discounted present value of the tax savings on capital expenditures is $\tau(1-b)\sum_{t=0}^{L-1}\{1/(1+\rho)^t\}$ yen, the after-tax marginal cost C is $\left[1-\tau[b+(1-b)\sum_{t=0}^{L-1}\{1/(1+\rho)^t\}]\right]$ yen.

When the ratio of current expenditures is $b=0.9$, current expenditures are JPY 0.9, and capital expenditures are 0.1 yen. When the corporate tax rate $\tau=0.2$ and the statutory useful life $L=5$, the tax savings on current expenditures is 0.2×0.9 = 0.18 yen and the tax savings on capital expenditures is $0.2\times0.1\times\{1/5 + (1/5)/(1+0.05) + (1/5)/(1+0.05)^2 + (1/5)/(1+0.05)^3 + (1/5)/(1+0.05)^4\} = 0.0182$ yen. Therefore, the after-tax marginal cost C is (1－0.18－0.0182)＝0.8018 yen.

Table 1 summarizes the after-tax marginal cost C of the various R&D expenditures considered in this section and shows the impact of an increase in one parameter on after-tax marginal costs, with the other factors given as comparative statics (top of column of Table 1).

Table 1 Impact of Increasing Parameters on After-tax Marginal Costs C and $B\ index$

Cases	Impact on after-tax marginal cost C (top of the column) and $B\ index$ (bottom of column) when parameters increase								
	τ	a	r	L	k	π	w	c	b
(1) Not deductible as loss	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	+	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
(2) Current expenditure (or immediate depreciation)	−	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
(3) Depreciation using the declining-balance method	−	−	+	N/A	N/A	N/A	N/A	N/A	N/A
	+	−	+	N/A	N/A	N/A	N/A	N/A	N/A
4) Depreciation using the straight-line method	−	N/A	+	+	N/A	N/A	N/A	N/A	N/A
	−	N/A	+	+	N/A	N/A	N/A	N/A	N/A
(5) Simple special deduction	−	N/A	N/A	N/A	−	N/A	N/A	N/A	N/A
	−	N/A	N/A	N/A	−	N/A	N/A	N/A	N/A
(6) Deduct excess from the previous period	−	N/A	−	N/A	N/A	N/A	N/A	N/A	N/A
	+	N/A	−	N/A	N/A	N/A	N/A	N/A	N/A
(7) Deduct excess from the average of the previous m years	−	N/A	−	N/A	N/A	N/A	N/A	N/A	N/A
	+	N/A	−	N/A	N/A	N/A	N/A	N/A	N/A
(8) Simple tax credit	−	N/A	N/A	N/A	N/A	N/A	N/A	−	N/A
	−	N/A	N/A	N/A	N/A	N/A	N/A	−	N/A
(9) Tax credit for the increased portion	−	N/A	N/A	N/A	N/A	−	N/A	−	N/A
	−	N/A	N/A	N/A	N/A	−	N/A	−	N/A
(10) Combination of case (2) and case (4)	−	N/A	+	+	N/A	N/A	N/A	N/A	+
	−	N/A	+	+	N/A	N/A	N/A	N/A	+

Note: "+" and "-" are the signs of $\partial C(x)/\partial x$ when the parameter x increases.

For example, if the corporate tax rate τ increases, the after-tax marginal cost will decrease. Thus, the after-tax marginal cost C is a decreasing function of the corporate tax rate τ ($\partial C(\tau)/\partial\tau < 0$). This indicates that firms facing a higher corporate tax rate τ will benefit more from the R&D credit; however, it is these firms that suffer from a high corporate tax burden in the first place.

5. Theoretical Examination of the B index

This section theoretically examines the B index, an indicator with more economic significance than the after-tax marginal cost of R&D. The B index is an indicator proposed by McFetridge and Warda (1983) that has recently been compared internationally by the OECD. [8]

Suppose that a firm has several R&D projects. For each R&D project, when the discounted present value of R&D-related marginal revenue DR and the discounted present value of R&D-related marginal cost DC are measured, the marginal rate of return π of the research projects can be calculated with the former as the numerator and the latter as the denominator. The subscript i refers to individual R&D projects.

$$\pi_i = DR_i/DC_i \tag{13}$$

When multiple R&D projects are arranged in order, starting with the R&D project with the highest marginal rate of return π, the marginal rate of return curve for R&D will be rightward sloping (see Figure 3). Firms can implement R&D projects efficiently with high marginal returns. Firms must determine to what extent they should implement R&D projects. In this case, the after-tax marginal cost discussed in the previous section provides information on which R&D tax system reduces the after-tax marginal cost but does not provide information on R&D project decision-making.

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[8] See OECD (2016, 2020), Palazzi (2011), Appelt, Galindo-Rueda Cabral (2019), Cabral, Appelt and Hanappi (2021), Ikeda and Ijichi (2023).

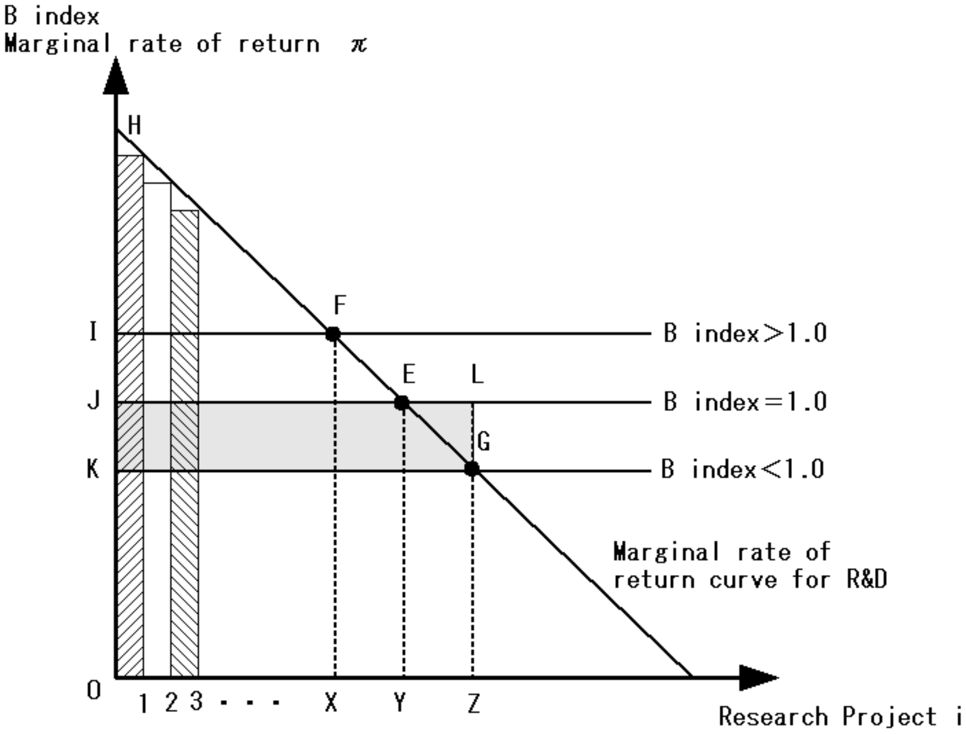

Figure 3: R&D projects and B index

This is where the concept of the B index emerges. The simplest index B is expressed as follows [9]:

$$B\ index = \frac{C}{1-\tau} = \frac{1-A_{R\&D}}{1-\tau} \qquad (14)$$

The B index is a component of the R&D tax capital cost $\tilde{p}_{R\&D}$ considered earlier. The denominator $(1-\tau)$ is the after-tax marginal opportunity cost

[9] According to OECD (2013), the generalized definition of the B index is as follows

$$B\ index = \frac{1-\tau\left[d\theta+(1-d)\psi_{\infty}\left\{1+\frac{(\theta-1)}{\psi_{\infty}}\psi_{O}\right\}\right]}{1-\tau\{d+(1-d)\psi_{\infty}\}}$$

where θ is the deduction rate for R&D expenditures, $d=1$ denotes a surplus firm, $d=0$ denotes a deficit firm, ψ is the tax abatement parameter for carrying forward deficits, ∞ means carry forward indefinitely, and O means the carry forward period. Note that the Japanese R&D tax system does not apply to loss-making firms and does not allow them to carry over deficits.

of the firm's non-R&D projects.

Since the marginal cost of non-R&D projects is deductible as a loss, the amount of tax savings is τ, and thus the after-tax marginal cost is $(1-\tau)$. From the above, the B index represents the cost–benefit ratio of the relative after-tax marginal cost (numerator) of R&D projects to the after-tax opportunity cost (denominator) of non-R&D projects. [10] The B index is also an indicator of the marginal rate of return because, under optimal R&D capital stock, the after-tax marginal cost equals the marginal rate of return.

When the marginal rate of return π_i is greater than or equal to the B index $(\pi_i \geq B\ index)$, the R&D project should be implemented; when the marginal rate of return π_i is less than the B index ($\pi_i < B\ index$), the R&D project should not be implemented. As shown in Figure 3, when $B\ index = 1$, R&D projects from 1 to Y are implemented at point E, which intersects with the R&D marginal revenue curve. When $B\ index > 1$, R&D projects can be implemented only from 1 to X, as at point F. When $B\ index < 1$, the R&D projects can be implemented from 1 to Z, as at point G.

Note that the B index is a concept that can be applied to individual firms and at the country level. The after-tax marginal cost is expressed in currency units, but the B index can be used for international comparisons because the currency units disappear. In this respect, it is an indicator that can be used for policy purposes, as emphasized by the OECD. For example, a country with a $B\ index < 1$ has a high level of domestic R&D but loses significant corporate tax revenue.

In the following, I present numerical examples by formulating $B\ index_j$ for cases (1) to (10) of the after-tax marginal cost C examined in the previous section. j is the subscript for these cases.

[10] According to Warda (2001), the B index was named to represent the cost–benefit ratio.

In case (1), R&D expenditures are not recognized as deductible expenses. This case is unlikely to be considered in a typical system; however, it is an important criterion for understanding the movement of the B index.

$$B\ index_1 = 1/1 - \tau \tag{15}$$

When the corporate income tax rate $\tau = 0.2$, then $B\ index_1$=1/(1－0.2)=1.25. In this case, an R&D project with a rate of return π greater than 1.25 would be implemented.

The second is case (2) of the current R&D expenditure (or immediate depreciation).

$$B\ index_2 = (1-\tau)/(1-\tau) = 1 \tag{16}$$

In Case (3), fixed assets depreciate using the declining balance method.

$$B\ index_3 = \frac{\{1-\tau a/(a+r)\}}{1-\tau} \tag{17}$$

When I assume interest rate $r = 0.05$ and statutory depreciation rate $a = 0.3$, then $B\ index_3$＝0.8286/(1－0.2)＝1.0357.

In Case (4), depreciation is calculated using the straight-line method for fixed assets.

$$B\ index_4 = \frac{\left[1-\tau \sum_{t=0}^{L-1}\{1/(1+r)^t\}\right]}{1-\tau} \tag{18}$$

When the statutory useful life is $L = 5$, then $B\ index_4$＝0.8182/（1－0.2）=1.0228.

Case (5) is a simple special deduction case.

$$B\ index_5 = \frac{\{1-\tau(1+k)\}}{1-\tau} \tag{19}$$

When the special deduction rate is $k = 0.1$, then $B\ index_5$＝(1－0.22)/(1－0.2)=0.975.

In case (6), the increased portion of R&D expenditures from the previous and current periods can be deducted from the current period's income.

$$B\ index_6 = \frac{[1-\tau\{1-1/(1+r)\}]}{1-\tau} \tag{20}$$

According to the numerical example, $B\ index_6 = 0.99/(1-0.2)=1.2375$.

In Case (7), the amount exceeding the average of past years' R&D expenditures can be deducted.

$$B\ index_7 = \frac{\left[1-\tau\left\{1-\sum_{n=0}^{m-1}(1+r)^{-n}/m\right\}\right]}{1-\tau} \quad (21)$$

In the case of the past three years ($m = 3$), $B\ index_7 = 0.8699/(1-0.2)=1.0874$.

Case (8) is a simple tax credit case.

$$B\ index_8 = \frac{\{1-t-c\}}{1-\tau} \quad (22)$$

When the tax credit rate $c = 0.1$, then $B\ index_8=0.7/(1-0.2)=0.875$.

In case (9), tax deductions are allowed for an increased portion of R&D expenditure to maintain substantial R&D capital stock.

$$B\ index_9 = \frac{[1-\{\tau+(1+\pi)c\}]}{1-\tau} \quad (23)$$

In the numerical example, $B\ index_9=0.697/(1-0.2)=0.8713$.

Case (10) is a combination of cases (2) and (4).

$$B\ index_{10} = \frac{\left[1-\tau\left[b+(1-b)\sum_{t=0}^{L-1}\{1/(1+\rho)^t\}\right]\right]}{1-\tau} \quad (24)$$

When the ratio of recurrent expenditure is $b = 0.9$, $B\ index_{10}=0.8018/(1-0.2)=1.0002$.

Table 1 shows the movement of the B index when the parameters increase as a comparative static analysis under various R&D tax systems (bottom of column of Table 1).

In addition, the OECD estimates the implied marginal R&D tax subsidy rate $(1 - B\ index)$.[11] According to Figure 3, when the marginal revenue curve intersects with the $B\ index < 1$, the firm implements R&D projects from 1 to Z. In this case, the rectangle JLGK is a "hidden subsidy." Therefore, the implied subsidy rate of the R&D tax system indicates the

[11] See OECD (2016, 2020), Palazzi (2011), Appelt, Galindo-Rueda Cabral (2019), Cabral, Appelt and Hanappi (2021), and Ikeda and Ijichi (2023).

extent to which the government subsidizes firms.

6. Estimating the Marginal Cost After-tax and B index for Japan's R&D Tax System

Japan's R&D tax system, which applies to fiscal years beginning on or after April 1, 2023, and ending on or before March 31, 2026, includes a general-type R&D tax system that can be applied to R&D expenditures and an open innovation type that can be applied to joint R&D projects involving two or more parties.[12] SMEs with capital of 100 million yen or less can apply for the Tax System for Strengthening the Technological Base of Small and Medium-Sized Enterprises, which offers a higher deduction rate than the general-type R&D tax system. In this section, after explaining the mechanisms of the general R&D tax system and the Tax System for Strengthening the Technological Base of Small and Medium-Sized Enterprises, I estimate the after-tax marginal costs C and B indices of Japan's R&D tax system.

6.1. Large firm cases

First, the deduction rate for the general-type R&D tax credit, which is mainly applied to large firms, changes depending on the ratio of increased/decreased R&D expenditure $\bar{p}$ and the ratio of comparative R&D expenditure $\bar{y}$. The increase/decrease ratio in R&D expenditures is the average of the comparative R&D expenditures E_0 for each fiscal year that began within the three years prior to the start of the fiscal year in which the R&D tax credit was applied, divided by the change $(E_0 - \bar{E})$ in the current

[12] For information on the institutional changes to Japan's R&D tax system, see Director General for Economic and Fiscal Management, Cabinet Office (2002), Tanaka (2008), Onishi and Nagata (2009), and Kato and Saito (2013).

fiscal year's R&D expenditures. Here, $t = 0$ is the current fiscal year.

$$\bar{p} = \frac{E_0 - (\sum_{t=-4}^{-1} E_t)/3}{(\sum_{t=-4}^{-1} E_t)/3} = \frac{E_0 - \bar{E}}{\bar{E}} \tag{25}$$

On the other hand, the ratio of R&D expenditures $\bar{y}$ is the ratio of R&D expenditures E_0 for the current period to the average amount of sales $\bar{Y}$ over the past four years.

$$\bar{y} = \frac{E_0}{(\sum_{t=-5}^{-1} Y_t)/4} = \frac{E_0}{\bar{Y}} \tag{26}$$

The deduction rate c^*_{LARGE} for large firms can be expressed as follows.

$$c^*_{LARGE} = \begin{cases} min\{0.115 + (\bar{p} - 0.12) \times 0.375,\ 0.14\} & if\ \bar{p} > 0.12 \\ max\{0.115 + (0.12 - \bar{p}) \times 0.25,\ 0.01\} & if\ \bar{p} \leq 0.12 \\ 0.085 & if\ \bar{E} = 0 \end{cases} \tag{27}$$

When the increase/decrease ratio in R&D expenditure $\bar{p}$ exceeds 12%, the deduction rate changes from 11.5% to a maximum of 14% at a slope of 0.375. When the ratio of R&D expenditures is 12% or less, the deduction rate changes from a minimum of 1% to 11.5% with a slope of 0.25. When the fiscal year of establishment or the comparative R&D expenditure $\bar{E}$ is zero, the deduction rate is 8.5%.

The tax credit for large firms J_{LARGE} is capped at 25% of the corporate tax amount T_0.

$$J_{LARGE} = max(c^*_{LARGE} E_0, 0.25 \times T_0) \tag{28}$$

These are general rules, but additional measures for the deduction rate and maximum deduction amount exist. When a firm's R&D expenditure ratio $\bar{y}$ exceeds 10%, the deduction rate c_{LARGE} can be applied as an additional measure of the deduction rate c^*_{LARGE} for large firms. The maximum reduction observed is 14%.

$$c_{LARGE} = min\{c^*_{LARGE} + (\bar{y} - 0.1) \times 0.5,\ 0.14\} \quad if\ \bar{y} > 0.1 \tag{29}$$

In other words, 50% of R&D expenditures that exceed 10% can be added to the deduction rate.

There are two upper limits to the deductions as additional measures. The first upper limit of the deduction $\hat{\gamma}_{LARGE}$ is as follows:

$$\hat{\gamma}_{LARGE} = \begin{cases} min\{0.25 + 0.625 \times (\bar{p} - 0.04), 0.3\} & if \ \bar{p} > 0.04 \\ 0.25 & if \ -0.04 > \bar{p} > 0.04 \\ max\{0.25 + 0625 \times (\bar{p} + 0.04), 0.2\} & if \ \bar{p} \leq -0.04 \end{cases} \quad (30)$$

When the increase/decrease ratio in R&D expenditures $\bar{p}$ is greater than 4%, the maximum deduction rate changes from 25% to 30%, with a slope of 0.625. When the increase/decrease ratio in R&D expenditures is between -4% and 4%, the maximum deduction rate is 25%. When the increase/decrease ratio in R&D expenditures is less than -4%, it changes from a minimum of 20% to 25% at a slope of 0.625. The second maximum deduction rate $\check{\gamma}_{LARGE}$ is as follows:

$$\check{\gamma}_{LARGE} = 0.25 + min\{(\bar{y} - 0.1) \times 2, \quad 0.1\} \quad (31)$$

A portion of the ratio of R&D expenditures exceeding 10% may be added to the maximum deduction limit rate up to a maximum of 10%. The larger of the two deduction limit rates above will be the final deduction limit rate γ_{LARGE}.

$$\gamma_{LARGE} = max(\hat{\gamma}_{LARGE}, \check{\gamma}_{LARGE}) \quad (32)$$

Therefore, the maximum deduction limit is 35%. [13]

Thus, a tax credit J_{SMES} that considers time-limited measures is required.

$$J_{LARGE} = max(c_{LARGR}E_0, \gamma_{LARGE}T_0) \quad (33)$$

6.2. Small and Medium-Sized Enterprise Cases

Second, SMEs are eligible for the Tax System for Strengthening the Technological Base of Small and Medium-Sized Enterprises, but not in combination with the general-type R&D tax system. The deduction rate

[13] For venture firms that have been established for less than 10 years, the maximum deduction limit is 40% of the corporate tax amount.

c_{SMES} for SMEs under the Tax System for Strengthening the Technological Base of Small and Medium-Sized Enterprises is as follows:

$$c^*_{SMES} = \begin{cases} min\{0.115 + (\bar{p} - 0.12) \times 0.375,\ 0.17\} & if\ \bar{p} > 0.12 \\ 0.12 & if\ \bar{p} \leq 0.12 \end{cases} \quad (34)$$

The deduction rate varied with a slope of 0.375 from a minimum of 12% to a maximum of 17%.

Tax credit for SMEs J_{SMES} is capped at 25% of corporate tax.

$$J_{SMES} = max(c^*_{SMES}E_0, 0.25 \times T_0) \quad (35)$$

While this is the general rule, SMEs are also subject to higher deduction rates and multiplier limits. When a firm's proportion of R&D expenditure $\bar{y}$ exceeds 10%, the deduction rate c_{SMES} may be applied as a top-up measure deduction rate c^*_{SMES} for SMEs. The maximum reduction observed is 17%.

$$c_{SMES} = min\{c^*_{SMES} + c^*_{SMES} \times (\bar{y} - 0.1) \times 0.5,\ 0.17\} \quad if\ \bar{y} > 0.1 \quad (36)$$

Two deduction caps are used as additional measures. The first deduction ceiling rate $\hat{\gamma}_{SMES}$ is as follows:

$$\hat{\gamma}_{SMES} = \begin{cases} 0.35 & if\ \bar{p} > 0.094 \\ 0.25 & if\ \bar{p} \leq 0.094 \end{cases} \quad (37)$$

When a firm's increase/decrease ratio in R&D expenditure, $\bar{p}$, is greater than 9.4%, the maximum deduction cap rate is 35%. The second maximum deduction rate $\check{\gamma}_{SMES}$ is as follows.

$$\check{\gamma}_{SMES} = 0.25 + min\{(\bar{y} - 0.1) \times 2,\quad 0.1\} \quad (38)$$

A portion of the ratio of R&D expenditures exceeding 10% may be added to the maximum deduction limit rate up to a maximum of 10%. The greater of the above two maximum deduction rates is the final maximum deduction rate γ_{SMES}.

$$\gamma_{SMES} = max(\hat{\gamma}_{SMES}, \check{\gamma}_{SMES}) \quad (39)$$

Thus, the maximum deduction is capped at 35%. [14]

Based on the above, a tax credit from J_{SMES} is required to address this time limitation.

$$J_{SMES} = max(c_{SMES}E_0, \gamma_{SMES}T_0) \tag{40}$$

6.3. Estimation of B index

After explaining Japan's R&D tax system, I estimate the after-tax marginal cost C and B index when the general-type R&D tax system and the Tax System for Strengthening the Technological Base of Small and Medium-Sized Enterprises are applied, assuming that large and small firms have a sufficient corporate tax burden ($J_{LARGE} = c_{LARGR}E_0$, $J_{SMES} = c_{SMES}E_0$). In the estimation, the Japanese corporate tax rate parameter τ is applied to large firms at the basic tax rate of 23.2% for ordinary corporations in FY2024. SMEs with capital of 100 million yen or less also use the basic tax rate of 23.2%, but a reduced tax rate of 15% is used for taxable income of 8 million yen or less per year.

First, for large firms, the deduction rate c_{LARGE} ranges from 1% to 14%. For a marginal R&D expenditure of 1 yen, the tax savings range from a minimum of (0.232+0.01)=0.242 yen to a maximum of (0.232+0.14)=0.372 yen. The minimum after-tax marginal cost is (1-0.372)=0.628 yen, and the maximum is (1-0.242)=0.758 yen. Therefore, $B\ index_{LARGE}$ is 0.628/(1-0.232)=0.8177 at the minimum and 0.758/(1-0.232)=0.9869 at the maximum. The implicit subsidy rate for R&D taxation (1- $B\ index_{LARGE}$) is (1-0.81177)=0.0131 at the minimum and (1-0.9869)=0.1823 at the maximum. [15]

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[14] The open innovation type is capped at 45% of the corporate tax amount.

[15] The OECD website R&D tax incentives in Japan (https://stip-pp.oecd.org/innotax/countries/Japan) provides estimates of the implicit marginal subsidy rate (1 - $B\ index$) for R&D taxation for large firms in

Second, for SMEs, the deduction rate of c_{SMES} ranges from a minimum of 12% to a maximum of 17%. For a marginal R&D expenditure of 1 yen, the tax savings range from a minimum of (0.232+0.12)=0.242 yen to a maximum of (0.232+0.17)=0.402 yen for the basic tax rate and from (0.15+0.12)=0.27 yen to a maximum of (0.15+0.17)=0.32 yen for the reduced tax rate. The after-tax marginal cost C ranges from a minimum of (1-0.402)=0.598 yen to a maximum of (1-0.242)=0.758 yen. Therefore, the $B\ index_{SMES}$ for the basic tax rate ranges from a minimum of 0.598/(1-0.232)=0.7786 to a maximum of 0.758/(1-0.232)=0.9870, while that for the reduced tax rate ranges from a minimum of 0.598/(1 -0.15)=0.7035 to a maximum of 0.758/(1-0.15)=0.8918 for the reduced tax rate. The implicit subsidy rate for R&D taxation (1-$B\ index_{SMES}$) is (1-0.9870)=0.013 at the minimum and (1-0.7035)=0.2965 at the maximum.

In other words, Japan's R&D tax system favors SMEs over large firms.

7. Conclusion

This study has demonstrated that Japan's R&D tax system causes the largest tax revenue loss among special taxation measures. However, the R&D tax system is still necessary because of positive externalities in firms' R&D activities (which would be underestimated if left to the market), information asymmetries, and uncertainty. Although subsidies can provide policy support for firms' R&D activities, the R&D tax system is more flexible and beneficial to the firm than subsidies, which are subject to the risk of idea outflow and require prior application and ex-post reporting of results.

Japan in 2023 estimates for Japan's large firms in 2023, with a minimum of 0.01 and a maximum of 0.17. The estimates are generally consistent with those in this study.

However, because of large tax revenue losses, there has been much interest in the results achieved by the R&D tax system, which has generated many empirical analyses. Therefore, this study provides a comprehensive survey of the previous empirical analyses of Japan's R&D tax system. It highlights the importance of a method for analyzing R&D taxation from the perspective of the cost of capital.

This study presents a firm behavior model that incorporates the R&D tax system, derives the cost of capital, and theoretically examines the after-tax marginal cost of R&D and the B index. Finally, I estimated the after-tax marginal cost of R&D and the B index based on Japan's R&D tax system. Japan's R&D tax system favors small and medium-sized enterprises (SMEs) over large firms.

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