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DEPRECIATION RATE OF R&D CAPITAL: PANEL DATA ANALYSIS OF LISTED FIRMS IN JAPANESE R&D-INTENSIVE INDUSTRIES

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ABSTRACT

Research and development (R&D) capital is thought to be at the core of technological progress. To measure the effect of R&D capital correctly, the knowledge of its depreciation rate is required. However, few studies have paid attention to the depreciation rate of R&D capital for recent Japanese firms. This study estimates the depreciation rate of R&D capital by two methods using panel data of listed Japanese firms in R&D-intensive industries. The results show that the rates are higher than the conventionally accepted 15 percent and those estimated by previous studies for Japanese firms.

Keywords: Research and development (R&D), Depreciation rate of R&D capital, Japanese firms, Panel data, Q model of investment, Multiple capital assets, Instrumental variable.

JEL Classification: O30; C81

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Contribution/ Originality

This study contributes in the existing literature in that it compares the results by two methods which have different assumptions. Another contribution of this study is to find that the depreciation rates of R&D capital for recent Japanese firms in R&D-intensive industries are higher than the conventionally accepted rate.

1. INTRODUCTION

The expected rate of potential growth in Japan is declining because of a rapidly aging population. Therefore, it is necessary to increase total factor productivity growth by technological progress to raise the rate of potential growth. Since Research and development (R&D) capital is thought to be at the core of technological progress, it is important to analyse the effect of R&D correctly. To measure the R&D effect, it is necessary to know the correct depreciation rate of R&D capital and construct the R&D capital series. Nevertheless, few studies have paid attention to the depreciation rate of R&D capital. Most of the previous studies, including Griliches and Mairesse (1984) used a constant depreciation rate (usually 15%).[1] However, whether the depreciation rate of R&D capital is constant across

[1] Previous studies such as Griliches and Mairesse (1984)., Hall and Mairesse (1995)., Los and Verspagen (2000)., and Branstetter (2000; 2001). used the constant depreciation rate of 15% for R&D capital stock.

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countries and industries has not been verified. The main objective of this paper is to measure the depreciation rate of R&D capital of Japanese R&D-intensive industries by applying the two methods: the market value approach, and the R&D-earnings approach. We construct the panel data of listed Japanese firms in four industries, namely, the pharmaceutical, electric and electronic manufacturing, chemical, and machinery industries, for the period 1986 to 2010. The rest of this paper is organized as follows. In Section 2, previous studies are reviewed. Next section of the paper considers the estimation method of the depreciation rate of R&D capital. Estimation results are shown in Section 4. Section 5 concludes the paper with suggestions for future research.

2. PREVIOUS STUDIES MEASURING THE DEPRECIATION RATE OF R&D CAPITAL

2.1. Patent Renewal Data Method

Bosworth (1978) estimates the technological knowledge obsolescence rate using patent renewal data. Pakes and Schankerman (1984); Goto *et al.* (1986) the Development Bank of Japan (2005) and Sakai (2013) also apply this method. For example, Bosworth (1978) uses U.K. patent data from the 1930s to the 1940s and estimates that the rate of obsolescence is 10 to 15 percent. Goto *et al.* (1986) and the DBJ (2005) both use Japanese patent data. Goto *et al.* (1986) estimate the depreciation rate of R&D capital to be 7 to 10 percent in the 1960s, and the DBJ (2005) estimates it to be 13 to 22 percent in the 1980s. Similarly, Sakai (2013) estimates the depreciation rate using Japanese patent data from 1996 to 1999 and reports the rate to be 13 to 22 percent. Pakes and Schankerman (1984) use the patent data of European countries from the 1930s and find the rate to be 25 percent. However, estimating the depreciation rate of R&D capital using this method has a weakness. Although the statistics covers a wide variety of patents, it covers only certain kinds of knowledge that can be patented. Moreover, patent renewal depends on the patent policies of each firm. Pakes and Schankerman (1984) identify sample selection bias resulting from the differences in the depreciation rate of patented innovations and that of other type of innovations. In addition, Goto and Suzuki (1989) show that Japanese patent holders tend to keep their patents even though they may no longer represent valuable knowledge because the renewal fee is relatively low. Therefore, the estimates of R&D depreciation rate using patent renewal data may be biased downward.

2.2. Market Value Method

Hall (2007) applies the idea proposed by Griliches (1981) and Hayashi and Inoue (1991) and estimates the depreciation rates of R&D capital assuming that R&D and physical capital are valued equally in the market. This method is forward looking in that it relies on the financial market's assessment of firm value. Hall (2007) estimates the rates to be 14.9 percent for pharmaceutical and 35.7 percent for electric manufacturing firms in the U.S. during 1974 to 2003.

Table-1. Estimated depreciation rate of R&D capital: previous studies

Study	Estimation type	Sample	Period	Depreciation rate of R&D capital
Bosworth (1978)	Patent renewal	UK patents	1934–1965	9.9–15.3%
Goto *et al.* (1986)	Patent renewal	Japan patents	1948–1968	7.1–10.4%
DBJ (2005)	Patent renewal	Japan patents	1980s	13.2–22.0%
Pakes and Schankerman (1984)	Patent renewal	UK, Germany, France, Netherlands and Switzerland patents	1930–1939	25%
Sakai (2013)	Patent renewal	Japan patents	1982–1999	12.6–21.6%
Hall (2007)	Market value	US manufacturing 1,521 firms	1974–2003	Chemicals: 19.4% Drugs: 14.9% Electrical: 35.7% Computers: 30.6%
Lev and Sougiannis (1996)	R&D-earnings relation	US Electrical 98 firms	1975–1981	Current 11.4% Preceding 17.7% … (Length of lags: 7 years)

Source: Prepared by author.

2.3. The R&D-Earnings Method

The estimation of R&D amortization rates proposed by Lev and Sougiannis (1996) is based on the fundamental relation between R&D and the earnings.[2] They define the R&D amortization rate in year *k* as the ratio of that year's expired benefits to the total benefits generated by R&D for *x* periods. Lev and Sougiannis (1996) estimate the rate of amortization on current R&D to be 11.4 percent, and the preceding year's R&D to be 17.7 percent.

3. METHODS OF ESTIMATING THE DEPRECIATION RATE OF R&D CAPITAL

3.1. Estimation Using the Market Value Method

3.1.1. Model

Hall (2007), which is based on the theoretical *Q* model of investment with multiple capital assets proposed by Hayashi and Inoue (1991), is applied in this section.

The model has two capitals—physical capital (K_p) and R&D capital (K_R)—with the corresponding investments *I* and *R*, prices p_t^I and p_t^R, and depreciation rates δ_C and δ_R. The expectation operator E_t is based on the information at period *t* and β is a constant discount rate.

Firm *i* maximize the following value function:

$$\begin{aligned} \max\ V_{it} &= E_t \sum_{j=0}^{\infty} \beta^j \left[\Pi\left(K_{Pi,t+j}, K_{Ri,t+j}, K_{Pi,t+j+1}, K_{Ri,t+j+1}; p_{i,t+j}\right) - p_{i,t+j}^I I_{i,t+j} - p_{i,t+j}^R R_{i,t+j} \right] \\ s.t.\quad K_{P,,t+j+1} &= (1-\delta_C) K_{P,,t+j} + I_{i,t+j} \\ K_{Ri,t+j+1} &= (1-\delta_R) K_{Ri,t+j} + R_{i,t+j} \end{aligned} \quad (1)$$

To solve Equation (1) using the condition where the cost of capital equals the marginal profit, following Jorgenson-type cost of capital functions are derived:

$$C_{it}^P = p_{it}^I - E_t\left[\beta(1-\delta_C) p_{i,t+1}^I\right] \quad (2)$$

$$C_{it}^R = p_{it}^R - E_t\left[\beta(1-\delta_R) p_{i,t+1}^R\right] \quad (3)$$

Now, Equation (1) can be rewritten as Equation (4):

$$\begin{aligned} V_t &= E_t \sum_{j=0}^{\infty} \beta^j \left[\Pi\left(K_{Pi,t+j}, K_{Ri,t+j}, K_{Pi,t+j+1}, K_{Ri,t+j+1}; p_{i,t+j}\right) - p_{i,t+j}^I I_{t+j} - p_{i,t+j}^R R_{t+j} \right] \\ &= E_t \sum_{j=0}^{\infty} \beta^j \left[\Pi\left(K_{Pi,t+j}, K_{Ri,t+j}, K_{Pi,t+j+1}, K_{Ri,t+j+1}; p_{i,t+j}\right) - C_{i.t+j}^P K_{Pi,t+j+1} - C_{i.t+j}^R K_{Ri,t+j+1} \right] \\ &\quad + (1-\delta_C) p_{it}^I K_{Pi,t} + (1-\delta_R) p_{it}^R K_{Ri,t} \end{aligned} \quad (4)$$

We assume the firm's supranormal rent (*W*) to be

$$W_{it} \equiv E_t \sum_{j=0}^{\infty} \beta^j \left[\Pi\left(K_{Pi,t+j}, K_{Ri,t+j}, K_{Pi,t+j+1}, K_{Ri,t+j+1}; p_{i,t+j}\right) - C_{i,t+j}^P K_{Pi,t+j+1} - C_{i,t+j}^R K_{Ri,t+j+1} \right] \quad (5)$$

Thus, Equation (6) is obtained from Equation (4) and (5).

$$V_{it} = (1-\delta_C) p_{it}^I K_{Pi,t} + (1-\delta_R) p_{it}^R K_{Ri,t} + W_{it} \quad (6)$$

By using Equation (6), conventionally measured Tobin's q can be shown as follows:

$$q_{it} = V_{it} / (1-\delta_C) p_{it}^I K_{Pi,t} = 1 + \left[(1-\delta_R) p_{it}^R K_{Ri,t} / (1-\delta_C) p_{it}^I K_{P,t}\right] + W_{it} / (1-\delta_C) p_{it}^I K_{Pi,t} \quad (7)$$

[2] This method differs market value method in that it focuses on the firm's realized earnings, rather than expected returns.

However, the correct depreciation rate is not known beforehand. Assuming that the depreciation rate δ_R is tentative, the regression result will be biased by $\hat{\gamma}$.

$$\ln q_{it} = \ln\{1+\gamma[(1-\delta_R)p_{it}^R K_{Ri,t}/(1-\delta_C)p_{it}^I K_{Pi,t}]+W_{it}/(1-\delta_C)p_{it}^I K_{Pi,t}\}+\varepsilon_{it} \quad (8)$$

If K_R^* is assumed to be the true R&D capital, where 'true' indicates that the R&D capital is computed using the correct depreciation rate δ, Equation (9) holds:[3]

$$\ln q_{it} = \ln[1+(1-\delta)p_{it}^R K_{Ri,t}^*/(1-\delta_C)p_{it}^I K_{Pi,t}]+\varepsilon_{it} \quad (9)$$

By defining $\hat{\gamma}(1-\delta_R)/(1-\delta_C) \equiv \hat{\Theta}$, following equation holds:

$$\ln q_{it} = \ln\{1+\hat{\gamma}[(1-\delta_R)p_{it}^R K_{Ri,t}/(1-\delta_C)p_{it}^I K_{Pi,t}]\}+\varepsilon_{it} = \ln[1+\hat{\Theta}(p_{it}^R K_{Ri,t}/p_{it}^I K_{Pi,t})]+\varepsilon_{it} \quad (10)^4$$

From Equations (9) and (10), Equation (11) is obtained.

$$(1-\delta)p_{it}^R K_{Ri,t}^*/(1-\delta_C)p_{it}^I K_{Pi,t} = \hat{\Theta}(p_{it}^R K_{Ri,t}/p_{it}^I K_{Pi,t}) \quad (11)$$

Assuming that R&D expenditure grows at a constant rate *g*, the following relation holds:

$$K_{R,t} = K_{R,t}^*(\delta+g)/(\delta_R+g) \quad (12)$$

Equation (13) follows from Equations (11) and (12):

$$(1-\delta)p_t^R K_{R,t}^*/(1-\delta_C)p_t^I K_{P,t} = \hat{\Theta}(p_t^R K_{R,t}/p_t^I K_{P,t}) = \hat{\Theta}(p_t^R/p_t^I K_{P,t})[K_{R,t}^*(\delta+g)/(\delta_R+g)] \quad (13)$$

Thus, the correct depreciation rate δ can be given in Equation (14), where we assume that δ_R is 15 percent as a starting value.

$$\delta = [(\delta_R+g)-(1-\delta_C)g\hat{\Theta}]/[(\delta_R+g)+(1-\delta_C)\hat{\Theta}] \quad (14)$$

3.1.2. Variables

Variable V_{it} denotes firm *i*'s market value, that is, its stock price multiplied by the number of stocks issued by firm *i* at time *t*; δ_C is the depreciation rate of physical capital, for which the rates of depreciation of goods proposed by Hayashi and Inoue (1991) are applied. Variables $p_t^I K_{P,t}$ and $p_t^R K_{R,t}$ are the nominal physical capital and R&D capital, respectively. Tentative R&D capital K_R is calculated by using δ_R and R_t, where R_t is R&D expenditure.

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[3] If K_P and K_R^* are at their optimal level and the marginal shadow value of both capitals are equal, γ should be one and *W* should be zero.

[4] Hall (2007). tries to add capital aggregator term $\phi(K_R/K_P)$ as an explanatory variable in Equation (10) to capture possible supranormal rents. However, the capital aggregator term and $\hat{\Theta}(p_{it}^R K_{Ri,t}/p_{it}^I K_{Pi,t})$ will be highly correlated across firms. Assuming that financial markets are efficient and firms quickly achieve equilibrium, Equation (10) is estimated without including the capital aggregator term.

Following the method used by Goto and Suzuki (1989) and Hall and Mairesse (1995) Equation (15) is used for setting the starting value of R&D capital (K_R),[5] where g is assumed to be constant for the estimation period.

$$K_{R,1} = R_0 + (1-\delta)R_{-1} + (1-\delta)^2 R_{-2} + \ldots = R_0 \sum_{s=0}^{\infty} [(1-\delta)/(1+g)]^S = R_1/(g+\delta) \quad (15)$$

3.1.3. Data

Panel data of listed firms used in this paper is on the NEEDS-Financial QUEST files between fiscal years 1986 and 2010. The sample, which satisfies all the necessary variables, includes 45 pharmaceutical, 271 electric and electronic manufacturing, 176 chemical, and 328 machinery firms.

3.2. Estimation Using the R&D-Earnings Method

3.2.1. Model

Applying Lev and Sougiannis (1996) Equation (16) where logarithms mitigate heteroscedasticity[6] is estimated by using the instrumental variables and the Almon lag procedure:

$$\ln OI_{it} = \alpha_0 + \alpha_1 \ln TA_{i,t-1} + \sum_{k=0}^{x} \alpha_{2,k} \ln RD_{i,t-k} + \alpha_3 \ln AD_{i,t-1} + e_{it} \quad (16)^7$$

Where OI is the operating income before depreciation, advertising and R&D expenses; TA is value of tangible assets; $RD_{i,t-k}$ is R&D expenditure with k lags; and AD is advertising capital. R&D amortization rate in year k is defined as the ratio of that year's expired benefits, $\hat{\alpha}_{2,,k}$ to the total benefits R&D generated.

$$\delta_k = \hat{\alpha}_{2,k} \Big/ \sum_k \hat{\alpha}_{2,k} \quad (17)$$

The length of lag is set by x, and $\hat{\alpha}_{2,x}$ is the last significant coefficient.[8]

3.2.2. Variables

Average R&D expenditure of other firms is used as instrument for RD_i,[9] as followed by Lev and Sougiannis (1996). Moreover, advertising expenditure is used instead of advertising capital for AD_i, because their effect on subsequent earnings is short-lived.

3.2.3. Data

Panel data of listed firms used in this paper is on the NEEDS-Financial QUEST files between fiscal years 1986 and 2010. The sample, which satisfies all the necessary variables, includes 38 pharmaceutical, 207 electric and electronic manufacturing, 145 chemical and 223 machinery firms.

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[5] It is assumed that we follow a perpetual inventory method to construct the R&D capital.

[6] Lev and Sougiannis (1996). do not take logarithms, but scale by total sales to mitigate heteroscedasticity.

[7] Liu (2005). also tries this type of method for 20 Japanese pharmaceutical firms during 1986–2000.

[8] This means that if $\alpha_{2,x+1}$ is insignificant while $\alpha_{2,x}$ is significant in Equation (16), then x is the last significant coefficient. In that, x is considered the useful life of R&D capital. However, finding the reasonable length of lags that affect the estimation result is quite difficult.

[9] An association between a firm's R&D expenditures and those of average R&D of other firms is induced by spillover. Cohen and Levinthal (1989). show that R&D develops the firm's absorptive capacity, the ability to assimilate and exploit others' knowledge.

4. RESULTS

4.1. Market Value Method

Table-2 shows the estimation results by market value method. Equation (10) is estimated by using nonlinear least squares with year and firm dummies, and δ is obtained by Equation (14). The rate ranges from 19.5 to 29.3 percent, which are found to be higher than the conventionally accepted 15 percent. Among them, the depreciation rate of R&D capital was the highest for electric and electronic manufacturing firms.

Table-2. Estimation results using the market value method

1986 to 2010	pharmaceutical	electric and electronic	chemical	machinery
$\hat{\Theta}$ (Standard errors)	0.663 (0.114)	0.462 (0.036)	0.573 (0.073)	0.706 (0.057)
δ, Estimated depreciation rate of R&D	20.9%	29.3%	21.6%	19.5%
Samples	926	4,545	3,353	5,751

Source: Author's calculation.

4.2. R&D-Earnings Method

Table-3 shows the estimation results of annual depreciation rate δ_k using Equation (16) with year and firm dummies.[10] The length of the statistically significant lagged R&D coefficient, $\alpha_{2,k}$, indicates the useful life of R&D capital. Thus, the average useful life is the shortest in electric and electronic manufacturing, seven years, followed by chemicals and pharmaceuticals, and the longest in machineries, ten years. R&D capital depreciates very quickly especially for electric and electronic manufacturing firms such that the amortization rate of current R&D was 22.4 percent, preceding year's R&D was 20.3 percent, and so on.

Table-3. Estimation results using the R&D-earnings method

	pharmaceutical			electric and electronic			chemical			machinery		
	α		δ_k	α		δ_k	α		δ_k	α		δ_k
const.	-2.120	(3.797)		0.949	(0.280)		0.019	(0.005)		-0.164	(0.019)	
α_0	-0.016	(0.022)		0.018	(0.003)		0.741	(0.031)		0.340	(0.043)	
α_1	0.144	(0.045)		0.493	(0.033)		0.201	(0.016)		0.254	(0.025)	
$\alpha_{2,0}$	0.138	(0.072)	11.8%	0.034	(0.010)	22.4%	0.218	(0.141)	12.7%	0.593	(0.073)	12.8%
$\alpha_{2,1}$	0.155	(0.063)	13.2%	0.031	(0.006)	20.3%	0.252	(0.070)	14.7%	0.608	(0.068)	13.1%
$\alpha_{2,2}$	0.163	(0.063)	14.0%	0.027	(0.006)	17.9%	0.269	(0.025)	15.6%	0.607	(0.068)	13.1%
$\alpha_{2,3}$	0.164	(0.066)	14.0%	0.023	(0.007)	15.0%	0.268	(0.039)	15.6%	0.589	(0.070)	12.7%
$\alpha_{2,4}$	0.156	(0.067)	13.4%	0.018	(0.007)	11.8%	0.249	(0.061)	14.5%	0.555	(0.071)	12.0%
$\alpha_{2,5}$	0.141	(0.065)	12.1%	0.012	(0.006)	8.2%	0.213	(0.069)	12.4%	0.504	(0.069)	10.9%
$\alpha_{2,6}$	0.118	(0.057)	10.1%	0.007	(0.004)	4.3%	0.160	(0.062)	9.3%	0.436	(0.064)	9.4%
$\alpha_{2,7}$	0.086	(0.044)	7.4%				0.089	(0.039)	5.2%	0.352	(0.054)	7.6%
$\alpha_{2,8}$	0.047	(0.025)	4.0%							0.251	(0.041)	5.4%
$\alpha_{2,9}$										0.134	(0.023)	2.9%
α_3	0.141	(0.022)		0.256	(0.023)		-12.374	(1.686)		0.141	(0.022)	
N	739			2,923			2,036			2,593		
$Adj.R^2$	0.963			0.881			0.950			0.845		

Note: Standard errors are in parentheses.
Source: Author's calculation

[10] Hall (2007). and Lev and Sougiannis (1996). are modified in estimating Equations (10) and (16) in that firm dummies are included to control for firm effects.

4.3. Comparison of Annual Depreciation of R&D Capital

Figure-1 shows how the R&D capital at period zero depreciates annually by using the market value (red line) and R&D-earnings (blue line) methods, and compares them with the conventionally accepted depreciation rate of 15 percent (green dotted line).

The estimated rates are found to be higher than 15 percent for all four industries, while the rates estimated by both methods follow a similar trend.

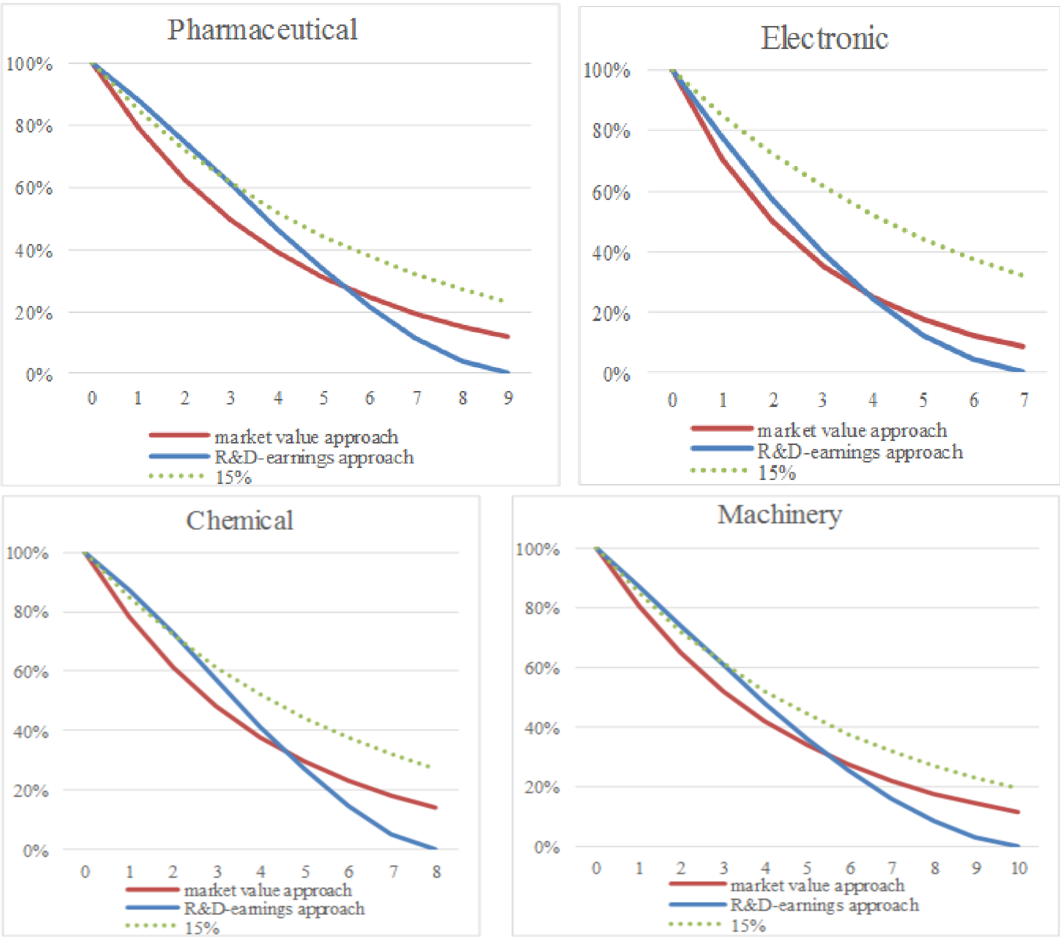

Figure-1. Comparison of annual depreciation of R&D capital

Source: Calculated and prepared by author.

5. DISCUSSION

In this paper, depreciation rates of R&D capital for Japanese firms in R&D-intensive industries are measured by using two methods with recent data. The estimated depreciation rates are found to be higher than the conventionally accepted 15 percent and the rates estimated by previous studies for Japanese firms, such as Goto *et al*. (1986).[11] Since the depreciation rate reflects technological progress, rapid technological progress[12] can be inferred especially for Japanese electric and electronic manufacturing firms.

[11] Estimated R&D depreciation rate for electric and electronic manufacturing firms also far exceed the rate estimated by the DBJ (2005). and Sakai (2013). while the estimated rate for other industries are around the upper limit of the results by these previous studies.

[12] All the previous studies introduced in this paper on Japanese firms are using the data before the year 2000. Therefore, it can be inferred from our results that rapid technological progress occurs after the year 2000.

The Japanese government will replace the System of National Accounts (SNA) from '1993 SNA' to '2008 SNA' in 2016. According to this change, R&D expenditures will be capitalized,[13] and the depreciation rate of R&D to estimate the R&D capital is necessary. Bureau of Economic Analysis (BEA) in U.S. Department of Commerce developed an R&D satellite account as a prelude to this change, and calculated R&D capital by using the R&D depreciation rate of 11 percent for chemicals and 15 percent for all other industries according to Mead (2007) which are far below the estimated result of this paper. In addition, there are no reasons to believe that the depreciation rates of R&D capital are identical by industries and will not change in the future. Applying the methods presented in this paper will be helpful to calculate the R&D capital correctly.

Two methods are used to estimate the depreciation rate of R&D capital in this paper. Each method is based on different assumptions and has different strengths and weaknesses. The first one is the market value method, which has a firm theoretical background. However, the assumptions for this method is strict. It assumes that financial market is efficient and that the firm can optimize its choice of R&D capital smoothly. If the adjustment cost in R&D capital is not negligible, then the method will not work well. The second one is the R&D-earnings method. It is intuitively comprehensible in that it focuses on the fundamental relation between R&D expenditures and subsequent benefits. However, it does not have a theoretical background. In addition, setting the reasonable length of lags in estimating Equation (16) is somewhat arbitrary.

Following two tasks remain to be solved for future research. Firstly, further test is needed for robustness checks based on the thorough review of other alternative methods. There are also other methods with different assumptions to estimate the rate of depreciation. Secondly, enlarge the sample size to unlisted firms is desirable. In this paper, we limit the sample to listed firms, while some unlisted small and medium-sized firms are actively promoting R&D.

Appendix

Descriptive statistics

1. Pharmaceutical

1986 to 2010	Mean	SD	Min.	Max.	Samples
depreciation rate of physical capital	5.83%	0.88%	0.21%	13.85%	933
nominal physical capital (one mil. yen)	28,827.5	37,642.4	397.0	293,590.3	979
nominal R&D capital (one mil. yen)	53,412.2	90,651.6	4.4	806,987.4	979
Q	6.47	4.64	0.02	21.62	926
real operating income (one mil. yen)	35,275.4	65,999.8	-638.4	578,154.6	848
real tangible fixed assets (one mil. yen)	23,997.3	31,009.2	1.1	322,428.6	1,133
real advertisement expenses (one mil. yen)	2,956.6	4,323.1	1.7	32,908.7	927
real R&D expenditure (one mil. yen)	13,763.1	29,390.8	0.9	280,748.8	1,028

2. Electric and electronic manufacturing

1986 to 2010	Mean	SD	Min.	Max.	Samples
depreciation rate of physical capital	6.51%	0.92%	4.72%	13.72%	5,032
nominal physical capital (one mil. yen)	58,934.1	203,389.8	61.7	1,891,353.0	5,723
nominal R&D capital (one mil. yen)	45,499.9	196,881.9	2.7	1,905,625.0	4,724
Q	3.43	2.81	0.00	13.00	4,545
real operating income (one mil. yen)	18,789.7	63,079.0	-43,339.9	821,238.8	3,914
real tangible fixed assets (one mil. yen)	24,013.0	74,754.9	0.8	895,604.8	6,068
real advertisement expenses (one mil. yen)	1,157.0	4,966.5	0.6	89,300.0	4,822
real R&D expenditure (one mil. yen)	7,488.4	29,265.0	0.6	295,877.6	4,756

[13] R&D expenditures are treated as intermediate consumption in the 1993 SNA.

3. Chemical

1986 to 2010	Mean	SD	Min.	Max.	Samples
depreciation rate of physical capital	7.00%	0.72%	4.86%	10.65%	4,197
nominal physical capital (one mil. yen)	27,494.7	55,820.1	0.6	555,396.0	4,571
nominal R&D capital (one mil. yen)	15,644.9	41,185.7	0.5	483,894.9	3,651
Q	2.50	1.64	0.10	6.79	3,353
real operating income (one mil. yen)	14,705.4	33,096.7	-1,241.9	274,977.1	2,700
real tangible fixed assets (one mil. yen)	33,496.2	63,699.2	1.2	535,629.8	4,576
real advertisement expenses (one mil. yen)	1,590.3	6,478.1	0.8	69,232.9	3,370
real R&D expenditure (one mil. yen)	3,574.1	8,993.2	0.8	96,399.9	3,572

4. Machinery

1986 to 2010	Mean	SD	Min.	Max.	Samples
depreciation rate of physical capital	6.86%	0.26%	6.16%	7.30%	7,414
nominal physical capital (one mil. yen)	40,349.8	165,890.2	1.2	3,387,446.0	8,572
nominal R&D capital (one mil. yen)	14,254.2	98,132.0	1.2	2,953,277.0	6,290
Q	2.34	1.59	0.03	6.32	5,751
real operating income (one mil. yen)	11,819.0	41,610.0	-55,174.4	852,088.9	4,573
real tangible fixed assets (one mil. yen)	29,737.3	96,152.3	1.8	1,410,652.0	8,570
real advertisement expenses (one mil. yen)	1,275.5	6,549.4	0.9	113,333.1	6,589
real R&D expenditure (one mil. yen)	3,137.9	21,677.0	0.9	555,302.9	5,947

Note: Nominal R&D capital is used in Equation (10). So, it is calculated by using the depreciation rate of 15 percent.

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