Measurement of R&D Investment by Firm and Multiple q^*: Analysis of Investment Behaviors by Capital Good at Listed Japanese Firms

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Abstract

In this paper, we measure R&D investment and stock data for listed enterprises in Japan and examine R&D investment behavior as well as tangible ones under the framework of Tobin's *q* theory. We estimate Multiple *q* investment functions, modified Tobin's *q* investment functions considering the heterogeneity of capital goods, and verify whether adding R&D as a new capital good improves the performance of the investment function estimation. Our measurement shows that the share of R&D stock to total stocks is more than 25% and that adding R&D as a new capital stock reduces the upward bias of average *q* as predicted from our theoretical analysis. In addition, we show that the performance of the Multiple *q* investment function improves: the coefficient of determination increases with the number of capital goods whose adjustment cost parameters are positive and estimated to be significant. On the other hand, even after considering R&D investment, redundant variables under the standard Tobin's *q* theory (cash flow ratio and interest-bearing debt ratio) continue to have strong explanatory power. Comparing the estimated values of adjustment cost parameter γ among capital goods, we find that R&D investment has, in particular, a strong correlation with the accumulation of other intangible assets. An international comparison of growth accounting suggests that for Japan's economic growth, it is desirable to implement policies that emphasize the accumulation of intangible assets rather than tangible fixed assets. At the very least, R&D can be captured on financial statements, making it possible to devise stimulus policies, such as investment tax cuts. This suggests that economic policies focused explicitly on stimulating R&D investment may, nevertheless, lead to policies that emphasize intangible asset accumulation more generally.

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I. Introduction

Tobin's *q* theory is the standard approach to empirical analysis of capital investment. Originally proposed by Tobin (1969), the *q* theory was combined with the neoclassical investment theory and its accompanying convex adjustment cost for capital investment by later scholars, and has been used as a framework for the empirical analysis of investment for many years. However, its theoretical robustness was not impressive when the theory was applied to real data through empirical analyses. For example, Asako and Kuninori (1989) summarized the performance of Tobin's *q* investment function in the following three points:

(1) The explanatory power of *q*, which should be a sufficient statistic of the investment rate, is not high (the *q* coefficient is not significant, or even if it is significant, the coefficient is extremely small).

(2) When variables other than *q* are added to the list of explanatory variables, such as cash flow, value of output, and capacity utilization ratio, these variables become significant and in some instances, decrease the explanatory power of *q* itself.

(3) A major serial correlation is seen with the residual term, and past *q* becomes significant as an explanatory variable.

Erickson and Whited (2000) point out that the following three are possibly responsible for the problems with the *q* theory in empirical analysis:

(1) The idea that owner-managers decide the investment amount solely on the basis of their expectations about future profits is not consistent with actual observations.

(2) The econometric assumptions used to derive linear investment functions of Tobin's *q* are not correct. Endogeneity between Tobin's *q* and the investment rate, nonlinear investment functions, etc. should be considered.

(3) Average *q* (original Tobin's *q*) is not sufficient as a proxy variable to marginal *q*, which has robust neoclassical micro foundations, on account of measurement errors.

This list is comprehensive, but fails to consider the heterogeneity of capital stocks, which is our objective of this paper.

Wildasin (1984) is the first theoretical study that considers the heterogeneity of capital in a convex-type adjustment cost framework premised on *q* theory. And, the empirical testing of this theory using data on Japanese listed firms has been conducted since Asako, Kuninori, Inoue and Murase (1989, 1997). They referred to Tobin's *q* as "Multiple *q*" when the heterogeneity of capital stocks was considered and as "Single *q*" when the heterogeneity of capital stocks was not considered. Asako, Kuninori, Inoue, and Murase (1989, 1997) divide capital goods into two categories, land and other fixed capitals, and aimed to clarify the characteristics of land investment, which is the greatest feature of investment behavior in the Japan's bubble economy of the 1980s. Tonogi, Nakamura and Asako (2010) and Asako and

Tonogi (2010) divide into a more detailed set of capital goods consisting of five categories and verified how behavior for the new acquisitions of capital goods and for sales and retirements of those differ after the bubble economy.

However, the results from Asako, Kuninori, Inoue and Murase (1989, 1997), Tonogi, Nakamura and Asako (2010), and Asako and Tonogi (2010) showed that "Multiple *q*" exhibited better fitness than "Single *q*," but the explanatory power did not improve significantly enough even by considering the heterogeneity of capital stocks. Therefore, in addition to convex-type adjustment costs, Asako and Tonogi (2010) introduced fixed costs into the investment function and tried to find a range of investment rate where fixed cost appears for each capital in their trial estimations. Asako, Tonogi and Nakamura (2014) enhanced accuracy in measuring the ranges and fined that the estimation performance slightly improved. While the only convex-type adjustment cost function explained investment dynamics in certain capitals, the non-convex costs appears in the most capitals. However, it was found that there was a considerable variation in the ranges that non-convex appears among capital goods.

These empirical results suggest that it is important to consider the heterogeneity of capital stocks and comprehensive structures of adjustment costs simultaneously. Cooper and Haltiwanger (2006) considered a comprehensive adjustment cost function that encompassed *q* theory and subsequent theoretical frameworks and tried to compare each theory through estimating their parameters to explain total investment, which means capital assets are homogeneous. Using the simulated method of moments (SMM) approach, they estimated the adjustment cost parameters of convex and fixed costs in addition to incorporating investment asymmetry, irreversibility and so on. They showed that a model that combines various cost adjustment structures fits the data reasonably well. Cooper and Haltiwanger (2006) suggested that different types of capital correspond to different adjustment cost processes and that considering a hybrid model is valid if the data for each capital good is unavailable. But, estimation of hybrid models, as in Cooper and Haltiwanger (2006), with heterogeneous capitals is subject to the "Curse of Dimensionality" problem.[1] Then, Tonogi, Nakamura, and Asako (2014) tried to classify the capital goods by factor analysis. If some of the estimated factor loadings are similar, their investment dynamics are also considered to be similar. Consequently, we can say analogously that the parameters for adjustment costs of these investments should be similar, without specifying the functional structures of the adjustment costs.[2] Their results showed that Building and Structure had similar factor loadings as did Machinery & Equipment, Vehicles & Delivery Equipment, and Tools, Furniture, & Fixture. This suggests that we could remedy the Curse of Dimensionality by bundling the investments that have similar factor loadings together and that identifying the functional structures of each group of capital goods can greatly improve the performance of empirical investment

[1] The number of estimated parameters = number of capital goods × number of adjustment cost parameters by capital good is a multiple of ten.

[2] See the Appendix of Tonogi, Nakamura and Asako (2014) for details on the relationship between adjustment cost parameters and factor analysis parameters.

equations.

Note that the above discussion about investment functions is limited to tangible fixed assets. In recent years, the importance of considering not only tangible, but also intangible assets have been recognized.[3] Investment in knowledge creation also includes human capital in the form of education and training, private scientific research, business expenditures on product research and development, market research, and business expenditures on organizational efficiency. These expenditures are strategic investments for long - term growth. Chun, Miyagawa, Pyo and Tonogi (2016) presented an international comparison of growth accounting that considers intangible assets. As can be seen from the comparison, intangibles are very important factor of an economic growth. In both the United States and the United Kingdom, one - third of labor productivity is due to capital deepening of intangibles. In this paper, before we will conduct a structural estimation of the hybrid model, also estimate a Multiple q investment model where R&D investment, one of the intangibles, are treated as another capital good. According to the Accounting Standards Board of Japan (2013), while international accounting standards include comprehensive intangible asset accounting standards, the definitions and conditions for recognizing intangible assets, the Business Accounting Council of Japan have announced "Accounting Standards for R&D and Software Expenditures," which means general definitions of intangible assets and requirements for recognizing other intangibles are not established in Japan. For this reason, accounting treatments of many other intangible assets is determined based on in - house practices. Therefore, economic analyses need measurements of the intangibles by estimation using related accounting items' values from financial statements under certain assumptions.[4] But, R&D expenditure doesn't need such measurement. Toyo Keizai Inc. have surveyed the values of R&D expenditure from each of the Japanese listed firms and have sold the database of R&D. The Japanese accounting standards have changed the treatment of R&D expenditure to a formal accounting item from an accounting notice since April 1998. Through, we can obtain reliable longer - term series on R&D investments and stocks of each Japanese listed firm by combining these database. In this paper, we attempt to estimate a Multiple q investment model using this R&D data. Chun, Miyagawa, Pyo and Tonogi (2016) showed that the amount of recent R&D investment is about one - third in total intangible investment and that the recent shares of R&D stock to sum of tangible and intangible stocks is considerable in the manufacturing industry in Japan.

As will be described in more detail in Section 2, excluding capital goods that should have been taken into consideration leads to an upward bias in average q. This can lead biases in estimates of adjustment costs. In this paper, we will estimate an investment model that treats

[3] Corrad, Goodridge, and Haskel (2011) attribute economic growth in high-income countries (EU, US, etc.) to investment in knowledge creation. They measure intangibles in three categories, "Computerize information," "Innovative property" and "Economic competencies," using the method introduced by Corrado, Hulten, and Sichel (2005, 2006). Measurements of intangible assets in Japan are released as JIP databases on the RIETI (Research Institute of Economy, Trade, & Industry) website.

[4] For example, see Miyagawa, Takizawa, and Edamura (2013).

R&D investment as a new capital good, which accounts for a considerable share of intangible assets and is measured with high accuracy over about 20 years long. We will also discuss its performance.

We organize the rest of the paper as follows. In Section 2, we review investment models with heterogeneous capital goods. Subsection 2.1 discusses the influence of adjustment cost on average q value, and Subsection 2.2 shows the consequences of ignoring capital goods that should have been taken into consideration in the estimation of investment models. Section 3 presents data generation methods, especially for R&D investment and stock series. Section 4 discusses the estimated results, while Section 5 conduct supplemental analysis on the current situation of R&D in Japanese listed firms. Section 6 presents the conclusion.

II. Multiple *q* investment theory

II-1. Convex adjustment cost and Tobin's q

Define V as a value function of firm, p_j as a deflator of the jth capital investment, δ_j as a depreciation rate of the jth capital asset and K_j as a stock of the jth capital asset. Then, a following equation is generally used to estimate "Multiple q" investment function;[5]

$$(q-1)P=\sum_{j=1}^{n}\gamma_j Z_j s_j-\sum_{j=1}^{n}\gamma_j a_j s_j, \tag{1}$$

where

$$q=\frac{V}{\sum_{j=1}^{n} p_j(1-\delta_j)K_j},$$

$$Z_j=\frac{K'_j-(1-\delta_j)K_j}{(1-\delta_j)K'_j},$$

$$P=\frac{\sum_{j=1}^{n} p_j(1-\delta_j)K_j}{\sum_{j=1}^{n}(1-\delta_j)K_j}=\sum_{j=1}^{n} p_j s_j,$$

$$\text{and } s_j=\frac{(1-\delta_j)K_j}{\sum_{j=1}^{n}(1-\delta_j)K_j}.$$

Here, q is the "average q" of capital stock aggregated over n types of capital goods and P is an implicit deflator of aggregate capital stock. In addition, s_j is the ratio of each capital good to aggregate capital stock. Given the data for variables on both sides of equation (1), first we

[5] If you would like to know how to derive equation (1) and the relationship between "Single q" theory, a Tobin's q theory and "Multiple q" theory, see the paper written by Nakamura, Tonogi and Asako in this volume, Vol. 13-2, of Public Policy Review. Single q theory is regarded as a special case where all γ_j are equal in Multiple q theory.

estimate a linear regression using $(q-1)P$ as the dependent variable, and $Z_j\, s_j\ (j=1,\dots,n)$ and $s_j\ (j=1,\dots,n)$ as explanatory variables. After obtaining the estimates of γ_j and $\gamma_j\, a_j$, which are the parameters of the adjustment cost function, we distinguish between γ_j and a_j for each capital good.[6]

If all γ_j are zero, that means no adjustment costs, then Tobin's q must satisfy

$$(q-1)P=0, \tag{2}$$

which suggest average q is always equal to 1. Comparing equations (1) and (2), we confirm that the average q deviates from 1 when some assets have positive values of γ_j.

II-2. Average q when one of the capital goods is ignored incorrectly.

II-2-1. Case $\gamma_j=0$ for all n assets: no adjustment costs exist.

We assume that $\gamma_j=0$ for all n assets as equation (2) in Section 2.1 to analyze how the average q is affected when one of the capital goods is ignored incorrectly when calculating average q. Suppose we have n capital goods and Tobin's q satisfy equation (2), but the nth capital good has been left out of consideration when calculating the value of average q, then we obtain

$$(q_{-n}-1)P_{-n}=\frac{p_n(1-\delta_n)K_n}{\sum_{j=1}^{n-1}(1-\delta_j)K_j}, \tag{3}$$

where

$$q_{-n}=\frac{V}{\sum_{j=1}^{n-1}p_j(1-\delta_j)K_j},$$

$$P_{-n}=\frac{\sum_{j=1}^{n-1}p_j(1-\delta_j)K_j}{\sum_{j=1}^{n-1}(1-\delta_j)K_j}.$$

From equation (3), it is clear that the value of pseudo average q, q_{-n}, deviate from 1 and that the divergence increases when the share of the nth capital stock (in nominal) increase. In the case that nth capital is intangible and others are tangibles, the more important intangible assets are, the more upward biased of the pseudo average q is, while true value of average q is zero.

For example, Tonogi, Nakamura, and Asako (2010), which estimated Multiple q equation for only tangible assets, found that the average q value[7] for certain listed firms in Japan exceeds 100 after the 1990s, primarily for companies in the information technology (IT) industry such as the software industry and computer-information services industry. They

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[6] In Tonogi, Nakamura and Asako (2010), it is reported that the values of a_j are positive for the assets whose estimates of γ_j are significantly positive (supporting a convex adjustment cost).

[7] Some of them exceeds 1,000.

discussed these abnormal values of Tobin's q occur as follows:

(1) The time of so-called "IT bubble" around 2000. But, this reason alone is insufficient to explain the appearance of abnormally high average q even until 2004 fiscal year.

(2) Differences in the source of corporate value. In IT-related businesses, there are many companies that require few tangible fixed assets and derive their corporate value from intangible assets, such as innovative business models and customer networks. Such intangible assets often do not appear in financial statements. Thus, if such firms calculate average q only by tangible assets, the denominator must be close to zero given current future earnings from intangibles in the numerator. This generate abnormally large values of Tobin's q.

Miyagawa, Takizawa and Edamura (2013) followed the definition and the classification of intangibles of Corrado, Hulten and Sichel (2009) (hereafter, CHS) and measured investments and stocks of intangibles and average q[8] by using corporate-level data. They showed that the average q when adding intangibles as new capital goods approaches 1 substantially in average and that its standard deviation also decreases. In this paper, we add only R&D as a new capital good, which accounts for a considerable proportion among intangible assets, then it is expected that the values of average similarly approach 1.

The pseud values of Tobin's q, which equal the nominal stock share of the nth investment good as shown in (3), can be correlated with the investment rates of other investment goods while the true values of Tobin's q don't correlate with the investment ratios as shown in equation (2). Then, there is a possibility to obtain a similar pseud relationship to equation (1) by estimation;

$$(q_{-n}-1)P_{-n}=\sum_{j=1}^{n-1}\gamma_{j,-n}^{*}Z_j s_{j,-n}-\sum_{j=1}^{n-1}\gamma_{j,-n}^{*}a_j^{*}s_{j,-n}, \tag{4}$$

where

$$s_{j,-n}=\frac{(1-\delta_j)K_j}{\sum_{j=1}^{n-1}(1-\delta_j)K_j}.$$

It is problematic that we can obtain pseud adjustment costs that should not have existed in equation (2).

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[8] In Miyagawa, Takizawa and Edamura (2013), R&D investments and stocks are calculated using individual firms' data of "Basic Survey of Japanese Business Structure and Activities" released by Ministry of Economy, Trade and Industry of Japan. They obtain R&D investments by subtracting the tangible fixed asset acquisition amount (for research) from total R&D expenditures (own research + contract research). It is calculated starting from fiscal year 1995 using the perpetual inventory method, which has been in use since 2000. This paper uses data on R&D investment going back to 1989 and is based on a survey by Toyo Keizai Inc., of privately listed companies.

II-2-2. Case $\gamma_j \neq 0$ for some of n assets: adjustment costs exist.

It is more problematic when $\gamma_j \neq 0$ for some of n assets. The corporate value[9] satisfies

$$V(A, K_1, \cdots, K_n) = \sum_{j=1}^{n} \frac{1}{(1-\delta_j)} \frac{\partial V(A, K_1, \cdots, K_n)}{\partial K_j}(1-\delta_j)K_j$$

$$= \sum_{j=1}^{n} \{\gamma_j(Z_j - a_j)(1-\delta_j)K_j + p_j(1-\delta_j)K_j\}, \tag{5}$$

then the Tobin's q becomes

$$(q_{-n}-1)P_{-n} = \sum_{j=1}^{n-1} \gamma_j(Z_j - a_j)s_{j,-n} + \gamma_n(Z_n - a_n)\frac{(1-\delta_n)K_n}{\sum_{j=1}^{n-1}(1-\delta_j)K_j} \tag{6}$$

$$+ \frac{p_n(1-\delta_n)K_n}{\sum_{j=1}^{n-1}(1-\delta_j)K_j}.$$

In addition to the stock share of nth assets that is ignored when measuring Tobin's q, the adjustment costs of other assets also contribute the deviation of pseud Tobin's q from 1. If we estimate a following investment model that ignores nth capital good;

$$(q_{-n}-1)P_{-n} = \sum_{j=1}^{n-1} \gamma_{j,-n}^{**}(Z_j - a_j^{**})s_{j,-n}, \tag{7}$$

and if the nominal stock share of the nth capital good correlate with the investment ratio and stock share of jth capital good, $\gamma_{j,-n}^{**}$ should bias from the true value of γ_j.

II-2-3. The meaning of adjustment cost parameter bias

Adjustment cost is what captures the Penrose effect. Odagiri (2000) offers specific examples of this effect, "*When you try to increase capital, investment costs will increase more than proportionately. For example, if you are trying to make two factories, rather than one, the second factory will have to be built on more expensive or inconvenient land. Furthermore, at the second factory the construction personnel and administrators will tend to be less experienced or less capable people. There are limitations on the number of people with sufficient experience and skills, and they are allocated to the new factories in order,*

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[9] If you would like to know how to deliver equation (6), see equation (6) - (8) in the paper written by Nakamura, Tonogi and Asako in this volume, Vol.13-2, of Public Policy Review.

starting with the best. In other words, when the growth of a company is fast, people with seasoned management skills are likely to be in short supply, and this will increase investment costs." Put more explicitly, the adjustment cost includes things, such as skills, experience, technology, etc. that can be considered as intangibles.

This example suggests that the biased estimates of parameters, $\gamma_{j,-n}^{**}$ $(j = 1, \ldots, n-1)$, for tangibles should not be discarded as meaningless. That is because we can reinterpret the biased adjustment cost of each tangible asset as the intangibles which are necessary to accumulate this tangible. Miyagawa and Kim (2010) measure intangible assets of Japanese individual firms by this approach.[10]

In this paper, we estimate two investment models: first, we consider only tangible assets as investment goods and second, we consider R&D as a capital in addition to tangibles. By treating R&D as a new capital good, the range of investment goods not considered in the model is reduced. Therefore, we expect that the deviation of average q from 1 also decrease. We also expect that we estimate smaller adjustment costs because the estimated adjustment costs of tangibles don't contain the correlation with R&D. The elimination of the bias would lead to more stable and more significant estimation results. Even after the R&D investment is taken into consideration as a new capital good, the existence of the remaining adjustment cost can be understood as something that accompanies the intangible assets other than R&D.

III. Data Creation Methodology

III-1. Tangible investments and stocks

The data used in our analysis are constructed from "DBJ Financial Database of Listed Firms" released by the Development Bank of Japan (hereafter, DBJ financial database), which contains individual firms' financial statement data listed in the First and Second Sections of the Tokyo, Osaka, and Nagoya Stock Exchanges. The data series are extended to FY 2014 in this paper, while it culminated in FY 2007 in Tonogi, Nakamura and Asako (2010). Our panel data-set is unbalanced one, as it contains delisted firms and newly listed ones. The capital stock series are constructed by the perpetual inventory method using 1977 or the first recorded year after 1977 in the DBJ financial database as a benchmark year for each firm.

The database contains detailed data of depreciable assets by 6 items: [1] Building, [2] Structure, [3] Machinery & Devices, [4] Vehicles & Delivery Equipment, [5] Shipment, and [6] Tools, Furniture & Fixture. We measure investment and stock for each of 6 items as well as those for [7] Land. We put these seven assets into five categories[11] and build the investment

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[10] Hall (2000, 2001) advocated this approach, the valuation approach, which assume perfect information of stock market where the stock price accurately reflects the company's future earnings. If we adopt this approach the future benefits of intangibles which defined CHS would be reflected in the stock prices.

[11] We bundle [1] Building and [2] Structure together and call it "Building & Structure." We also bundle [4] Vehicles & Delivery Equipment and [5] Shipment together and call it "Ship & Vehicle."

ratio data for each of the categories; [a] Building & Structure, [b] Machinery & Devices, [c] Ships & Vehicles, [d] Tools, Furniture & Fixture, [e] Land.

The investment amount is theoretically defined as "the amount of the new acquisitions of capital goods" minus "the residual market prices of sales and retirements of capital goods." However, there does not exist any observable data on the residual market prices of sales and retirements of capital goods, and moreover, the data that can be used for estimations is limited. Therefore, in previous research, roughly speaking three kinds of facile methods have been used.

[1] A method (hereinafter referred to as the "proportional method") that uses a value obtained by multiplying the book value of the sales and retirements amount, which is calculated using the fiscal identity, by the "market value/book value ratio." This method has been adopted by Asako, Kuninori, Inoue, and Murase (1989), and Hayashi and Inoue (1991), among others.

[2] The method (hereafter referred to as the "book value method") that directly uses the book value of the sales and retirements amount, which is calculated from the fiscal identity. This method has been adopted by Suzuki (2001).

[3] Since data constraints make accurate calculations impossible for sales and retirements of capital goods and the ratio of the amount to the total investment is considered relatively small, Hori, Saito and Ando (2004) have adopted a method (hereafter referred to as "zero method") where the value of sales and retirements amount of capital goods are assumed and treated as zero. As another interpretation of the zero method, the sales and retirement amount might be thought to be included in depreciation and amortization as a fixed ratio of existing capital stock. Of course, this interpretation can be criticized for ignoring non-periodical and large-scale sales and retirements.

If we compare and contrast the above three methods, it should be noted that if we estimate the investment function using investment data from the zero method, the results of the estimates will only reflect behavior to new acquisitions of capital goods. In contrast, when using data from the other two methods, behavior to sales and retirement of capital goods is also incorporated into the analysis. For more details on the data methodology, please refer to Tonogi, Nakamura and Asako (2010).

III-2. R&D investment and stock

We combined the R&D expenditure data of listed firms in “Data of Depreciation & Amortization, Capital Spending and R&D Expenditure” from Toyo Keizai Inc. (hereafter, Toyo Keizai R&D database) with that of the DBJ financial database to create long-term investment and stocks in [f] R&D for each firm.[12]

We treat the R&D expenditures recorded in both database as nominal R&D investment and use those of Toyo Keizai R&D database for the period before March 2000 and those of the DBJ financial database after that period. Both databases overlap at the period ending March 31, 2000. We calculate the ratio of DBJ’s R&D expenditure to Toyo Keizai ones for each firm in non-consolidated basis at this period. The percentage of firms whose ratios are greater than 0.9 and smaller than 1.1 is 90%. Only firms that satisfy this condition are included in our data for estimation since we regard these firms’ R&D data as consistent. The firms whose closing month fluctuated are removed because its’ length of accounting period change abruptly and the R&D expenditure at those periods cannot be used consistently.

For each firm, if there are missing values of R&D expenditure from the starting period to the final period when the R&D are expenditures are recorded, the linear interpolation method is used to fill the missing values for the intermediate periods. But we decided to drop the firms with two or more missing values to prevent impairing the accuracy of R&D investment measurements.

We obtain a series of R&D deflator as follows. First, we sum the labor cost, raw material cost, leasing fee, and other expenses, as well as tangible fixed asset depreciation expenses of internal research expenditures of all industries in “Survey of Research and Development” released by Statistics Bureau, Director-General for Policy Planning (Statistical Standards) and Statistical Research and Training Institute of Japan. We treat the sum as a series of nominal in-house research expenses. Second, we deflate these series using the fixed salary index of monthly labor statistics (for firms with more than 5 people), intermediate goods price index from the corporate price index, general index excluding imputed rent from the consumer price index, and total fixed capital formation deflator respectively. Then we sum them up to calculate a series of real in-house research expenses. Third, we divide the nominal internal research expenses by the real one to obtain a series of R&D deflator.[13] This R&D deflator series is used for all firms in common.

For firm i, the real R&D investment at time t, $I_{t,i}^{RR}$, is obtained by deflating the nominal R&D investment amount, $I_{t,i}^{NR}$, by the common R&D deflator.

The capital depreciation rate of real R&D stock, δ^R, is set at 0.15 per year in common

[12] Mr. Jun-ichi Nakamura of Japan Development Bank provided valuable advice on combining the two data sets.

[13] To generate a corporate R&D investment deflator, we followed the method of Tonogi (2016).

Table 1. Summary statistics of R&D investment and stock

Variable		Mean	Std. Dev.	Min	Max	Observations
Nominal R&D Investment	overall	6,195.07	19,995.03	3.00	453,046.00	N = 10899
	between		17,569.31	26.42	284,874.70	n = 477
	within		7,822.05	-94,265.33	314,912.70	T-bar = 22.8491
R&D Deflator	overall	0.9873	0.0283	0.8921	1.0202	N = 12402
	between		-	0.9873	0.9873	n = 477
	within		0.0283	0.8921	1.0202	T-bar = 26
Real R&D Investment	overall	6,256.77	20,137.63	3.03	444,056.40	N = 10899
	between		17,750.59	27.01	288,552.00	n = 477
	within		7,739.90	-89,341.12	305,539.50	T-bar = 22.8491
Real R&D Stock	overall	37,421.84	119,847.80	-19,905.57	2,268,758.00	N = 11017
	between		110,614.70	-6,730.83	1,968,989.00	n = 475
	within		31,174.51	-324,055.30	1,000,627.00	T-bar = 23.1937

among the all firms based on BEA[14] (2006) and ESRI[15] (2010).

The initial real R&D capital stock amount, $K_{t_i^*,i}^{RR}$, is estimated for each company using the following formula:

$$K_{t_i^*,i}^{RR} = \frac{\left(\sum_{j=0}^{4} I_{t_i^*+j,i}^{RR}\right)/5}{\left(\sum_{j=0}^{4}(I_{t_i^*+1+j,i}^{RR}/I_{t_i^*+j,i}^{RR}-1)\right)/5+\delta^{R}},$$

where t_i^* is defined as the time when firm *i* records its initial R&D investment data.

For each firm, real R&D capital stocks, $K_{t,i}^{RR}$, after the initial period, t_i^*, are measured using the perpetual inventory method as follows:

$$K_{t+1,i}^{RR} = (1-\delta^{R})I_{t,i}^{\mathrm{RR}} + K_{t,i}^{RR} \;\; (t > t_i^*).$$

The summary statistics for the real R&D investment and stock series are shown in Table 1. As can be seen, we obtain the R&D capital stocks of 475 firms for our estimation, and the average duration of R&D investment series is 22.85 years among the firms.

14 U.S. Bureau of Economic Analysis.

15 Department of National Account, Economic and Social Research Institute, Cabinet Office of Japan. In this paper, we say it "ESRI" shortly.

III-3. Average q

As the previous studies concerning Multiple q mentioned above like Tonogi, Nakamura, and Asako (2010), Asako, Kuninori, Inoue and Murase (1989, 1997), we assume investments of depreciable fixed assets and land have their own adjustment costs in this study. In this paper, we add R&D as one of capital goods and it has its own adjustment cost. On the other hand, we assume that the assets other than depreciable fixed assets, land and R&D have no adjustment costs.

Total q, consistent with the investment model given by Multiple q and as shown in equation (1), is expressed as

$$\frac{\text{firm value} - \text{market value of assets other than capital stocks}}{\text{Replacement value of capital stocks}}.$$

Note that, as the beginning-of-period model is assumed, these values are all measured at the beginning of the period.

Assuming that the current prices of liabilities and assets other than the capital stock are equal to the book values, then Tobin's q can be expressed as follows;

$$\frac{\begin{array}{c}\text{stock price} \times \text{number of outstanding shres}\\ + \text{liability book value} - \text{book value of held assets other than capital stock}\end{array}}{\text{replacement value of capital stock}}.$$

We acquired stock prices from "Nikkei Financial Quest." Because the value of the denominator varies depending on how to measure residual market prices of sales and retirements of capital goods, Total q values are calculated for each of the three methods, which mentioned in Sec. 3.1 separately.

III-4. On the handling of abnormal values

We calculate the average *q* values of each firm for each of the three methods (proportional, zero, and book value). Then, we check the values of the top 1% and the bottom 1% among firms for each year by data construction methods and remove the data which did not fall within that range as outliers. Table 2, Table 3, and Table 4 show the summary statistics of panel datasets used for the proportional, zero, and book valuation methods, respectively after removing the outliers.

Table 2. Summary statistics of proportional method data set

Variable			Mean	Std. Dev.	Min	Max	Observations
(Tobin's *q* - 1) * Deflator		overall	0.1589	1.4830	-3.2985	14.7801	N = 9536
		between		0.9219	-2.0192	5.2670	n = 475
		within		1.2336	-5.1540	12.6883	T-bar = 20.0758
Investment Rate * Stock Share	[a] Building & Structure	overall	0.0143	0.1168	-6.5540	2.3909	N = 9429
		between		0.0633	-1.2997	0.0985	n = 475
		within		0.1081	-5.2401	2.3395	T-bar = 19.8505
	[b] Machinery & Devices	overall	-0.0019	1.9669	-184.3080	20.8863	N = 9322
		between		0.4057	-8.3776	0.9552	n = 470
		within		1.9209	-175.9323	19.9291	T-bar = 19.834
	[c] Ships & Vehicles	overall	0.0011	0.0173	-0.1551	1.4196	N = 8912
		between		0.0086	-0.0122	0.1581	n = 466
		within		0.0161	-0.1785	1.2625	T-bar = 19.1245
	[d] Tools, Furniture & Fixture	overall	0.0076	0.0384	-0.8660	2.4684	N = 9423
		between		0.0104	-0.0449	0.1109	n = 475
		within		0.0369	-0.8330	2.3651	T-bar = 19.8379
	[e] Land	overall	-0.0002	0.0833	-4.3757	1.1490	N = 9411
		between		0.0174	-0.1895	0.1260	n = 475
		within		0.0816	-4.1863	1.0229	T-bar = 19.8126
	[f] R&D	overall	0.0602	0.0418	0.0000	0.4473	N = 9430
		between		0.0376	0.0027	0.1954	n = 475
		within		0.0194	-0.0397	0.3247	T-bar = 19.8526
Stock Share	[a] Building & Structure	overall	0.2597	0.1172	0.0025	0.9079	N = 9895
		between		0.1086	0.0624	0.7899	n = 475
		within		0.0528	-0.2185	0.5594	T-bar = 20.8316
	[b] Machinery & Devices	overall	0.2172	0.1513	0.0000	0.7643	N = 9895
		between		0.1448	0.0000	0.7110	n = 475
		within		0.0537	-0.2949	0.5015	T-bar = 20.8316
	[c] Ships & Vehicles	overall	0.0047	0.0215	0.0000	0.5728	N = 9895
		between		0.0251	0.0000	0.4907	n = 475
		within		0.0055	-0.0661	0.2057	T-bar = 20.8316
	[d] Tools, Furniture & Fixture	overall	0.0663	0.0714	0.0000	0.6248	N = 9895
		between		0.0680	0.0055	0.5874	n = 475
		within		0.0235	-0.2497	0.3606	T-bar = 20.8316
	[e] Land	overall	0.1326	0.1179	0.0000	0.8643	N = 9895
		between		0.1066	0.0007	0.6046	n = 475
		within		0.0584	-0.2416	0.5428	T-bar = 20.8316
	[f] R&D	overall	0.3196	0.1917	0.0000	0.9893	N = 9895
		between		0.1820	0.0164	0.8682	n = 475
		within		0.0696	-0.0366	0.8720	T-bar = 20.8316
Interest Debt Ratio		overall	0.5973	0.8150	0.0000	16.1864	N = 9536
		between		0.8309	0.0000	9.8633	n = 475
		within		0.4245	-6.1720	12.7750	T-bar = 20.0758
Cashflow Ratio		overall	0.0486	0.0526	-0.2473	0.3718	N = 9895
		between		0.0348	-0.0635	0.2007	n = 475
		within		0.0409	-0.2620	0.3739	T-bar = 20.8316

Table 3. Stummary statistics of zero method data set

Variable			Mean	Std. Dev.	Min	Max	Observations
(Tobin's *q* - 1) * Deflator		overall	-0.0332	1.2979	-3.0940	12.2504	N = 9536
		between		0.8370	-1.9218	5.0199	n = 475
		within		1.0665	-4.9769	10.2528	T-bar = 20.0758
Investment Rate * Stock Share	[a] Building & Structure	overall	0.0194	0.0359	0.0000	0.6732	N = 9429
		between		0.0121	0.0020	0.0990	n = 475
		within		0.0343	-0.0795	0.6467	T-bar = 19.8505
	[b] Machinery & Devices	overall	0.0290	0.0340	0.0000	0.5279	N = 9343
		between		0.0198	0.0000	0.1488	n = 470
		within		0.0283	-0.0523	0.4885	T-bar = 19.8787
	[c] Ships & Vehicles	overall	0.0010	0.0055	0.0000	0.2884	N = 9402
		between		0.0051	0.0000	0.0840	n = 474
		within		0.0035	-0.0825	0.2054	T-bar = 19.8354
	[d] Tools, Furniture & Fixture	overall	0.0098	0.0128	0.0000	0.2207	N = 9429
		between		0.0101	0.0005	0.0745	n = 475
		within		0.0079	-0.0457	0.1840	T-bar = 19.8505
	[e] Land	overall	0.0059	0.0260	0.0000	0.7158	N = 9429
		between		0.0083	0.0000	0.0903	n = 475
		within		0.0250	-0.0844	0.6314	T-bar = 19.8505
	[f] R&D	overall	0.0517	0.0382	0.0000	0.4128	N = 9430
		between		0.0352	0.0017	0.1734	n = 475
		within		0.0162	-0.0417	0.2911	T-bar = 19.8526
Stock Share	[a] Building & Structure	overall	0.2661	0.1113	0.0283	0.7938	N = 9895
		between		0.1063	0.0772	0.6674	n = 475
		within		0.0441	-0.0323	0.5098	T-bar = 20.8316
	[b] Machinery & Devices	overall	0.2368	0.1481	0.0000	0.7526	N = 9895
		between		0.1454	0.0000	0.7173	n = 475
		within		0.0419	-0.0535	0.4639	T-bar = 20.8316
	[c] Ships & Vehicles	overall	0.0062	0.0242	0.0000	0.5774	N = 9895
		between		0.0280	0.0000	0.5055	n = 475
		within		0.0065	-0.0680	0.2188	T-bar = 20.8316
	[d] Tools, Furniture & Fixture	overall	0.0751	0.0823	0.0010	0.6256	N = 9895
		between		0.0796	0.0050	0.5884	n = 475
		within		0.0235	-0.1621	0.3781	T-bar = 20.8316
	[e] Land	overall	0.1450	0.1244	0.0009	0.8486	N = 9895
		between		0.1127	0.0011	0.6165	n = 475
		within		0.0587	-0.2130	0.5381	T-bar = 20.8316
	[f] R&D	overall	0.2708	0.1743	0.0000	0.9454	N = 9895
		between		0.1693	0.0092	0.8120	n = 475
		within		0.0533	-0.0497	0.7190	T-bar = 20.8316
Interest Debt Ratio		overall	0.4739	0.5932	0.0000	11.9607	N = 9536
		between		0.6128	0.0000	7.8867	n = 475
		within		0.2988	-4.8004	6.0506	T-bar = 20.0758
Cashflow Ratio		overall	0.0486	0.0526	-0.2473	0.3718	N = 9895
		between		0.0348	-0.0635	0.2007	n = 475
		within		0.0409	-0.2620	0.3739	T-bar = 20.8316

Table 4. Summary statistics of book value method data set

Variable			Mean	Std. Dev.	Min	Max	Observations
(Tobin's q - 1) * Deflator		overall	0.0915	1.4043	-3.2261	12.9478	N = 9513
		between		0.8866	-1.9865	5.2256	n = 475
		within		1.1643	-5.1584	11.7467	T-bar = 20.0274
Investment Rate * Stock Share	[a] Building & Structure	overall	0.0167	0.0459	-1.2986	0.6939	N = 9408
		between		0.0146	-0.1359	0.0982	n = 475
		within		0.0443	-1.2823	0.6655	T-bar = 19.8063
	[b] Machinery & Devices	overall	0.0268	0.0397	-1.0262	0.7449	N = 9322
		between		0.0198	-0.0370	0.1601	n = 470
		within		0.0348	-0.9624	0.6960	T-bar = 19.834
	[c] Ships & Vehicles	overall	0.0009	0.0052	-0.0571	0.2719	N = 9358
		between		0.0038	-0.0022	0.0705	n = 472
		within		0.0042	-0.0923	0.2023	T-bar = 19.8263
	[d] Tools, Furniture & Fixture	overall	0.0094	0.0122	-0.1892	0.2794	N = 9408
		between		0.0096	-0.0013	0.0766	n = 475
		within		0.0076	-0.1785	0.2467	T-bar = 19.8063
	[e] Land	overall	0.0004	0.0700	-3.6032	1.0501	N = 9390
		between		0.0149	-0.1554	0.1138	n = 475
		within		0.0685	-3.4474	0.9366	T-bar = 19.7684
	[f] R&D	overall	0.0570	0.0396	0.0000	0.4291	N = 9408
		between		0.0363	0.0025	0.1830	n = 475
		within		0.0175	-0.0411	0.3100	T-bar = 19.8063
Stock Share	[a] Building & Structure	overall	0.2627	0.1151	0.0279	0.8453	N = 9872
		between		0.1093	0.0695	0.7350	n = 475
		within		0.0478	-0.1539	0.5434	T-bar = 20.7832
	[b] Machinery & Devices	overall	0.2321	0.1489	0.0000	0.7800	N = 9872
		between		0.1458	0.0000	0.7320	n = 475
		within		0.0430	-0.0635	0.4644	T-bar = 20.7832
	[c] Ships & Vehicles	overall	0.0055	0.0204	0.0000	0.5170	N = 9872
		between		0.0232	0.0000	0.4391	n = 475
		within		0.0059	-0.0586	0.2063	T-bar = 20.7832
	[d] Tools, Furniture & Fixture	overall	0.0745	0.0796	0.0010	0.6438	N = 9872
		between		0.0774	0.0050	0.6023	n = 475
		within		0.0225	-0.1009	0.3835	T-bar = 20.7832
	[e] Land	overall	0.1245	0.1100	0.0000	0.8606	N = 9872
		between		0.0994	0.0007	0.6014	n = 475
		within		0.0541	-0.2450	0.5318	T-bar = 20.7832
	[f] R&D	overall	0.3008	0.1806	0.0000	0.9488	N = 9872
		between		0.1750	0.0143	0.8394	n = 475
		within		0.0571	-0.0364	0.7163	T-bar = 20.7832
Interest Debt Ratio		overall	0.5550	0.7165	0.0000	13.7286	N = 9513
		between		0.7529	0.0000	8.5352	n = 475
		within		0.3529	-5.1175	8.1460	T-bar = 20.0274
Cashflow Ratio		overall	0.0487	0.0527	-0.2473	0.3718	N = 9872
		between		0.0349	-0.0635	0.2007	n = 475
		within		0.0409	-0.2620	0.3819	T-bar = 20.7832

IV. Estimation

IV-1. Multiple q investment equations to be estimated

We estimate two Multiple q equations. The first one is the Multiple q investment model that treat tangibles and R&D as capitals;

$$(q-1)P=\sum_{j=1}^{n}\gamma_j Z_j s_j-\sum_{j=1}^{n}\gamma_j a_j s_j, \tag{1}$$

where

$$q=\frac{V}{\sum_{j=1}^{n}p_j(1-\delta_j)K_j},$$

$$Z_j=\frac{K'_j-(1-\delta_j)K_j}{(1-\delta_j)K'_j},$$

$$P=\frac{\sum_{j=1}^{n}p_j(1-\delta_j)K_j}{\sum_{j=1}^{n}(1-\delta_j)K_j}=\sum_{j=1}^{n}p_j s_j,$$

$$s_j=\frac{(1-\delta_j)K_j}{\sum_{j=1}^{n}(1-\delta_j)K_j}.$$

The second one is the Multiple q investment model that treat only tangibles as capitals and doesn't treat R&D as one of capitals[16] incorrectly as follows:

$$(q_{-n}-1)P_{-n}=\sum_{j=1}^{n-1}\gamma_{j,-n}^{**}(Z_j-a_j^{**})s_{j,-n}, \tag{7}$$

where

$$q_{-n}=\frac{V}{\sum_{j=1}^{n-1}p_j(1-\delta_j)K_j}=\frac{p_n(1-\delta_n)K_n}{\sum_{j=1}^{n-1}(1-\delta_j)K_j},$$

$$P_{-n}=\frac{\sum_{j=1}^{n-1}p_j(1-\delta_j)K_j}{\sum_{j=1}^{n-1}(1-\delta_j)K_j},$$

$$s_{j,-n}=\frac{(1-\delta_j)K_j}{\sum_{j=1}^{n-1}(1-\delta_j)K_j}.$$

The average q values in equation (7) deviate more from 1 relative to equation (1) if firms

[16] The nth asset is R&D capital in the models.

have higher nominal stock share of R&D capital. In addition, the adjustment cost parameter, $\gamma^{**}_{j,-n}$, in equation (7) are larger than γ_j in equation (1) for each of tangible assets. Because equation (1) more closely approaches the true model, it is expected that estimates should be more stable and significant than equation (7).

IV-2. Estimation results

Looking at the summary statistics by data construction method of the tangible fixed assets in Tables 2 to 4, the share of R&D stock in average is quite large and these values range from 0.27 to 0.31. Based on the theoretical discussions in Section 2.2, they should lead upward biases in average q when R&D is not treated as a capital. Tonogi, Nakamura and Asako (2010) considered only tangibles as capitals and calculate Tobin's q, which we say pseud Tobin's q in this paper. Comparing $(q-1)P$ of this paper to $(q_{-n}-1)\,P_{-n}$ of Tonogi, Nakamura and Asako (2010) in average, $(q-1)P$ approaches 0 more closely than $(q_{-n}-1)\,P_{-n}$. Similarly, comparing Tobin's q in minimum and the maximum, $(q-1)P$ approaches 0 more closely than $(q_{-n}-1)\,P_{-n}$. Tonogi, Nakamura and Asako (2010) found that Tobin's q in certain industries tend to be outliers, but the tendency get weaken significantly by including R&D capital as a new capital good in this paper. These comparisons support the analytical results in Section 2.2.

Table 5 shows the estimation results of the Multiple q model including R&D as one of capitals. The models (1), (3), and (5) of the estimation results correspond to the results from estimating equation (1) using proportional, zero, and book value data, respectively. Models (2), (4), and (6) are the results from estimating equation (1) using proportional, zero, and book value data, respectively, but with the addition of interest-bearing debt and cash flow ratios. If we add "redundant" explanatory variables, such as cash flow ratio and interest-bearing debt ratio, to the investment model under the Multiple q framework and find that these variables, at least one of them, are significant, then the problem that empirical performance is disappointing in Single q framework attribute to not only heterogeneity of capital goods but also to redundant explanatory variables which Tobin's q theory does not assume.

Table 5 contains the results of both the fixed effects and the random effects estimations for each of the estimation models from (1) to (6). In any of the models, Hausman test supports statistically the fixed effect estimations rather than the random effect ones in our estimations. While γ_j of [c] Ships & Vehicles in the proportional method, [e] Land in the zero method, and [b] Machinery & Devices in the book value method are not estimated significantly, all other γ_j and most of $-a_j\gamma_j$ are estimated significantly in the fixed effects estimations of (1), (3), and (5) models. The signs of γ_j for [c] Ships & Vehicles are estimated to be negative in all three methods. According to factor analysis results in Tonogi, Nakamura and Asako (2014), the adjustment cost parameters for [3] Machinery & Equipment, [4] Vehicle & Delivery Equipment, and [6] Tools, Furniture, & Fixture, are considered to be close. Because the change in one of these capital investments can explain the changes of Tobin's q driven by the

Table 5. Estimation results of Multiple *q* including R&D

Estimation Results of Multiple *q* with R&D (Proportional Method): Trimmed Data

Variable		Model (1)				Model (2)			
		Fixed Effect Model		Random Effect Model		Fixed Effect Model		Random Effect Model	
		Coef.	(Std. Error)	Coef.	(Std. Error)	Coef.	(Std. Error)	Coef.	(Std. Error)
Investment Rate * Stock Share	[a] Building & Structure	0.363	(0.140) ***	0.547	(0.138) ***	0.268	(0.134) **	0.553	(0.131) ***
	[b] Machinery & Devices	0.020	(0.006) ***	0.020	(0.006) ***	0.022	(0.006) ***	0.021	(0.006) ***
	[c] Ships & Vehicles	-0.591	(0.760)	-0.306	(0.763)	-0.502	(0.715)	-0.242	(0.718)
	[d] Tools, Furniture & Fixture	2.767	(0.581) ***	2.928	(0.581) ***	1.825	(0.547) ***	1.876	(0.548) ***
	[e] Land	-0.385	(0.158) **	-0.404	(0.160) **	-0.580	(0.149) ***	-0.649	(0.151) ***
	[f] R&D	17.371	(0.721) ***	17.439	(0.686) ***	13.419	(0.689) ***	12.996	(0.655) ***
Stock Share	[a] Building & Structure	4.792	(0.659) ***	4.330	(0.469) ***	4.946	(0.620) ***	3.903	(0.430) ***
	[b] Machinery & Devices	7.048	(0.710) ***	4.634	(0.488) ***	7.200	(0.667) ***	4.317	(0.446) ***
	[c] Ships & Vehicles	42.585	(2.637) ***	20.271	(1.464) ***	37.479	(2.483) ***	16.992	(1.332) ***
	[e] Land	2.858	(0.667) ***	2.036	(0.472) ***	2.942	(0.627) ***	1.800	(0.432) ***
	[f] R&D	2.140	(0.665) ***	0.745	(0.476)	2.862	(0.625) ***	1.080	(0.436) **
Interest Debt Ratio						0.143	(0.033) ***	0.295	(0.028) ***
Cashflow Ratio						10.006	(0.307) ***	9.999	(0.300) ***
Constant		-4.969	(0.607) ***	-3.616	(0.425) ***	-5.573	(0.571) ***	-3.872	(0.388) ***
Observation		8,520				8,520			
Number of Firms		465				465			
R-square	within	0.144		0.133		0.244		0.231	
	between	0.021		0.049		0.068		0.182	
	overall	0.046		0.078		0.119		0.193	
Hausman Test		275.27				333.32			

Notice: Robust standard errors are in parentheses. "***" denotes p<0.01, "**" denotes p<0.05, and "*" denotes p<0.1.

Estimation Results of Multiple *q* with R&D (Zero Method): Trimmed Data

Variable		Model (3)				Model (4)			
		Fixed Effect Model		Random Effect Model		Fixed Effect Model		Random Effect Model	
		Coef.	(Std. Error)	Coef.	(Std. Error)	Coef.	(Std. Error)	Coef.	(Std. Error)
Investment Rate * Stock Share	[a] Building & Structure	2.785	(0.350) ***	3.103	(0.352) ***	2.339	(0.330) ***	2.621	(0.333) ***
	[b] Machinery & Devices	0.931	(0.438) **	1.489	(0.436) ***	-0.025	(0.413)	0.612	(0.413)
	[c] Ships & Vehicles	-5.776	(3.192) *	-1.183	(3.211)	-6.437	(3.004) **	-1.849	(3.033)
	[d] Tools, Furniture & Fixture	9.028	(1.659) ***	7.996	(1.653) ***	6.429	(1.564) ***	5.358	(1.563) ***
	[e] Land	-0.361	(0.435)	-0.152	(0.441)	0.050	(0.415)	-0.088	(0.420)
	[f] R&D	16.326	(0.681) ***	16.188	(0.646) ***	12.823	(0.650) ***	12.317	(0.620) ***
Stock Share	[a] Building & Structure	7.729	(0.586) ***	5.850	(0.422) ***	7.514	(0.553) ***	5.216	(0.397) ***
	[b] Machinery & Devices	8.540	(0.657) ***	4.924	(0.450) ***	8.797	(0.619) ***	4.680	(0.421) ***
	[c] Ships & Vehicles	39.622	(2.029) ***	20.193	(1.267) ***	36.523	(1.914) ***	18.256	(1.190) ***
	[e] Land	4.812	(0.594) ***	2.492	(0.424) ***	4.484	(0.560) ***	2.058	(0.396) ***
	[f] R&D	5.022	(0.587) ***	2.370	(0.435) ***	5.444	(0.553) ***	2.449	(0.407) ***
Interest Debt Ratio						0.061	(0.035) *	0.229	(0.029) ***
Cashflow Ratio						8.225	(0.249) ***	8.189	(0.246) ***
Constant		-7.418	(0.535) ***	-4.869	(0.384) ***	-7.647	(0.503) ***	-4.825	(0.359) ***
Observation		8,987				8,987			
Number of Firms		470				470			
R-square	within	0.201		0.189		0.292		0.278	
	between	0.076		0.117		0.112		0.207	
	overall	0.095		0.133		0.156		0.224	
Hausman Test		323.17				414.59			

Notice: Robust standard errors are in parentheses. "***" denotes p<0.01, "**" denotes p<0.05, and "*" denotes p<0.1.

Estimation Results of Multiple *q* with R&D (Book Value Method): Trimmed Data

Variable		Model (5)				Model (6)			
		Fixed Effect Model		Random Effect Model		Fixed Effect Model		Random Effect Model	
		Coef.	(Std. Error)	Coef.	(Std. Error)	Coef.	(Std. Error)	Coef.	(Std. Error)
Investment Rate * Stock Share	[a] Building & Structure	2.195	(0.301) ***	2.248	(0.301) ***	1.875	(0.284) ***	1.969	(0.285) ***
	[b] Machinery & Devices	0.176	(0.388)	0.766	(0.388) **	-0.999	(0.367) ***	-0.374	(0.368)
	[c] Ships & Vehicles	-9.228	(2.946) ***	-5.047	(2.951) *	-9.526	(2.774) ***	-5.199	(2.791) *
	[d] Tools, Furniture & Fixture	14.165	(1.800) ***	13.416	(1.791) ***	9.779	(1.700) ***	8.832	(1.697) ***
	[e] Land	-0.487	(0.174) ***	-0.548	(0.176) ***	-0.420	(0.164) **	-0.538	(0.166) ***
	[f] R&D	16.424	(0.696) ***	16.468	(0.662) ***	13.008	(0.663) ***	12.719	(0.633) ***
Stock Share	[a] Building & Structure	9.177	(0.660) ***	6.684	(0.469) ***	8.839	(0.622) ***	5.783	(0.436) ***
	[b] Machinery & Devices	11.563	(0.731) ***	6.657	(0.495) ***	11.630	(0.688) ***	6.083	(0.458) ***
	[c] Ships & Vehicles	44.579	(2.354) ***	24.653	(1.518) ***	40.668	(2.220) ***	21.462	(1.409) ***
	[e] Land	7.094	(0.675) ***	4.185	(0.477) ***	6.745	(0.636) ***	3.443	(0.443) ***
	[f] R&D	6.516	(0.678) ***	3.234	(0.485) ***	6.686	(0.638) ***	2.949	(0.450) ***
Interest Debt Ratio						0.087	(0.031) ***	0.226	(0.027) ***
Cashflow Ratio						9.205	(0.279) ***	9.122	(0.275) ***
Constant		-9.194	(0.612) ***	-5.921	(0.430) ***	-9.319	(0.577) ***	-5.622	(0.399) ***
Observation		8,936				8,936			
Number of Firms		469				469			
R-square	within	0.173		0.161		0.267		0.253	
	between	0.034		0.068		0.069		0.169	
	overall	0.063		0.100		0.123		0.198	
Hausman Test		316.25				417.24			

Notice: Robust standard errors are in parentheses. "***" denotes p<0.01, "**" denotes p<0.05, and "*" denotes p<0.1.

remaining capital investments, it is considered that the estimated adjustment cost parameters of the remaining capitals are not significantly positive. Of course, there is another possible reason that the fact that relatively few firms have own vehicles may lead insufficient and non-robust results. In addition, γ_j for [e] Land is negative and significant with the book value method. With land prices declining after the collapse of the Japan's economic bubble of 1980s, a negative investment, that is, selling off land, may be interpreted as a case leading to the improvement of Tobin's q. Tonogi, Nakamura and Asako (2014) found that Land moves independently from other capital goods by factor analysis. This suggests that the fact that γ_j for [e] Land is not estimated significantly to be positive do not attribute to other capital goods.

The estimated coefficients for the interest-bearing debt ratio and the cash flow ratio in the fixed effects models of models (2), (4), and (6) are significant in common. These results are contradictory to the theoretical consequence that the explanatory variables in the Multiple q model should be sufficient statistics under Tobin's q framework. There remains a problem associated with redundant explanatory variables being significant and it is still difficult for Multiple q model to fully explain investment dynamics by adding R&D as a new capital good.

Table 6 shows the estimation results of Multiple q model when R&D is not included as one of capital goods. The models (1), (3), and (5) in the estimation results correspond to the estimation of equation (7) using proportional, zero, and book value data, respectively. In models (2), (4), and (6), interest-bearing debt and cash flow ratios are added as additional redundant variables. The number of significant coefficients is smaller than Table 5 where R&D is included as a capital. Concerning to positive and significantly estimated coefficients of Model (3)[17], [a] Building & Structure, [b] Machinery & Devices, [d] Tools, Furniture & Fixture have higher coefficient than those of Table 5. Concerning to Model (5), [a] Building & Structure and [d] Tools, Furniture, & Fixture have higher coefficients than those of Table 5. The value of R-square is smaller than that Table 5. These facts prove that adding R&D as one of capitals improve performance of Multiple q investment equation.

For each of the models (1), (3), and (5) in Table 5, we find the following relationship about γ_j among the capitals:

[b] Machinery & Devices < [a] Building & Structure <
< [d] Tools, Furniture & Fixture < [f] R&D.

The estimated γ_j of [d] Tools, Furniture & Fixture are high at 14.1 and 9.0 for the book value and zero system respectively while 2.7 for the proportional method. Especially, the estimated γ_j of [f] R&D are high at 16-17 in all methods. The Penrose effect means the estimated value of the parameter γ_j captures intangibles which are necessary to accumulate jth capital good. The above results show that the investments in [d] Tools, Furniture & Fixture and

[17] Model (1) is excluded from the comparison because of its significantly low R-square.

Table 6. Estimation results of Multiple *q* not including R&D

Estimation Results of Multiple *q* without R&D (Proportional Method): Trimmed Data

Variable		Model (1)				Model (2)			
		Fixed Effect Model		Random Effect Model		Fixed Effect Model		Random Effect Model	
		Coef.	(Std. Error)	Coef.	(Std. Error)	Coef.	(Std. Error)	Coef.	(Std. Error)
Investment Rate * Stock Share	[a] Building & Structure	0.059	(0.123)	0.181	(0.123)	-0.071	(0.115)	0.039	(0.115)
	[b] Machinery & Devices	0.033	(0.037)	0.040	(0.038)	-0.006	(0.035)	-0.001	(0.035)
	[c] Ships & Vehicles	-0.440	(0.889)	-0.232	(0.893)	-0.486	(0.833)	-0.352	(0.837)
	[d] Tools, Furniture & Fixture	0.972	(0.444) **	1.166	(0.447) ***	0.849	(0.442) *	1.193	(0.444) ***
	[e] Land	-0.578	(0.185) ***	-0.551	(0.186) ***	-0.789	(0.173) ***	-0.788	(0.175) ***
Stock Share	[a] Building & Structure	2.337	(0.695) ***	2.072	(0.558) ***	2.777	(0.652) ***	2.162	(0.513) ***
	[b] Machinery & Devices	5.350	(0.739) ***	2.874	(0.568) ***	5.397	(0.696) ***	2.770	(0.521) ***
	[c] Ships & Vehicles	57.534	(3.291) ***	32.754	(2.353) ***	48.830	(3.094) ***	26.932	(2.149) ***
	[e] Land	1.091	(0.719)	-0.168	(0.564)	1.344	(0.676) **	0.072	(0.517)
Interest Debt Ratio						0.073	(0.019) ***	0.100	(0.019) ***
Cashflow Ratio						17.856	(0.523) ***	18.330	(0.513) ***
Constant		-2.237	(0.605) ***	-0.874	(0.477) *	-3.339	(0.570) ***	-1.855	(0.438) ***
Observation		8,889				8,889			
Number of Firms		466				466			
R-square	within	0.061		0.056		0.176		0.168	
	between	0.005		0.002		0.011		0.054	
	overall	0.001		0.003		0.064		0.115	
Hausman Test		253.31				313.94			

Notice: Robust standard errors are in parentheses. "***" denotes p<0.01, "**" denotes p<0.05, and "*" denotes p<0.1.

Estimation Results of Multiple *q* without R&D (Zero Method): Trimmed Data

Variable		Model (3)				Model (4)			
		Fixed Effect Model		Random Effect Model		Fixed Effect Model		Random Effect Model	
		Coef.	(Std. Error)	Coef.	(Std. Error)	Coef.	(Std. Error)	Coef.	(Std. Error)
Investment Rate * Stock Share	[a] Building & Structure	3.140	(0.432) ***	3.326	(0.437) ***	2.328	(0.406) ***	2.472	(0.411) ***
	[b] Machinery & Devices	1.526	(0.573) ***	2.672	(0.574) ***	-0.232	(0.539)	0.886	(0.541)
	[c] Ships & Vehicles	1.463	(4.855)	4.355	(4.926)	-1.662	(4.552)	0.963	(4.625)
	[d] Tools, Furniture & Fixture	17.213	(1.807) ***	16.939	(1.814) ***	12.453	(1.700) ***	11.889	(1.708) ***
	[e] Land	-0.042	(0.593)	0.295	(0.602)	0.475	(0.563)	0.500	(0.571)
Stock Share	[a] Building & Structure	10.086	(0.649) ***	7.574	(0.516) ***	9.307	(0.610) ***	6.468	(0.482) ***
	[b] Machinery & Devices	12.827	(0.742) ***	6.861	(0.549) ***	12.519	(0.695) ***	6.294	(0.510) ***
	[c] Ships & Vehicles	49.667	(2.485) ***	29.505	(1.889) ***	44.341	(2.337) ***	26.018	(1.761) ***
	[e] Land	6.951	(0.677) ***	3.063	(0.519) ***	6.101	(0.636) ***	2.299	(0.482) ***
Interest Debt Ratio						0.102	(0.043) **	0.236	(0.039) ***
Cashflow Ratio						13.876	(0.397) ***	14.257	(0.395) ***
Constant		-9.448	(0.580) ***	-5.707	(0.451) ***	-9.433	(0.544) ***	-5.610	(0.419) ***
Observation		9,339				9,339			
Number of Firms		471				471			
R-square	within	0.146		0.134		0.250		0.236	
	between	0.000		0.010		0.014		0.082	
	overall	0.020		0.049		0.078		0.161	
Hausman Test		383.09				535.31			

Notice: Robust standard errors are in parentheses. "***" denotes p<0.01, "**" denotes p<0.05, and "*" denotes p<0.1.

Estimation Results of Multiple *q* without R&D (Book Value Method): Trimmed Data

Variable		Model (5)				Model (6)			
		Fixed Effect Model		Random Effect Model		Fixed Effect Model		Random Effect Model	
		Coef.	(Std. Error)	Coef.	(Std. Error)	Coef.	(Std. Error)	Coef.	(Std. Error)
Investment Rate * Stock Share	[a] Building & Structure	2.786	(0.381) ***	2.717	(0.383) ***	2.166	(0.358) ***	2.108	(0.361) ***
	[b] Machinery & Devices	0.131	(0.514)	1.075	(0.516) **	-1.691	(0.485) ***	-0.788	(0.488)
	[c] Ships & Vehicles	-1.701	(4.386)	1.044	(4.442)	-4.189	(4.117)	-1.595	(4.181)
	[d] Tools, Furniture & Fixture	24.294	(2.036) ***	25.289	(2.042) ***	16.758	(1.924) ***	17.282	(1.934) ***
	[e] Land	-0.476	(0.224) **	-0.535	(0.227) **	-0.336	(0.210)	-0.444	(0.214) **
Stock Share	[a] Building & Structure	9.984	(0.697) ***	8.013	(0.568) ***	9.074	(0.655) ***	6.647	(0.526) ***
	[b] Machinery & Devices	14.967	(0.777) ***	8.959	(0.595) ***	14.338	(0.730) ***	7.890	(0.548) ***
	[c] Ships & Vehicles	54.597	(2.889) ***	36.876	(2.270) ***	48.048	(2.718) ***	31.312	(2.097) ***
	[e] Land	8.372	(0.721) ***	5.060	(0.576) ***	7.456	(0.678) ***	3.925	(0.533) ***
Interest Debt Ratio						0.111	(0.038) ***	0.216	(0.034) ***
Cashflow Ratio						16.016	(0.463) ***	16.409	(0.460) ***
Constant		-10.156	(0.616) ***	-6.738	(0.497) ***	-10.066	(0.580) ***	-6.391	(0.459) ***
Observation		9,312				9,312			
Number of Firms		470				470			
R-square	within	0.117		0.107		0.223		0.209	
	between	0.006		0.000		0.003		0.056	
	overall	0.006		0.022		0.055		0.132	
Hausman Test		350.97				461.45			

Notice: Robust standard errors are in parentheses. "***" denotes p<0.01, "**" denotes p<0.05, and "*" denotes p<0.1.

especially [f] R&D have strong correlations with the accumulation of other intangibles.

The estimation results above are summarized as follows:

- The share of R&D stock accounts for about a quarter or more and the upward bias of average q has been reduced by adding R&D investment as one of capital goods.
- In addition, the performance of the Multiple q investment function improves. The number of capital goods with significantly positive adjustment cost parameters increases. The coefficient of determination also increases.
- On the other hand, even after considering R&D as one of capitals, redundant variables (cash flow ratio and interest-bearing debt ratio) still have strong explanatory power.
- Comparing estimated value of the adjustment cost parameter γ_j among capital goods, the investments in [d] Tools, Furniture & Fixture and especially [f] R&D investment have strong relationships with the accumulation of other intangibles.

IV-3. Policy Implications

In this paper, we measure R&D investment and stocks and estimate Multiple q investment equation which consider heterogeneity of capitals by adding R&D as one of capital goods. We find that the average q value approaches 1 and that the performance of the Multiple q investment function greatly improved by treating R&D as a new capital goods as well as tangible assets. The adjustment cost capture the Penrose effect and includes things, such as skills, experience, technology, etc. that can be considered as intangibles. The estimated value of the adjustment cost parameter γ_j captures the correlation between the investment ratio of the jth capital good and the stock share of intangible assets other than R&D as shown in Section 2.2 and the estimated adjustment costs tantamount to the intangibles (excluding R&D) necessary for the accumulation of jth capital good. The estimation results suggest that the investments in [d] Tools, Furniture, & Fixture and especially in [f] R&D are strongly related to other intangibles.

The international comparison of growth accounting in Chun, Miyagawa, Pyo and Tonogi (2016) showed that the capital deepening of intangibles contributes about one-third of labor productivity in the United States, the United Kingdom, and France, and about one-fifth in Germany and Finland. On the other hand, at one-tenth in Japan, which is the smallest among developed countries. The Abenomics' "growth strategy" has specified a plan to promote private investment. The international comparison of growth accounting suggests that it is desirable for economic growth in Japan to implement policies that emphasize the accumulation of intangible assets, rather than tangible fixed assets.

According to the Accounting Standards Board of Japan (2013), there is no accounting standard for intangible assets in general, but only software and R&D have their standards exist in Japan. Thus R&D expenditure can be observed on financial statements and this enable us to make economic policies to stimulus investments in intangibles such as investment tax cuts. Currently, in order to strengthen our country's growth potential and international competitiveness through accelerated innovation by maintaining and expanding R&D

investment by private enterprises responsible for the majority of R&D investment in Japan (70 - 80%), a system has been introduced, in which "if research and development expenses are counted as a loss when calculating earnings, you can claim a deduction from the corporate tax amount (national tax) for that business year. This amount can be calculated by multiplying the R&D expenses by the tax credit ratio."[18, 19]

The estimation results in this paper show that a strong correlation between promotion of R&D investment and accumulation of intangible assets. There is a possibility that the economic policies to promote R&D investment promote investment in other intangible assets and that the promotion in intangible investments can accelerates the economic growth furthermore.

Note that it is not possible to specify the causal relation among them in this paper. We will have to measure other intangibles to analyze the actual effects of such policies in future research.

V. Supplement Analysis of R&D Investment in Japan

V-1. Data construction method

In this section, we will add supplement analysis of R&D Investment in Japan by combining annual survey slips of the "Financial Statements Statistics of Corporations by Industry (FSSCI)" collected by Ministry of Finance of Japan with the data analyzed in the Section 4. These databases are matched using company name and capital fund.[20, 21] The merits that we combine FSSCI data is that this database contain the region code, the classification of second and third business as well as main business, and their sales respectively. The data created in this paper is limited to listed firms in Japan, but it contains precise R&D investment and stock data in individual firm level and covers long time about 20 years.

Major macro - statistcs in Japan on R&D are the "Survey of Research and Development" by the Ministry of Internal Affairs and Communications, and the "R&D, Innovation, and Productivity (RDIP) Database" which aggregate individual firms data of "Survey of Research and Development" into the industries which enables international comparison and into

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[18] For small- and medium-sized enterprises, as well as local taxes, incentive measures are being taken to calculate the base amount for local corporate taxes as the amount adjusted for deductions through the R&D tax system.

[19] From Ministry of Economy, Trade and Industry "R&D Tax System" http://www.meti.go.jp/policy/tech_promotion/tax.html

[20] We matched the databases by individual firm from 2003 onward, when firm names start to be written in "kanji", Chinese character used in Japanese writing, in FSSCI.

[21] For matching, we kindly received the cooperation of Mr. Jun-ichi Nakamura of Japan Development Bank.

regions to analyze R&D economic effect.[22] In addition, SNA (System of National Accounts) in Japan has been changed from 93SNA to 08SNA, and has treated R&D investment as a new investment item since December 2016. These macro data are useful to analyze trends and productivities of R&D by industry and region in Japan, but difficult to analyze distribution of R&D among individual firms. Our dataset enable us to analyze the facts obtained by macro- and semi-macro analysis on an individual basis. In the following sections, we add supplement analysis to know the distribution and disparities of R&D among individual firms.

V-2. Relationship between R&D and degree of concentration for core business

FSSCI survey considers a possibility that firms carry on business in a plurality of industries, then the survey investigates sales of the core business (first industry type) and secondary business (second industry type, other industry type) in its questionnaire for each firm. In this section, we analyze the relationship between R&D (stock share and investment rate) and degree of concentration for core business.

The top three tables in Table 7 show the averages of sales share for each business by degree of R&D investment rate at FY2003 (OLD) and FY 2013 (NEW). We classify firms into high degree ones and low degree ones by the data construction methods for tangibles as follows. Firstly, we calculate an average of R&D investment rate through time for each firm. Secondly, we calculate a median from these averages among individual firms and define it as a threshold. Finally, we classify firms as high degree ones as for R&D investment rate if its' average values are over the threshold while we classify other firms as low degree ones. For any of the data construction methods, we find that the firms with high degree of R&D investment rate have larger sales share in core business than the firms with low degree.

The lower three tables in Table 7 show the averages of sales share for each business by degree of R&D stock share at FY2003 (OLD) and FY 2013 (NEW). We similarly classify firms into high degree ones and low degree ones by the data construction methods for tangibles as follows. We classify firms into high degree ones and low degree ones by the data construction methods as follows. Firstly, we calculate an average of R&D stock share through time for each firm. Secondly, we calculate a median of these averages among individual firms and define it as a threshold. Finally, we classify firms as high degree ones if its' average values are over the threshold while we classify other firms as low degree ones. For any of the data construction methods, we find that the firms with high degree of R&D stock share have larger sales share in core business than the firms with low degree. The relation between R&D and sales share in core business is clearer in the bottom three tables than the top three tables.

Our findings in this section are summarized that firms with higher R&D stock share and

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[22] This database is released in Japanese at the website of National Institute of Science and Technology Policy (NISTEP) of Japan, http://www.nistep.go.jp/research/scisip/data-and-information-infrastructure/rdip-database.

Table 7. Means of Tobin's *q* and Sales Shares by R&D intensity

	Tobin's *q*	Sales Share of First, Second and Third Industry					
		OLD			NEW		
		First	Second	Third	First	Second	Third
x: Investment Rate of R&D with Proportional Method							
x <= medium	0.9364	0.9182	0.0489	0.0329	0.9460	0.0345	0.0195
x > medium	1.4299	0.9360	0.0354	0.0286	0.9589	0.0255	0.0156
Total	1.1826	0.9270	0.0422	0.0308	0.9524	0.0300	0.0176
x: Investment Rate of R&D with Zero Method							
x <= medium	0.7706	0.9221	0.0504	0.0276	0.9512	0.0343	0.0145
x > medium	1.2228	0.9322	0.0337	0.0341	0.9536	0.0256	0.0208
Total	0.9962	0.9270	0.0422	0.0308	0.9524	0.0300	0.0176
x: Investment Rate of R&D with Book Value Method							
x <= medium	0.8995	0.9219	0.0489	0.0292	0.9509	0.0345	0.0146
x > medium	1.3381	0.9322	0.0354	0.0324	0.9539	0.0255	0.0206
Total	1.1183	0.9270	0.0422	0.0308	0.9524	0.0300	0.0176
x : Stock Share of R&D with Proportional Method							
x <= medium	1.1668	0.9107	0.0510	0.0382	0.9333	0.0403	0.0264
x > medium	1.1985	0.9421	0.0340	0.0238	0.9701	0.0205	0.0094
Total	1.1826	0.9270	0.0422	0.0308	0.9524	0.0300	0.0176
x : Stock Share of R&D with Zero Method							
x <= medium	0.9908	0.9090	0.0501	0.0409	0.9361	0.0389	0.0251
x > medium	1.0017	0.9439	0.0348	0.0213	0.9677	0.0217	0.0106
Total	0.9962	0.9270	0.0422	0.0308	0.9524	0.0300	0.0176
x : Stock Share of R&D with Book Value Method							
x <= medium	1.1231	0.9113	0.0503	0.0384	0.9330	0.0405	0.0265
x > medium	1.1135	0.9414	0.0348	0.0237	0.9702	0.0204	0.0094
Total	1.1183	0.9270	0.0422	0.0308	0.9524	0.0300	0.0176

investment rate have fewer sales in secondary businesses. But, it is notable that we don't investigate causes why the relation between R&D and sales share in core business is observed. The leading firms in each industry might have to conduct R&D capital investment more than other following firms. Or, the accumulation of R&D in an industry might be low versatile in other industries. Investigating the causes is our future research.

V-3. Average q, R&D stock share and R&D investment rate by region

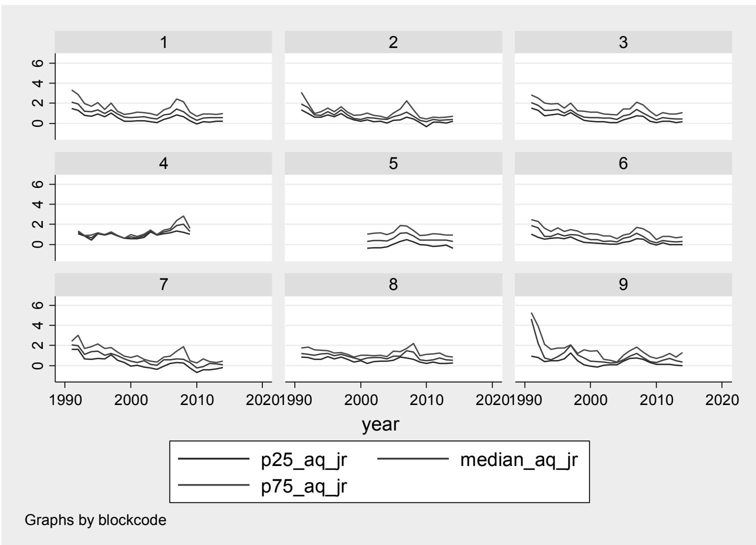
In this section, we use mainly the data of proportional method, in which investment behavior reflect not only acquisition but also retirement. Figure 1 shows how the 75th percentile, median, and 25th percentile of average *q* have changed for each regional block where firms are located. There are 9 regional blocks; [1] Tokyo, [2] Kanto excluding Tokyo, [3] Kinki, [4] Hokkaido, [5] Tohoku, [6] Tokai, [7] Shin-etsu & Hokuriku, [8] Chugoku & Shikoku, and [9] Kyushu. For any of the 75th percentile, median, and 25th percentile lines, we observe the slight upward trends in [4] Hokkaido. On the other hand, we observe declines at the beginning of the 1990s and follow by flat lines in other regions for any of the lines.

Figure 2 shows how the 75th percentile, median, and 25th percentile of R&D stock share have changed by regional blocks. [9] Kyusyu have shown a consistent downward trend in the 75th percentile. And we find that the regions other than [4] Hokkaido and [9] Kyushu have expanded the difference between the 75th and the 25th percentile, which means the disparity between R&D capital-intensive firms and other firms have been expanding.

Figure 3 shows how the 75th percentile, median, and 25th percentile of R&D investment rate have changed by regional blocks. We find that flat, or slight declining trends in general.

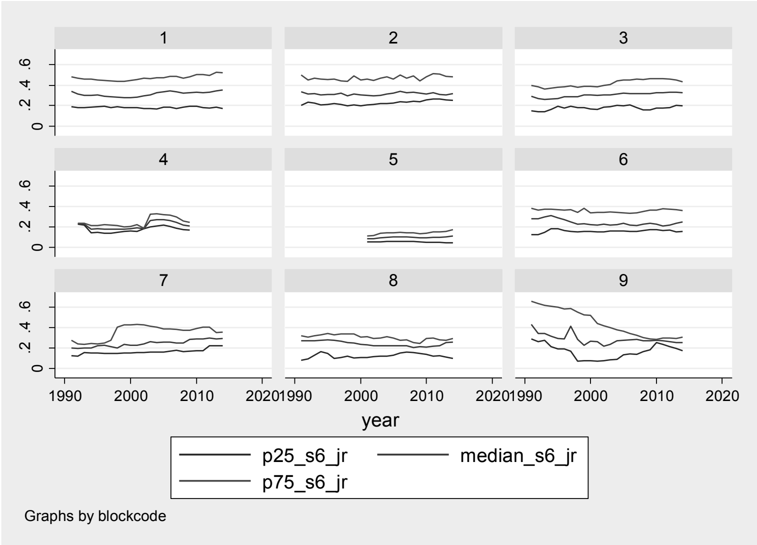
As described above, our dataset enable us to analyze the differences and distributions among individual firms, which it is difficult for macro and semi-macro data. Our dataset consists of various items of financial statements, then we would like to investigate why these difference and distributions of R&D occurs in the future.

Figure 1. Changes in average *q* (proportional method) by regional block



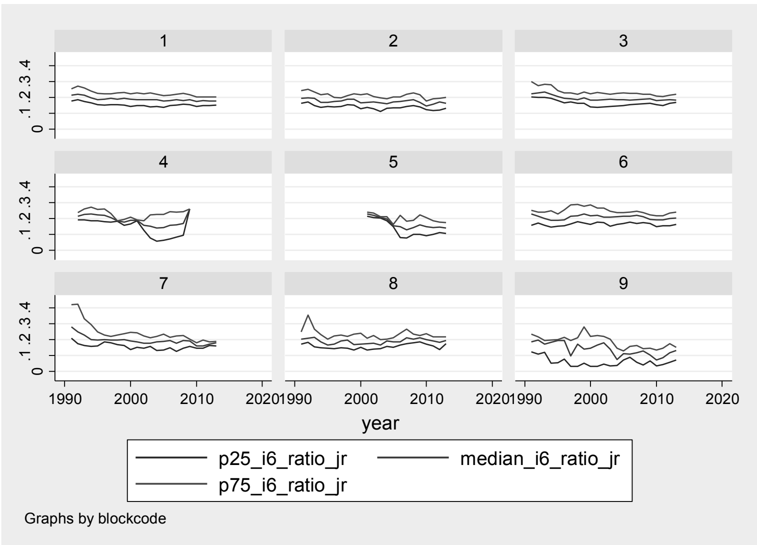
Note: Block codes denotes as following: 1=Tokyo, 2=Kanto(excl. Tokyo), 3=Kinki, 4=Hokkaido, 5=Tohoku, 6=Tokai, 7=Shin-ets & Hokuriku, 8=Chugoku & Shikoku, 9=Kyusyu

Figure 2. Changes in R&D stock share (proportional method) by regional block



Note: Block codes denotes as following: 1=Tokyo, 2=Kanto(excl. Tokyo), 3=Kinki, 4=Hokkaido, 5=Tohoku, 6=Tokai, 7=Shin-ets & Hokuriku, 8=Chugoku & Shikoku, 9=Kyusyu

Figure 3. Changes in R&D investment rate (proportional method) by regional block



Note: Block codes denotes as following: 1=Tokyo, 2=Kanto(excl. Tokyo), 3=Kinki, 4=Hokkaido, 5=Tohoku, 6=Tokai, 7=Shin-ets & Hokuriku, 8=Chugoku & Shikoku, 9=Kyusyu

VI. Conclusion

In this paper, we measure R&D investment and stock data for listed firms in Japan and examines R&D investment behavior as well as tangible ones under the framework of Tobin's q theory. We estimate Multiple q investment functions, modified Tobin's q investment functions considering the heterogeneity of capital goods, and verify whether adding R&D as a new capital good improves the performance of Multiple q investment function estimation.

We discussed the Multiple q model and its estimation theoretically in Section 2. We show pseudo average q, which ignore some capital assets incorrectly, deviate from 1 and this divergence increases when the share of the ignored capital stocks (in nominal) increase. By treating R&D as one of capitals in addition to tangibles, the range of capital goods not considered in the model is reduced. Therefore, the deviation of average q from 1 should also decrease. In addition, we discussed that inclusion of R&D as a new capital good should reduce biases in estimated adjustment cost parameter and should leads more stable and highly significant estimation for Multiple q investment model.

Our measurement shows that the share of R&D stock to total stocks is more than 25% and we find that adding R&D as a new capital stock reduces the upward bias of average q as predicted from our theoretical analysis. We also find that the performance of the Multiple q investment function improves: the coefficient of determination increases and the number of capital goods whose estimated adjustment cost parameters are positive and significant increases. On the other hand, even after considering R&D as one of capitals, redundant variables under the standard Tobin's q theory (cash flow ratio and interest-bearing debt ratio) continue to have strong explanatory power.

Comparing the estimated values of adjustment cost parameter γ among capital goods, we find that R&D investment especially has strong correlations with the other intangibles. Adjustment costs capture the Penrose effect. So the estimated adjustment cost is equivalent to the intangibles, such as skills and technology, which are necessary for tangibles and R&D investments.

The international comparison of growth accounting in Chun, Miyagawa, Pyo and Tonogi (2016) suggests that it is desirable for Japan's economic growth to implement policies that emphasize the accumulation of intangible assets rather than tangible fixed assets. R&D expenditure have been captured on financial statements. Then it can be used as a devise of economic policies, such as investment tax cuts. In this policy, the direct target is just R&D, but there is a possibility that this policy also stimulates intangible asset accumulation more generally.

Estimation of Multiple q investment function and structural estimation of comprehensive adjustment cost functions with heterogeneity of tangible and intangible assets are our future researches.

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