Investment Behaviors by Capital Good and Enterprise Size: Testing Capital Goods Heterogeneity and Capital Market Imperfection with the FSSCI*

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Abstract

This paper examines the validity of the Multiple q model, an augmented version of the Tobin's q theory to consider the heterogeneity of capital goods, using individual firm data which includes small and medium-sized enterprises as well as large ones. We divide capital goods into land and non-land tangible fixed assets, taking into account the imperfection of the capital market, and estimate the Multiple q investment equations by corporate size based on FY 2004-2013 annual survey slips of the Financial Statements Statistics of Corporations by Industry (FSSCI) collected by the Ministry of Finance, Japan.

Our estimation results show that, irrespective of enterprise size, land itself should be treated as an independent capital good that incurs unique adjustment costs as confirmed by earlier studies on publicly listed Japanese firms, indicating the validity of the Multiple q model by considering explicitly the heterogeneity between land and non-land tangible fixed assets. However, at the same time, we find that variables such as debt ratio and tangibility that are considered as redundant under the standard Tobin's q theory have significant explanatory power and that there are lumpy investment behaviors that cannot be handled by a smooth adjustment cost function presumed for the Tobin's q theory. Our estimation results also suggest that the lumpiness of investment behaviors is higher for smaller firms and that capital market imperfection would constrain some lumpy investments.

Keywords: capital investment, capital goods heterogeneity, Multiple q, capital market imperfection, lumpy investment

JEL Classification: D22, D92, E22, G31

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I. Introduction

The standard approach to the empirical analysis of corporate investment behavior is the so-called "q theory" or "q model," in which the investment rate is a linear function of only the "q" ratio, which is the firm's market value measured by its capital goods (in other words, "q" becomes a sufficient statistic). With the concept of Tobin (1969) as a starting point, q theory was established with a neoclassical micro-foundation alongside the investment adjustment cost. As is well-known, the explanatory power with regards to actual investment data from estimates of the q theoretic linear investment equation was proved to be unsatisfactory. Due to its theoretical robustness, however, its importance as a benchmark for analysis remains unchanged.

Quite a few research projects have been conducted on the poor empirical applicability of q theory or on improvements to the models based on it. Discussions are still ongoing and can be broadly categorized into two directions. The first is a rethinking of the theoretical assumptions of q theory; the second is an attempt to improve the empirical analysis in terms of the selection of the dataset and techniques for a more refined analysis. In the former research, the real-world validity of assumptions such as single capital goods (or homogeneous multiple capital goods), the quadratic adjustment cost function, and the perfect capital market have been examined, and attempts have been made to explain the broader reality. The latter strand of research includes a search for estimation methods that can overcome measurement errors in the "q" ratio, analyses based on panel data collected from time series data by company or by industry, and the stricter treatment of "negative investments," such as the disposal and sale of facilities.[1]

This paper is the first to attempt estimations of the investment function in the Multiple q framework ("Multiple q model" hereafter), introduced by Wildasin (1984) and developed and applied by Asako, Kuninori, Inoue, and Murase (1989, 1997), using survey slip data from the Financial Statements Statistics of Corporations by Industry (FSSCI). Following Asako, Kuninori, Inoue, and Murase (1989, 1997), a series of estimations were conducted on the investment function from the Multiple q model framework using data on Japanese firms by, among others, Tonogi, Nakamura, and Asako (2010), Asako and Tonogi (2010), and Asako, Nakamura, and Tonogi (2016). However, these studies all used data on listed firms. There are advantages to analyzing listed firms, as this enables the use of detailed financial data based on securities reports in the form of panel data pooling time series data for each individual firm; moreover, the data necessary for the analysis, such as those of capital investment and capital stock for each type of capital goods, can be constructed in a strict way. However, the samples will generally be limited to major enterprises.

In this paper, we explore the room to improve the explanatory power of q theoretic frameworks in aforementioned two directions. Namely, the first is towards the direction of

[1] See Asako, Nakamura, and Tonogi (2016) for more detail on these discussion points.

rethinking the theoretical assumptions by explicitly dealing with the diversity and heterogeneity of capital goods that the standard *q* theory abstracts, and the second is towards the direction of expanding the dataset by including unlisted, smaller firms into our sample. The latter becomes possible for the first time by using individual survey slip data from the FSSCI. The analysis period was set as 10 years, from fiscal 2004 to fiscal 2013, in order to continue on sequentially from the period covered in Tonogi, Nakamura, and Asako (2010) and Asako and Tonogi (2010). Analyzing this period enables us to see whether changes have occurred in the effects of the heterogeneity of capital goods since fiscal 2004 for the major enterprises.

Much of the research on investment behavior across sample periods has incorporated the possibility that the capital market is imperfect, including studies on small and medium-sized emterprises (SMEs), but all of these studies were based on the assumption of single capital goods. After controlling for the heterogeneity of capital goods, we can expect to obtain new findings on how the imperfect nature of the capital market affects investment behavior by considering how relationships among and the significance of financial variables such as leverage, which should be inherently redundant under the perfect capital markets, differ depending on enterprise size. The FSSCI has fewer survey items than those disclosed in a securities report and is also affected by replacements of the sample firms. Thus, a conventional method of analysis premised on panel data cannot simply be applied. Therefore the techniques developed to construct the dataset with acceptable quality under these constraints is another important contribution of this paper.

The rest of this paper is organized as follows. Section II reviews the framework of Multiple *q* investment equation. Section III explains the framework of the empirical analysis and data construction. Section IV presents the main results of our estimation for the investment function incorporating capital goods heterogeneity by enterprise size based on the survey slip data from the FSSCI and interprets them. Finally, Section V provides a conclusion and discusses future research possibilities.

II. Investment function from the Multiple *q* model

Many studies have discussed the theoretical foundations of the Multiple *q* model and its methods of empirical analysis, starting with Asako, Kuninori, Inoue, and Murase (1989, 1997) and Tonogi, Nakamura, and Asako (2010). Therefore, this section provides only an overview focusing on how the basic form of the investment function used in this paper was derived and the meanings of the concepts used in the analysis.

II-1. Multiple q model

Wildasin (1984) was the first to attempt extending the standard Tobin's *q* theory by relaxing the assumption of homogeneous capital goods and followed by Asako, Kuninori, Inoue, and Murase (1989). Wildasin (1984) showed that, in the multiple goods model, a monotonic one - to - one relationship between the simply totaled investment amount and the "q" ratio does not hold any longer but that q can be expressed as a linear combination of the investment amount for each of the multiple capital goods.

Asako, Kuninori, Inoue, and Murase (1989) called the multiple goods theory in Wildasin (1984) the "Multiple q theory" and called the conventional q theory that assumes homogeneous capital goods the "Single q theory." They showed systematically in what sense the Multiple q theory can be regarded as the generalization of Single q theory by introducing new concepts such as "Partial q," corresponding to the "q" ratio by capital good, and "Total q," their integration. They also established the fundamental methodology for the empirical analysis, including a statistical test for whether the heterogeneity of capital goods, an assumption of Multiple q theory, is valid. Tonogi, Nakamura, and Asako (2010) noted that, while the correspondence with theory is unclear in the continuous time model, the empirical analysis using financial data requires specifying the timing of capital investment at the beginning or the end of the fiscal period (in other words, whether capital investment in the current fiscal period will contribute to production in the same fiscal period), and they derived two kinds of investment function based on discrete - time models corresponding to each of these two assumptions. They also tested data on Japanese listed firms and confirmed that the "beginning - of - period model" is generally a better fit than the "end - of - period model."

Based on this beginning - of - period model, Asako and Tonogi (2010) reconstructed concepts such as "Partial q" and "Total q" developed for the continuous - time model in Asako, Kuninori, Inoue, and Murase (1989, 1997) in the context of the discrete - time model. Moreover, they considered expanding the Multiple q model to ease the assumption of a smooth, convex adjustment cost function. Below, we provide a brief overview of the basic theoretical framework used in this paper for the analysis of the survey slip data of FSSCI— the beginning - of - period version of Multiple q model that assumes a smooth, convex adjustment cost function.

In the beginning - of - period model, a firm's owner–manager makes investment decisions in each period based on information about the businesses environment observed at the beginning of the period (represented by productivity shock A) and immediately carries out the investment. Newly installed capital stock contributes to full production during the current period, and capital depreciation for one period occurs at the end of the period. There are n types of capital goods, and let the physical depreciation rate of j - th capital goods be denoted by δ_j $(j = 1, 2, \dots, n)$, the capital stock at the end of the previous period after the depreciation by $(1-\delta_j)\ K_j$, the capital investment at the beginning of the current period by I_j, and the capital stock after the investment by K'_j. Then, we should have

$$I_j = K'_j - (1-\delta_j)K_j, \tag{1}$$

and the net investment rate Z_j after the capital depreciation is written as

$$Z_j \equiv \frac{I_j}{(1-\delta_j)K'_j}\ , \tag{2}$$

which can take any value in the range of $Z_j \leq 1/(1-\delta_j)$, including negative values. When investing, the firm has to incur the adjustment cost, in addition to the purchase costs of capital goods. We assume the adjustment cost can be separated for each capital good and expressed as the quadratic function of the investment rate Z_j of the relevant capital good as follows:

$$C(K'_1, \cdots, K'_n, K_1, \cdots, K_n) = \sum_{j=1}^{n} \frac{\gamma_j}{2} (Z_j - a_j)^2 (1-\delta_j)K'_j\ . \tag{3}$$

The parameter $\gamma_j > 0$ represents the size of the adjustment cost (strength of friction) for each capital good, and a_j is the parameter corresponding to the investment rate in which the adjustment cost takes the minimum value. The more the investment rate Z_j deviates from a_j, the greater the rate of increase of the adjustment cost.[2]

The firm's production (gross profit) function is assumed to be of a Cobb–Douglas type:

$$F(A, K'_1, \cdots, K'_n) = AK'^{\alpha_1}_1 \cdots K'^{\alpha_n}_n, \qquad \text{with} \sum_{j=1}^{n} \alpha_j = 1, \tag{4}$$

where α_j's are nonnegative constants. Then, the Bellman equation of the dynamic optimization problem for the maximization of enterprise value V in each period is expressed as follows:

$$V(A, K_1, \cdots, K_n) = \max_{K'_j} \Bigg[AK'^{\alpha_1}_1 \cdots K'^{\alpha_n}_n - \sum_{j=1}^{n} \frac{\gamma_j}{2} (Z_j - a_j)^2 (1-\delta_j)K'_j \\ - \sum_{j=1}^{n} p_j\big(K'_j - (1-\delta_j)K_j\big) + \beta E_{A'|A}\left\{ V(A', K'_1, \cdots, K'_n) \right\} \Bigg]. \tag{5}$$

Here, p_j is the price of capital good j relative to the product price as the numeraire, β is the discount factor, and $E_{A'|A}\{\cdot\}$ is the expected value operator based on the forecasted productivity shock in the next period, which is based on information on the current period. As both the production function and the investment adjustment cost function are homogeneous of degree one, the value function V also becomes homogeneous of degree one for n capital stocks.

On partially differentiating equation (5) with regards to K_j, the first-order maximization condition for enterprise value is expressed as follows:

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2 As with Z_j, a_j can take any value in the range of $a_j \leq 1/(1-\delta_j)$, including a negative value.

$$\frac{\partial V(A, K_1, \cdots, K_n)}{\partial K_j} = (1-\delta_j)\gamma_j(Z_j - a_j) + (1-\delta_j)p_j\ . \tag{6}$$

From Euler's theorem on homogeneous functions

$$\sum_{j=1}^{n} \frac{1}{(1-\delta_j)} \frac{\partial V(A, K_1, \cdots, K_n)}{\partial K_j} (1-\delta_j)K_j = V(A, K_1, \cdots, K_n) \tag{7}$$

is established. Thus, from equations (6) and (7),

$$\sum_{j=1}^{n} \gamma_j(Z_j - a_j)(1-\delta_j)K_j + \sum_{j=1}^{n} p_j(1-\delta_j)K_j = V(A, K_1, \cdots, K_n) \tag{8}$$

follows immediately.

Therefore, on dividing both sides of equation (8) by $\sum_{j=1}^{n}(1-\delta_j)K_j$ and rearranging it, we obtain the following investment function:

$$(q-1)P = \sum_{j=1}^{n} \gamma_j Z_j s_j - \sum_{j=1}^{n} \gamma_j a_j s_j. \tag{9}$$

Here, the three newly defined variables are in order, namely

$$q = \frac{V}{\sum_{j=1}^{n} p_j(1-\delta_j)K_j}, \tag{10}$$

as the average q by weighted average of the capital goods when aggregating n kinds of capital goods;

$$P = \frac{\sum_{j=1}^{n} p_j(1-\delta_j)K_j}{\sum_{j=1}^{n}(1-\delta_j)K_j} = \sum_{j=1}^{n} p_j s_j\ , \tag{11}$$

as the implicit deflator of the aggregated capital stock ; and

$$s_j = \frac{(1-\delta_j)K_j}{\sum_{j=1}^{n}(1-\delta_j)K_j}, \tag{12}$$

as the share of each of the capital goods in the aggregated capital stock.[3]

[3] Here, on placing the constraint that the two adjustment-cost function parameters of γ_j and $\gamma_j a_j$ shall be equal for all the capital goods, equation (9) is reduced to the standard investment function (Single q model, where the investment rate is a linear function of the average q) based on the assumption of single capital goods.

Equation (9) is our investment function in the Multiple q model. $(q-1)P$, $Z_j s_j$, and s_j appearing in (9) are all observable data; thus, in accordance with (9), once the term $(q-1)P$ is linearly regressed on the variables $Z_j s_j$ and s_j, we can obtain the estimates of γ_j and $\gamma_j a_j$, which are the coefficient parameters of the adjustment cost function.

As the right side of equation (9) is transformed into

$$\begin{aligned}(q-1)P &= \frac{V}{\sum_{j=1}^{n}(1-\delta_j)K_j} - P \\ &= \sum_{j=1}^{n}\left(\frac{1}{(1-\delta_j)}\frac{\partial V(A, K_1, \cdots, K_n)}{\partial K_j}\cdot s_j\right) - P \\ &= \sum_{j=1}^{n}\left(\frac{1}{(1-\delta_j)}\frac{\partial V(A, K_1, \cdots, K_n)}{\partial K_j} - p_j\right)s_j,\end{aligned} \tag{13}$$

it is understandable that $(q-1)P$ is equal to the weighted average of the marginal efficiency of each capital good, with the weight as s_j.

Asako, Kuninori, Inoue, and Murase (1989, 1997) named the marginal profitability of each capital good divided by the capital - good purchase price, *i.e.*,

$$q_j \equiv \frac{\partial V(A, K_1, \cdots, K_n)/\partial K_j}{(1-\delta_j)p_j}, \tag{14}$$

the “Partial q” of that capital good, and named the normal average q “Total q,” in the sense that it is the concept of q that covers all capital goods. From equations (13) and (14), it is understood that the relationship between Total q and Partial q is

$$(q-1)P = \sum_{j=1}^{n}(q_j - 1)p_j s_j, \tag{15}$$

or

$$q = \sum_{j=1}^{n} q_j\left(\frac{p_j s_j}{P}\right). \tag{16}$$

And, once the Partial q of (14) is substituted into equation (6), we obtain the relationship between the Partial q and the investment rate Z_j defined in (2) as

$$q_j = \frac{\gamma_j}{p_j}(Z_j - a_j) + 1, \tag{17}$$

from which,

$$Z_j = a_j + \frac{1}{\gamma_j} p_j (q_j - 1), \tag{18}$$

is derived. Thus, the investment rate of each capital good is expressed by the linear function of the corresponding Partial q.

II-2. Review of the empirical research on the Multiple q model

As explained, Asako, Kuninori, Inoue, and Murase (1989, 1997), Tonogi, Nakamura, and Asako (2010), and Asako and Tonogi (2010) estimated the Multiple q investment function assuming a smooth, convex adjustment cost function and making use of listed firm data and average q based on share price information. We briefly review the main results obtained from these analyses.

Asako, Kuninori, Inoue, and Murase (1989, 1997), analyzing the manufacturing industry, obtained estimates from two types of capital goods, land and capital stock other than land, as this paper does. Here, the calculation of capital stock other than land followed the method of Hayashi and Inoue (1991). After creating capital stocks and gross investment series for multiple capital goods that considered the differences in the price-change rate and capital deprecation rate for five types of capital assets, such as buildings, structures, and machinery, those were totaled together with inventory. Asako *et al.* (1989, 1997) focused on land within capital goods and carried out the analysis from two capital goods because, in those days, land in Japan was being actively invested in alongside the rapid increase in the share prices and land prices; it was thought that treating land as a capital good (a quasi-fixed factor of production) that incurs a unique adjustment cost when it is invested in might improve the goodness of fit of the q model.

For this reason, great care was taken in constructing the land data, and precise calculations were made considering elements such as the differences in the rates of increase of land values according to purpose of use and location. Using cross-section data from each year, the validity of the following three models was tested:

Model 1 (Single q that does not include land): There is no adjustment cost for investment in land and thereby Partial q of land is always equal to one.

Model 2 (Single q that includes land): Land is homogeneous with other capital goods and can be added as it is.

Model 3 (Multiple q): There are different adjustment costs for investments in land and for investments in buildings, machinery and equipment; land and other capital goods each has different Partial q.

Asako, Kuninori, Inoue, and Murase (1989), analyzing from fiscal 1977 to fiscal 1987, showed that, within the Single q framework, cases in which land was included in capital stock were more compatible with q theory than were cases in which it was not. In addition, the results of the estimations from the Multiple q model showed clear differences in the estimation values of the adjustment cost parameter of land and capital stock other than land indicating that the Single q model was not suitable. However, there were some years in which the Partial Q corresponding to $p_j(q_j - 1)$ in equation (18) obtained from the estimation results of the Multiple q model took a negative value. Moreover, although the estimated values for Partial Q of capital stock other than land were somewhat consistent with the trend in the investment rate, inconsistencies with theory remained regarding the results for land; for example, the investment rate for land was consistently positive even in years in which a negative Partial Q was obtained. Asako *et al.* (1989) argued that the land Partial Q was negative (q_j was less than one) because of a bubble in land prices and an excessively high price of land as a capital good.

Asako, Kuninori, Inoue, and Murase (1997), who extended the analysis period up to fiscal 1994 to be sequential with the previous study, tried to answer the questions left unanswered in Asako *at al.* (1989) by making modifications, such as excluding the increase in the value of land due to increased real land prices from land investment by individual firms as well as using the concept of gross investment rather than net investment for capital goods other than land. As a result, while Asako *et al.* (1989) found several years in which the Partial Q of capital goods other than land took a negative value, this value became positive every year holding stable and positive correlation with the gross investment rate consistently with the theory. On the other hand, the Partial Q of land, which took a positive value for several years in Asako *at al.* (1989), was negative every year, and the result was once again inconsistent with the gross investment rate of land. Although land was a factor of production with its own unique adjustment costs, according to their interpretation, this result might have been caused by a bubble in land prices and the overestimation of its contribution as a factor of production.

Subsequently, Tonogi, Nakamura, and Asako (2010) and Asako and Tonogi (2010) analyzed the Multiple q model based on unbalanced panel data from approximately 2,500 listed firms including the non-manufacturing industry, covering from fiscal 1982 to fiscal 2004 (divided into four periods for each business cycle phase). After subdividing capital goods other than land into four categories (i.e., buildings and structures; machinery and equipment; vessels and vehicles; and tools, furniture, and fixtures), they created a time series for gross investment and capital stock using three data construction methods with regard to the evaluation of the sale and the retirement amounts for existing facilities. They also added the cash flow ratio and the interest-bearing debt ratio as additional control variables, and they estimated the Multiple q investment function.

First, Tonogi, Nakamura, and Asako (2010) rejected the null hypothesis that the parameters relating to the adjustment costs of the five types of capital goods, including land, were all equal for all four sample periods. Based on this result, Asako and Tonogi (2010), considering the possibility of partial homogeneity, tested the homogeneity between “certain capital goods” and the “other four capital goods that are regarded (temporarily) as homogeneous,” and also conducted a pairwise test in which any two of the capital goods were homogeneous. They confirmed that, while partial homogeneity was not rejected in some cases, these combinations were not uniform depending on the sample period and the data construction method regarding gross investment and capital stock, and concluded that the Multiple *q* model should be used based on the assumption that these five capital goods were fundamentally heterogeneous. However, concerning the goodness of fit as the investment function, the significance and robustness of the parameters of the adjustment cost function were not high. Even in cases with relatively high explanatory power, where the sales and retirement amounts of existing facilities were considered as being uniformly zero, the cash flow ratio and the interest-bearing debt ratio, which should be inherently redundant in the framework of *q* theory, were estimated to be significant; it was confirmed that factors remained that could not be explained by simply considering the heterogeneity of capital goods while maintaining the same convex-type adjustment cost framework.[4]

The parameter of the adjustment cost function was often estimated to be insignificant, perhaps due to the influence of additional control variables. There were also major differences in the estimates of Partial *q* in Asako and Tonogi (2010) depending on the analysis period and the data construction method. In these results, the estimates of land Partial *q* were comparatively stable, and, regardless of the data construction method, they took significantly positive values in the estimation periods up to bubble economy periods (1982-86, 1987-91) and significantly negative values in the estimation periods after the collapse of a bubble economy (1992-97, 1998-2004).

II-3. Analysis by corporate size using the individual survey slip data from the FSSCI

The individual survey slip data from the FSSCI have only two categories of information on tangible fixed assets—land and capital goods other than land—and it is difficult to form panel data over a long period of time because the data are collected on a random sampling basis for smaller enterprises. Our dataset also has various restrictions, such as the absence of market evaluations of firm value and the impossibility of using the perpetual inventory method to construct the capital stock data. On the other hand, it targets enterprises of a wide range of sizes, from listed firms to micro enterprises with share capital of less than 10 million yen. Therefore, when conducting estimates from the Multiple *q* model, it has the advantages described below.

First, one of the reasons why the investment function including Multiple *q* was not always a good fit in the research on listed firms is that most listed firms have several business units belonging to different industries, and it may be impossible to ascertain their investment behavior with a single function. Moreover, *q* theory is premised on perfect competition, which may not be even close to reality among listed firms. These problems are less serious for smaller firms. If an investment function that is a poor fit for major enterprises is found to be significant for SMEs, this would seem to support the conjecture described above.

[4] From this, Asako and Tonogi (2010) and Asako, Tonogi, and Nakamura (2014) eased the constraint of a smooth, convex adjustment cost function and attempted to estimate the nonlinear Multiple *q* investment function. Although this line of extension yielded new findings, this paper does not deal with the discussion of non-convexity.

Conversely, an analysis of the investment behavior of manufacturing business establishments in the United States by Doms and Dunne (1998) found that the smaller the establishment, the more pronounced the characteristics of so-called "lumpy investment" behavior. Lumpy investments cannot be analyzed within the framework of the smooth, convex adjustment cost function that is assumed by the Multiple *q* model in this paper. If this effect is strong, a fit for SMEs would be rather poorer than major enterprises.

Second, by comparing the Single *q* model and the Multiple *q* model based on the assumption that the convex adjustment cost function framework has a certain degree of real-world validity, we can test with respect to each firm size whether land is a capital good with an adjustment cost, and, if so, whether there is intrinsic heterogeneity between land and capital stock other than land. For instance, if the land-acquisition behaviors of small enterprises are fundamentally synonymous with the acquisition of new buildings and the expansion of business establishments, land may be homogeneous with capital stock other than land, or otherwise, as small enterprises tend to acquire small parcels of land, the adjustment cost may also remain within a negligible range.

Third, the fact that the cash flow ratio and interest bearing debt ratio are estimated to be significant in the investment function was formerly considered evidence that the imperfect nature of the capital market, such as liquidity constraints, influences investment behavior. However, the fact that even among listed enterprises, which should be able to easily access the capital market, and even after controlling the simultaneity problems which would cause spurious correlation, these variables are still robustly significant, thus casting doubt on this interpretation. As an alternative explanation, for example, non-negligible measurement errors in the "*q*" ratio or information on future investment opportunities that cash flow contains have been pointed out though this issue has not yet been settled. To address this point, it would be useful to compare major enterprises and SMEs, which differ in accessibility to the capital market, and to analyze the time period of a global financial crisis in which even major enterprises face liquidity constraints. Although this sort of research has already been carried out to some extent, this paper would seem to be the first that occurs within a framework that includes land investment specific to Japanese enterprises and that takes the heterogeneity of capital goods into consideration.

III. Empirical analysis framework and data construction

As mentioned, individual survey slip data from the FSSCI used for this analysis have various restrictions that differ from those for listed firms. Since it is not possible to simply apply conventional analytical methods that assume panel data based on securities reports, we develop appropriate techniques to deal with the data constraints in the empirical analysis.

III-1. Basic framework of the analysis

In the basic framework for the analysis described below, we estimate the equation which includes several control variables such as cash flow ratio and interest-bearing debt ratio as well as the year, industry, and other dummy variables into the right-hand-side of equation (9) using the individual survey slip data from FSSCI (for all industries except the financial and insurance industries). There are three major constraints with analyzing FSSCI data compared to previous studies using data on listed firms: (i) it is not possible to calculate the average q using share prices, (ii) it is not possible to construct capital stock data by the perpetual inventory method due to the difficulty in forming panel data, and (iii) there are only two categories of capital goods—land and goods other than land.

Regarding the first two constraints, we have to find appropriate proxy variable of marginal q which comprises the dependent variable, and also have to construct the capital stock using various techniques, such as borrowing the market to book value ratio and the deflator for each capital good by industry from the listed firms' data. The rest of this section explains the basic ideas behind the proxy of marginal q. Section III-3 describes the basic ideas behind the construction of the parameters that are necessary for calculating q and the capital stock and investment-related data.

In conventional q theory developed with the assumption of single capital goods, marginal q is defined as "the sum of discounted present value of expected marginal earnings that will be newly created in the future by adding one unit of capital stock in the current period (i.e., the shadow price of capital) divided by the replacement cost of one unit of capital goods." When it is problematic to use the average q based on share prices to estimate the investment function, for reasons such as the existence of a share-price bubble, some proxy of marginal q are used instead. For example, if linear homogeneity is assumed with regards to the value function, marginal earnings are equivalent to average earnings; thus, a lot of previous studies estimate the marginal q with vector autoregression (VAR) model using the data of current average return on capital (or profit rate) obtained from the accounting values under the assumption that the stochastic process for the past profit rate and discount rate estimated from the VAR model will be stable over time.[5] However, this method cannot be applied here, as panel data cannot be used. Therefore, marginal q is estimated below assuming a steady state in which the static expectation formation becomes a rational expectation formation.

When assuming a steady state, in general two estimation methods can be considered depending on whether or not the capital depreciation rate is included in expected marginal earnings (*EME*), which is the marginal q numerator. Thus, with ρ as the current period's profit rate, δ as the depreciation rate, r as the discount rate, and g as the expected growth rate, *EME* by the net method is expressed as

$$EME = \frac{\rho}{r-g}K, \tag{19}$$

and by the gross method that considers capital depreciation as

[5] See, for example, Abel and Blanchard (1986) and Otaki and Suzuki (1986).

$$EME = \frac{\rho+\delta}{r+\delta-g}K. \tag{20}$$

While it is not clear which is the main focus of investors and of enterprises, in the correspondence with the actual data, if any of the denominators or numerators take negative values, the estimates of marginal q implicitly computable from equations (19) to (20) as the ratio *EME/K*, becomes non-existent and thereby are left out of our sample. Therefore, the gross method is used in this paper to reduce the probability of this non-existence problem occurring.[6] For expected growth rate g, we do not find a candidate proxy except for the growth rate of the book value of total assets (*BTA*) available in our dataset based on the FSSCI. However, it is a rather noisy proxy and the possibility that the denominator takes a negative value in (20) may increase. Taking these shortcomings into account, we uniformly set g as zero for all samples without estimation.

III-2. Control variables and the estimation equation

In addition to the above calculation which is the backbone of the investment function based on Tobin's q theory, we follow Tonogi, Nakamura, and Asako (2010) and introduce some control variables that are supposed to be redundant in the framework of q theory to look over the validity of q theory and its assumption of a perfect capital market by checking significance of those control variables. In so doing, we at first introduce the following additional variables, which are often employed in estimations of investment function, to the explanatory variables:

Interest-bearing debt ratio = interest-bearing debt (*D*)/book value of total assets (*BTA*),
Tangibility = total book value of land and other tangible fixed assets (*BK*) / book value of total assets (*BTA*),
Enterprise size = book value of total assets' logarithmic value, *ln* (*BTA*).

Needless to say, the lower limit of the interest-bearing debt ratio is zero; however, there has been a recent increase in zero-leverage firms that have reached this limit, regardless of enterprise size. Therefore, we further add a *zero-leverage dummy* (*ZLD*) to our list of explanatory variables to capture this effect. Incidentally, cash flow, which is frequently used in estimations of the investment function, almost always happens to overlap in terms of numerical values with the marginal q numerator in this paper's dataset. To avoid a development that would improve the model's explanatory power in appearance (i.e., purely for the technical reason in the data construction), it was decided not to include it in the list of our explanatory variables.

In the Multiple q model investment function (9), if these control variables are estimated to be significant in addition to the theoretically derived q (to be precise, $(q-1)P$) because, for instance, the capital market is imperfect, the following interpretation is established for their

6 Refer to Suzuki (2001) as an empirical study that adopted the gross method.

signs.

First, concerning the coefficient of the zero-leverage dummy (*ZLD*) and the interest-bearing debt ratio (*D* / *BTA*), if, for example, (i) the supply-side factors in the capital market (i.e., the higher the profit rate, the greater the bank's willingness to lend), (ii) the disciplinary effects of debt (i.e., the higher the debt rate, the higher the profit rate from the effects of discipline), and (iii) the tax saving effects of debt (i.e., income deduction from interest expenses) are predominant, it is expected that the coefficient of zero-leverage dummy will be significantly negative and the coefficient of interest-bearing debt ratio will be significantly positive. Contrariwise, if, for example, (iv) demand-side factors in the capital market (high debt ratio due to past low profitability with serial correlations in profit rates) and (v) the risk of bankruptcy (i.e., the higher the debt ratio, the higher the discount rate) are predominant, it is expected that the coefficient of zero-leverage dummy will be significantly positive and the coefficient of interest-bearing debt ratio will be significantly negative. In the estimations of the Multiple q model by Tonogi, Nakamura, and Asako (2010), the zero-leverage dummy was not included in the list of control variables and they targeted listed firms and used the average q for q though, the coefficient of interest-bearing debt ratio was robustly positive and significant.

Second, tangibility is used as a proxy variable for pledgeability, which is considered to promote the use of external debt, in research on the determinants of the capital structure. In the Multiple q model investment function, if pledgeability has the effect of easing borrowing constraints, it is expected that the possibility of realizing earnings opportunities increases, from which tangibility becomes positive and significant with regards to q. Conversely, tangibility is given another role to control the effects of intangible assets, which are not considered in our framework. From this aspect, it is expected that the coefficient of tangibility will be negative and significant for the reasons described below.

To clarify the underlying mechanism of this negative effects, we consider a company consisting only of tangible fixed assets including land (K) and intangible fixed assets (R). For simplicity, real values, nominal values, and book values are assumed to be always consistent. As assumed in our framework, if intangible fixed assets' Partial q_R is always equal to 1, tangible fixed assets' Partial q_K is calculated as follows:

$$q_K = \frac{V - R}{K}, \tag{21}$$

where V denotes firm value. However, if intangible fixed assets should also be considered as capital stock with an adjustment cost (a quasi-fixed factor of production) in reality and therefore q_R deviates from 1, the firm value function is expressed as follows

$$V = q_K K + q_R R\ . \tag{22}$$

Then, (21) is replaced by

$$\frac{V-R}{K} = q_K + \frac{(q_R-1)R}{K}\,, \tag{23}$$

which indicates that q_K of (21) deviates from the true Partial q_K by a margin of the second term in the right-hand-side of (23), which is positire insofar as $q_R > 1$.

Meanwhile, since by definition tangibility $= K/(K+R)$ is negatively correlated with intangible to tangible capital assets ratio *R/K*, the second term on the right-hand-side of (23) is correlatives negatively with tangibility. Therefore, in summary, the variable tangibility absorbs the upward bias of q_K from its true value, rendering the coefficient estimate of tangibility be negative. Therefore, if this negative effect is greater than the tangible fixed assets' pledgeability effect, the coefficient of tangibility will likely be negative and significant.

Third, enterprise asset size, *ln* (*BTA*), is usually a factor reflecting easing borrowing constraints due to effects such as the diversification of the business portfolio. It is thus expected to take a positive sign. Conversely, if enterprise asset size is positively correlated with the company's degree of maturity (i.e., it is negatively correlated with growth potential), it may take a negative sign.

Last, year dummies, industry dummies, and capital size dummies are considered as dummy variables in the constant term of the estimation equation. The industry dummies are based on FSSCI industry classification table, and the capital size dummies are based on share capital and classified into four categories: 1 billion yen or more (major enterprises), 100 million yen to 1 billion yen (medium-sized enterprises), 10 million yen to 100 million yen (small enterprises), and less than 10 million yen (micro enterprises).

The final investment function (9) is thus estimated with additional control variables as follows:

$$\begin{aligned}(q-1)P = {} & \gamma_K Z_K s_K + \gamma_L Z_L s_L - \gamma_K a_K s_K - \gamma_L a_L s_L + C_0 ZLD \\ & + C_1 \frac{D}{BTA} + C_2 \frac{BK}{BTA} + C_3 ln\,(BTA) + C_4 year\ dummies \\ & + C_5 industry\ dummies + C_6 capital\ size\ dummies,\end{aligned} \tag{24}$$

where subscripts *K* and *L* correspond to capital goods other than land and land, respectively.

III-3. Data construction and elimination of outliers

The investment related data by the category of capital goods and the parameters necessary for calculating the "*q*" ratio are constructed according to the process described below.

(i) Nominal investment

As in the studies subsequent to Asako, Kuninori, Inoue and Murase (1997), this paper adopts the concept of "gross investment" for the investment rate, which is calculated by

$I_K =$ the difference between the beginning and end of the fiscal period in the book value of tangible fixed assets other than land + depreciation expenses,

I_L = the difference between the beginning and end of the fiscal period in the book value of land.

In the survey slip of FSSCI, special depreciation expenses are also surveyed. However, they are basically special tax break measures and often not directly deducted from the book value in the accounting treatment. Therefore, it was judged that noise would increase if they were included in the calculation of I_K, so they are excluded. Depreciation expenses in the survey slip include those of intangible fixed assets, which should be excluded from depreciation expenses in our model. However, as the breakdown is unknown, these are difficult to estimate. Therefore, we just exclude samples above a certain ratio of intangible fixed assets to tangible fixed assets as outliers.

(ii) Nominal capital stock

As mentioned, it is difficult to construct sufficient panel data to apply the perpetual inventory method from the survey slip data of FSSCI. Therefore, based on listed firms' financial data, a nominal capital stock series was created by industry for 1977 onwards using the perpetual inventory method, and calculations are made by multiplying the book value of the survey slip data and the industry's "market value-book value ratio," which is the industry's nominal capital stock value divided by the corresponding book value.

(iii) Deflator

For the capital stock deflator, a real capital stock series by industry and by capital goods from 1977 onwards was created based on the listed firms' financial data using the perpetual inventory method, and calculations were made by dividing this by the nominal capital stock created in (ii). An attempt was made to create a deflator for investment flow using data on listed firms' real and nominal capital investment though we did not obtain a stable series. Therefore, we also use the capital stock deflator in place of the deflator for investment flow.

(iv) Capital depreciation rate δ

Capital depreciation rate δ is obtained by multiplying the depreciation rate of capital stock other than land and the weight of capital stock other than land in real capital stock (as it is natural to consider the depreciation rate of land to be zero). The weighted averages of the depreciation rate by capital goods in Hulten and Wykoff (1977, 1981)[7] were used for the depreciation rate of capital stock other than land, with the weights of real capital stock by capital good and by industry from 1977 onwards created using the perpetual inventory method based on listed firms' financial data. When calculating Single q that does not include land, the depreciation rate of capital stock other than land (not multiplied by the weight) is used for δ.

(v) Profit rate ρ

For each firm and for each year, the values from (ordinary profit/loss before depreciation and interest − taxes paid)/nominal capital stock at the beginning of the fiscal period are used. Taxes paid are calculated by subtracting after-tax profit/loss from pre-tax profit/loss. When calculating the Single q that does not include land, land is excluded from the denominator of

[7] Buildings were 0.047, structures 0.0564, machinery and equipment 0.09489, vessels and vehicles 0.1470, and tools, furniture, and fixtures 0.08838.

the nominal capital stock.

(vi) Discount rate r

In the same way, for each firm and for each year, the values obtained from interest paid and others/(interest - bearing debt + the notes receivable discount balance) are used. However, the discount rate of zero - leverage firms is replaced with the minimum value (>0) among the relevant firms in each year, and for values exceeding 20%, Winsorizing processing is carried out with an upper ceiling of 20%.

Some data were considered outliers and eliminated from the target sample. It was considered that some data included errors caused by respondents' misunderstanding of the question items or mistaken entries; moreover, transcription or input errors may have occurred when the collected questionnaires were processed, and such values were also considered "outliers."

Specifically, variables which are considered to need elimination of outliers based on the theoretical/empirical grounds were as follows. First, in the sample of $Q = (q-1)P \geqq 10$, the contribution of intangible assets to enterprise value was too great, which is difficult to explain within the framework of this paper; second, the $(q-1)P \leqq -10$ sample was meaningless, as it included a proxy variable of q that should theoretically be positive; third, the (depreciation expenses/the book value of depreciable assets)$\geqq 1$ sample likely included mistaken entries, such as in the entries of the accumulated depreciation amount in current depreciation expenses; fourth, regarding the book value of total assets, the sample showing a large discontinuity such that (end of fiscal period/beginning of fiscal period) $\geqq$ 1.5 was likely due to mergers and acquisitions rather than ordinary economic activities; therefore, these were excluded from the estimations.

III-4. Descriptive statistics

As is summarized in Table 1, a total of 105,470 samples were obtained after the outlier processing for the 10 - year period from fiscal 2004 to fiscal 2013. Medium - sized enterprises (with capital of 100 million yen to 1 billion yen) accounted for the greatest portion while major enterprises (with capital of 1 billion yen and above) and small enterprises (with capital of 10 million yen to 100 million yen) were the close second and third. There were 3,800 micro enterprises (with capital of less than 10 million yen), less than 4% of the total. In terms

Table 1. Number of samples by capital size and industry (FY 2004 to 2013)

	Major enterprises	Medium-sized enterprises	Small enterprises	Micro enterprises	Total
Manufacturing	16,499	15,122	11,046	1,157	43,824
Non-manufacturing	16,196	24,685	18,122	2,643	61,646
All industries	32,695	39,807	29,168	3,800	105,470

Note: Major enterprises have capital of 1 billion yen and above, medium-sized enterprises have capital of 100 million yen to 1 billion yen, small enterprises have capital of 10 million yen to 100 million yen, and micro enterprises have capital of less than 10 million yen.

Table 2. Summary statistics by capital size and industry (FY 2004 to 2013)

All enterprises	$(q-1)P$	$Z_K s_K$	$Z_L s_L$	s_K	s_L	D/BTA	ZLD	BK/BTA
Mean	0.951	0.055	-0.003	0.508	0.492	0.371	0.114	0.405
Median	0.547	0.030	0.000	0.494	0.506	0.325	0.000	0.361
Standard deviation	1.990	0.118	0.074	0.250	0.250	0.456	0.318	0.240

Major enterprises	$(q-1)P$	$Z_K s_K$	$Z_L s_L$	s_K	s_L	D/BTA	ZLD	BK/BTA
Mean	1.105	0.066	-0.004	0.561	0.439	0.239	0.137	0.350
Median	0.673	0.046	0.000	0.563	0.437	0.199	0.000	0.297
Standard deviation	1.975	0.120	0.071	0.235	0.235	0.223	0.344	0.222

Medium-sized enterprises	$(q-1)P$	$Z_K s_K$	$Z_L s_L$	s_K	s_L	D/BTA	ZLD	BK/BTA
Mean	1.010	0.055	-0.004	0.511	0.489	0.350	0.125	0.409
Median	0.575	0.029	0.000	0.491	0.509	0.319	0.000	0.363
Standard deviation	1.988	0.121	0.078	0.247	0.247	0.315	0.330	0.244

Small enterprises	$(q-1)P$	$Z_K s_K$	$Z_L s_L$	s_K	s_L	D/BTA	ZLD	BK/BTA
Mean	0.764	0.045	0.000	0.450	0.550	0.506	0.081	0.441
Median	0.403	0.017	0.000	0.421	0.579	0.504	0.000	0.413
Standard deviation	1.951	0.110	0.073	0.252	0.252	0.670	0.273	0.235

Micro enterprises	$(q-1)P$	$Z_K s_K$	$Z_L s_L$	s_K	s_L	D/BTA	ZLD	BK/BTA
Mean	0.445	0.040	0.004	0.475	0.525	0.689	0.045	0.571
Median	0.219	0.005	0.000	0.452	0.548	0.672	0.000	0.580
Standard deviation	2.245	0.106	0.052	0.279	0.279	0.682	0.207	0.252

Manufacturing	$(q-1)P$	$Z_K s_K$	$Z_L s_L$	s_K	s_L	D/BTA	ZLD	BK/BTA
Mean	0.616	0.058	-0.002	0.567	0.433	0.346	0.102	0.350
Median	0.420	0.041	0.000	0.578	0.422	0.291	0.000	0.322
Standard deviation	1.400	0.088	0.048	0.227	0.227	0.564	0.302	0.181

Non-manufacturing	$(q-1)P$	$Z_K s_K$	$Z_L s_L$	s_K	s_L	D/BTA	ZLD	BK/BTA
Mean	1.189	0.052	-0.003	0.467	0.533	0.389	0.122	0.445
Median	0.693	0.021	0.000	0.426	0.574	0.354	0.000	0.409
Standard deviation	2.291	0.135	0.088	0.257	0.257	0.358	0.328	0.267

of industry, around 40% of firms were from the manufacturing industry, and around 60% were from the non-manufacturing industry. The manufacturing percentage increased as the size of the firm's share capital grew and exceeded 50% for major enterprises.

Table 2 shows the basic descriptive statistics of variables for the regression equation of the Multiple q model (24); namely, of $(q-1)P$ as the dependent variable; of $Z_K s_K$ and $Z_L s_L$ as the product of the investment rate and the share of capital stock with regards to tangible fixed assets other than land and land, respectively; and of s_K and s_L as the shares of capital stock with regards to tangible fixed assets other than land and land, respectively; and of the main control variables.

To begin with, the average value of dependent variable $(q-1)P$ is 0.95 and the median value is 0.55 for the whole sample, which seem plausible. These values grew as capital increased. At an industry level, the manufacturing industry average was 0.62, the non-manufacturing industry average was 1.19, nearly twice as high. The average value of $Z_K s_K$ as the product of the investment rate in fixed assets other than land and the corresponding share of capital stock was 0.055, whereas the average value of $Z_L s_L$ as the product of the investment rate in land and the corresponding share of capital stock was slightly negative overall. Since the share value is always positive, we understand that the investment rate in tangible fixed assets other than land is correspondingly positive on average, whereas the investment rate in land is negative on average.

The overall average values of s_K, s_L as the share of capital stock of tangible fixed assets other than land and land are basically half and half. For major and medium - sized enterprises and manufacturing firms, s_K is more than half, whereas for small enterprises and micro enterprises and non - manufacturing firms, s_L is more than half. The interest - bearing debt ratio (D/BTA) grew as capital decreased; it was 0.24 for major enterprises and reached 0.69 for micro enterprises. It was slightly higher in the non - manufacturing industry. The ratio of zero - leverage enterprises ($ZLD = 1$) was 11.4%, which decreased as capital decreased. It was found that 4.5% of micro enterprises were zero - leveraged. It was slightly higher in the non - manufacturing industry. Tangibility grew as capital decreased, and it was higher in the non - manufacturing industry.

IV. Main estimation results and interpretation

IV-1. Baseline model for all sample enterprises

In estimating equation (24), Multiple *q* model investment function, we run three types of regressions as baseline model depending on the included control variables; namely, with none of the control variables or the case of "no control variable"; with all of the control variables but the zero - leverage dummy or the case of "not including zero - leverage dummy"; and with all of the control variables or the case of "including zero - leverage dummy". Table 3 shows the results of the standard OLS (ordinary least squares) estimations for these baseline

Table 3. Baseline model results (FY 2004 to 2013)

	No control variable		Not including zero-leverage dummy		Including zero-leverage dummy	
	Coefficient		Coefficient		Coefficient	
γ_K	3.05	**	2.25	**	2.35	**
γ_L	-1.75	**	-1.80	**	-1.87	**
$-\gamma_K a_K$	1.60	**	1.22	**	1.95	**
$-\gamma_L a_L$	1.70	**	1.37	**	2.05	**
C_0					-1.39	**
C_1			0.20	**	-0.05	
C_2			-2.55	**	-2.90	**
C_3			0.13	**	0.10	**
R-squared	0.280		0.337		0.373	
N of obs.	105,470		105,470		105,470	

Note 1. Standard errors are heteroscedastically robust (Huber‐White estimator), with ** and * denoting significance at the 5% and 10% levels, respectively.

2. The results of the year dummies, industry dummies, and capital size dummies are omitted from the table.

models.

First, concerning the estimates of γ_K, γ_L, $-\gamma_K a_K$, $-\gamma_L a_L$ for three types of regressions, each γ parameter of the tangible fixed assets other than land is significantly positive, while each γ parameter of the land is significantly negative. The fact that parameter γ_K is positive indicates that the investment behavior for tangible fixed assets other than land does not necessarily contradict the convex, smooth adjustment cost framework. However, the fact that the control variables are also significant in cases of estimation including these variables is not consistent with q theory. The fact that parameter γ_L is negative is in line with the result obtained in Asako, Kuninori, Inoue, and Murase (1989, 1997) but inconsistent with the result in Tonogi, Nakamura, and Asako (2010).

Tonogi, Nakamura, and Asako (2010) used a more detailed classification for capital goods other than land, but it is unlikely that this affects the results of the land estimates. It is more likely partly attributable to their use of panel analysis controlling firm fixed effects. Meanwhile, all of the estimation values of $-\gamma_K a_K$ and $-\gamma_L a_L$ are positive and significant, suggesting that the investment rate a that minimizes the adjustment cost (3) is negative for tangible fixed assets other than land and positive for land.

Regarding the control variable, C_1, the coefficient of the interest-bearing debt ratio, is estimated to be positive and significant if it does not include the zero-leverage dummy, suggesting the possible involvement of supply factors of the lending market, the disciplinary effects of debt, and tax-saving effects; this result is consistent with Tonogi, Nakamura, and Asako (2010). On adding the zero-leverage dummy to the explanatory variables, the coefficient of the zero-leverage dummy C_0 is negative and significant, and the interest-bearing debt ratio loses its explanatory power. The results still suggest the involvement of supply factors of the lending market, the disciplinary effects of debt, and tax-saving effects, but many of the positive effects of the interest-bearing debt ratio prove to be attributable to the differences between zero-leverage enterprises and enterprises with debt.

The results of the estimations of the tangibility coefficient C_2 and the enterprise asset size coefficient C_3 are stable both with and without the zero-leverage dummy, with the former being negative and significant and the latter being positive and significant. The fact that tangibility is negative and significant suggests that the role played by the correction of the distortion of q from the existence of intangible assets is stronger than are the effects of pledgeability. On the other hand, the fact that enterprise asset size is positive and significant may reflect the easing of borrowing constraints from the effects of corporate size.

IV-2. Test of the heterogeneity of capital goods: comparison with the Single q model

Following Asako, Kuninori, Inoue, and Murase (1989, 1997), this section tests the heterogeneity of capital goods by conducting estimations from three models—Single q that does not include land, Single q that includes land, and Multiple q—and by comparing and contrasting their respective performances. When all capital goods are homogeneous, the expression of Multiple q model (9) reduces to

$$(q-1)P=\gamma(Z-a). \quad (25)$$

Thus, as for the Single q model, the investment function that rewrites (25):

$$Z=a+\frac{1}{\gamma}(q-1)P \quad (26)$$

is estimated from the Z, q, P data that are consistent with the concepts of the capital goods for each model. The variable Z represents the investment rate, calculated as the ratio of total investment to total capital stock obtained by aggregating the capital goods. To focus on the comparison with Asako, Kuninori, Inoue, and Murase (1989, 1997),[8] control variables are excluded from the estimations in all models, and standard OLS estimations are conducted using cross-section data for each year. In Tables 4-1 to 4-3, as well as the estimation results for all of the samples, the results of the estimations for only major manufacturing firms are

Table 4-1. Single q model results (year by year), not including land

	Full sample	Manufacturing, major enterprises
	$1/\gamma$	$1/\gamma$
2004	-0.0143	0.0012
2005	0.0080 **	0.0009
2006	0.0085 **	0.0075 **
2007	0.0072 **	0.0113 **
2008	0.0090 **	0.0100 **
2009	0.0081 **	0.0058 *
2010	0.0073 **	0.0057 **
2011	0.0085 **	0.0035
2012	0.0076 **	0.0089 **
2013	0.0071 **	0.0074 **

Table 4-2. Single q model results (year by year), including land

	Full sample	Manufacturing, major enterprises
	$1/\gamma$	$1/\gamma$
2004	0.0080 **	0.0159 **
2005	0.0100 **	0.0175 **
2006	0.0099 **	0.0169 **
2007	0.0113 **	0.0215 **
2008	0.0139 **	0.0249 **
2009	0.0103 **	0.0122 *
2010	0.0104 **	0.0129 **
2011	0.0125 **	0.0222 **
2012	0.0117 **	0.0183 **
2013	0.0098 **	0.0155 **

Note 1. Standard errors are heteroscedastically robust (Huber-White estimator), with ** and * denoting significance at the 5% and 10% levels, respect
2. The results of the industry dummies and capital size dummies are omitted from the table.

Table 4-3. Multiple q model results (year by year)

	Full sample				Manufacturing, major enterprises			
	γ_K	γ_L	$-\gamma_K a_K$	$-\gamma_L a_L$	γ_K	γ_L	$-\gamma_K a_K$	$-\gamma_L a_L$
2004	3.083 **	-2.288 **	2.096 **	2.168 **	3.433 **	-4.330 **	0.499 **	0.768 **
2005	2.660 **	-1.711 **	2.448 **	2.408 **	2.797 **	-2.013 **	1.073 **	1.387 **
2006	2.485 **	-1.464 **	1.835 **	1.865 **	3.155 **	-0.690	0.961 *	1.282 **
2007	3.350 **	-1.469 **	1.169 **	1.450 **	2.669 **	-0.592	0.148	0.354
2008	2.488 **	-0.127	0.953 **	0.976 **	3.565 **	-0.720	-0.576	-0.402
2009	2.935 **	-1.587 **	0.607 **	0.560 **	1.902 **	-1.842	-0.273	-0.427
2010	3.305 **	-2.357 **	1.038 **	1.085 **	1.535 **	-2.051	0.590 **	0.314
2011	3.142 **	-1.742 **	1.079 **	1.188 **	3.253 **	1.783	0.485	0.680 **
2012	4.024 **	-1.407	0.855 **	1.117 **	2.917 **	-1.553	0.907 *	1.092 **
2013	3.573 **	-2.273 **	1.385 **	1.709 **	4.943 **	-3.254 *	0.031	0.137

Note 1. Standard errors are heteroscedastically robust (Huber-White estimator), with ** and * denoting significance at the 5% and 10% levels, respectively.
2. The results of the industry dummies and capital size dummies are omitted from the table.

[8] However, unlike in this paper, Asako, Kuninori, Inoue, and Murase (1989, 1997) employed the average q concept.

also shown as Asako *et al*. (1989, 1997) centered on the listed manufacturing firms.

To interpret the estimation results, the Single q model that does not include land (see Table 4 - 1) shall first be compared to the Single q model that includes land (see Table 4 - 2). Looking at the $1/\gamma$ estimates in all of the samples, only 2004 for the case that excludes land is not significant. All other years are significant in both cases, but the parameter estimates are larger and relatively more plausible in the case that includes land.

For major manufacturing enterprises, the case that includes land differ more obviously from one that does not. In the latter case, $1/\gamma$ is not significant from 2004 to 2005 and in 2011; in the former case, it is positive and significant in all years. Even when $1/\gamma$ is estimated as significant in both cases, the estimates in the case that includes land are evidently greater and are more theoretically plausible as well. Therefore, it is strongly suggested that, within the Single q framework, capital stock should include land. This conclusion was also reached by Asako, Kuninori, Inoue, and Murase (1997), who analyzed listed enterprises in the manufacturing industry from 1977 to 1992. In a more detailed comparison, in Asako *et al*. (1997), the $1/\gamma$ estimate of the case that includes land was nearly 10 times larger than the one that does not, and the deviation between them was much larger than the corresponding deviation derived in this paper.

However, for the $1/\gamma$ estimate in the case that includes land, its average among those years estimated to be significant is 0.023, slightly larger than the 0.018 for major manufacturing enterprises in this paper. In other words, a large part of the extreme difference between the case that includes land and the one that does not in Asako *et al*. (1997) occurs because the $1/\gamma$ estimates for the case that does not include land are too small. At the very least, the estimation results from the Single q model that includes land obtained in Asako *et al*. (1997) and in this paper are quite similar overall, considering that the estimation periods and the method of constructing q are totally different.

Now, we examine the results of the estimations from the Multiple q model (Table 4 - 3). In the estimations for all of the sample enterprises, all of the variables are estimated to be significant, except γ_L in 2008 and 2012, and the sign is positive for γ_K, $-\gamma_K a_K$, $-\gamma_L a_L$ and negative for γ_L , which is generally consistent with the baseline model estimation results over the entire sample period 2004 - 2013 obtained in Table 3 as the case of no control variable. In the estimations for the sample limited to major manufacturing firms, though the estimates of γ_K and their year - by - year variation differ slightly from those of the entire sample; they are positive and significant in all years. As for the other three parameters, the sign in the years estimated to be significant is consistent with that for the baseline model with entire sample, but the significance declines considerably overall. However, regarding consistency with the assumption of a smooth, convex adjustment cost function, the fact that γ_L is not estimated to be significantly negative and that $-\gamma_K a_K$ and $-\gamma_L a_L$ are not significant (suggesting $a_K = 0$ and $a_L = 0$) is not necessarily a denying result.

The estimate of γ_K, which is equivalent to the slope of the marginal adjustment cost curve of tangible fixed assets other than land, is a maximum of 4.0 in 2012 from the estimation of all samples, and 4.9 in 2013 in the estimation of major manufacturing enterprises. This is

Table 5. Estimated partial Q values (year by year)

	Full sample		Manufacturing, major enterprises	
	partial Q_K	partial Q_L	partial Q_K	partial Q_L
2004	2.250	2.185	0.711	0.779
2005	2.582	2.425	1.273	1.381
2006	1.978	1.871	1.204	1.368
2007	1.376	1.450	0.367	0.412
2008	1.102	0.976	-0.303	-0.448
2009	0.749	0.560	-0.159	-0.433
2010	1.198	1.087	0.662	0.307
2011	1.243	1.190	0.657	0.646
2012	1.092	1.118	1.034	1.044
2013	1.604	1.712	0.367	0.140

theoretically far more plausible than the value of γ suggested by the estimation result of the Single q model including land (which exceeds 50 even for relatively smaller figure with major manufacturing firms). Furthermore, by an F test for the years in which both γ_K and γ_L are estimated to be significant, the null hypothesis of $\gamma_K = \gamma_L$ is rejected at a significance level of 1% for all years. Thus, from the three models within the q theory framework, we can conclude that the Multiple q model has the strongest conformity to the data.

Next, based on the results shown in Table 4-3, we calculate in Table 5 the Partial Q_j ($=p_j(q_j-1)$) corresponding to the explanatory variable of the investment function by capital goods in equation (18).[9] In all samples, positive values are estimated for every year for the Partial Q_K imputed to tangible fixed assets other than land and for the Partial Q_L imputed to land. For major manufacturing enterprises, closer to the sample set employed in Asako, Kuninori, Inoue, and Murase (1997), both Partial Q_K and Partial Q_L take positive values in every year except 2008 and 2009. Partial Q_K is negative in 2008 and 2009 because the $-\gamma_K a_K$ estimation values are negative, but they are not significant. Integrating the results of the estimations in Asako, Kuninori, Inoue, and Murase (1989, 1997) and Asako and Tonogi (2010), Partial Q_L is negative from 1977 to 1983, positive from 1984 to 1991, negative from 1992 to 2004, and positive from 2004 onwards which is the estimation sample period of this paper. Thus, the sign changes according to the time period, reflecting factors such as trends in land prices.[10]

IV-3. Comparison of estimation results by share capital size

Along with differences in investment behavior through the heterogeneity of capital goods, we estimate the investment function by share capital size to identify the different effects of

9 From (17) or (18), with $\hat{\gamma}_j$ and $\hat{a}_j$ as the respective estimates, partial $Q_j = \hat{\gamma}_j (Z_j - \hat{a}_j)$ is obtained.

10 In q theory, it goes without saying that the investment amount and partial Q are determined simultaneously, and the estimation of the regression equation should be carried out paying attention to this simultaneity problem. However, consistent with the estimation method employed in the previous papers, we use the ordinary least squares method (OLS).

the imperfect nature of the capital market on major enterprises and smaller enterprises, as well as differences in the capital stock adjustment process. This section examines the results in Table 6, which shows the estimations by share capital size for the basic three cases of equation (24).

First, the estimations of the investment adjustment cost function parameters γ_K, γ_L, $-\gamma_K a_K$, $-\gamma_L a_L$ significantly indicate that γ_j is positive for tangible fixed assets other than land and negative for land, while $-\gamma_j\, a_j$ is positive for both. These basic features are the same as in baseline model in Table 3, and they are common regardless of share capital size. However, the estimates of parameter γ_K relating to tangible fixed assets other than land increases as capital size gets larger, suggesting that the smaller the enterprise, the greater the cost when adjusting the capital stock.

For the control variables, the estimation results are also broadly the same as for the whole sample baseline model. Regarding the interest-bearing debt ratio coefficient C_1, however, when the zero-leverage dummy, *ZLD*, is not included, its positive coefficients take smaller values according as enterprises shift to be in their smaller share capital categories; for micro enterprises, it is even negative and significant. These results occur because, as capital size gets smaller, the factors that cause the interest-bearing debt ratio coefficient to be positive (such as supply factors of the lending market, the disciplinary effects of debt, and tax-saving effects) become weaker, while the factors that cause the coefficient to be negative (including demand factors of the lending market and risk of bankruptcy) become stronger. On the other hand, when adding the zero-leverage dummy to the explanatory variables, the zero-leverage dummy coefficient C_0 is significant and negative at every capital size level, as in the results of the baseline model for all samples, suggesting the involvement of supply factors of the lending market, the disciplinary effects of debt, or tax-saving effects; however, the interest-bearing debt ratio coefficient C_1 is negative and significant except for small enterprises, suggesting the involvement of elements such as demand factors of the lending market and risk of bankruptcy, which is opposite to the zero-leverage dummy.[11] After removing the differences exceeding the size level and absorbing the supply factors of the lending market, the disciplinary effects of debt, and tax-saving effects from the zero-leverage dummy, factors such as demand factors of the lending market and risk of bankruptcy—which are not ascertained in the estimation of the full sample—are ascertained as differences between enterprises similar in capital size.

The extent to which the tangibility coefficient C_2 is negative shrinks as enterprises shift to be in their smaller share capital categories. This occurs because, as share capital decreases, the importance of the factors causing the coefficient to be negative (the importance of intangible assets) also decreases, while the importance of the factors causing the coefficient to be positive (the easing of borrowing constraints from pledgeability) strengthens.

The results reflect the funding constraints facing smaller enterprises in the sense that a smaller share capital implies investment is easily restrained by a higher interest-bearing debt

[11] For small enterprises, it is positive and significant, but the coefficient value is extremely small.

Table 6. Baseline model results by share capital size (FY 2004 to 2013)

Major enterprises

	No control variable		Not including zero-leverage dummy		Including zero-leverage dummy	
	Coefficient		Coefficient		Coefficient	
γ_K	2.82	**	1.95	**	2.06	**
γ_L	-1.34	**	-1.22	**	-1.39	**
$-\gamma_K a_K$	1.95	**	1.89	**	2.75	**
$-\gamma_L a_L$	1.88	**	1.81	**	2.64	**
C_0					-1.43	**
C_1			0.53	**	-0.40	**
C_2			-3.06	**	-3.26	**
C_3			0.11	**	0.08	**
R-squared	0.346		0.407		0.444	
N of obs.	32,965		32,695		32,695	

Medium-sized enterprises

	No control variable		Not including zero-leverage dummy		Including zero-leverage dummy	
	Coefficient		Coefficient		Coefficient	
γ_K	2.89	**	2.05	**	2.10	**
γ_L	-1.86	**	-1.85	**	-1.88	**
$-\gamma_K a_K$	1.74	**	1.61	**	2.48	**
$-\gamma_L a_L$	1.78	**	1.70	**	2.47	**
C_0					-1.49	**
C_1			0.42	**	-0.21	**
C_2			-2.82	**	-3.12	**
C_3			0.14	**	0.11	**
R-squared	0.305		0.370		0.408	
N of obs.	39,807		39,807		39,807	

Small enterprises

	No control variable		Not including zero-leverage dummy		Including zero-leverage dummy	
	Coefficient		Coefficient		Coefficient	
γ_K	3.18	**	2.53	**	2.56	**
γ_L	-1.84	**	-2.04	**	-2.13	**
$-\gamma_K a_K$	0.77	**	0.89	**	1.37	**
$-\gamma_L a_L$	0.95	**	1.17	**	1.65	**
C_0					-1.40	**
C_1			0.15	*	0.03	**
C_2			-2.15	**	-2.47	**
C_3			0.13	**	0.11	**
R-squared	0.215		0.266		0.296	
N of obs.	29,168		29,168		29,168	

Micro enterprises

	No control variable		Not including zero-leverage dummy		Including zero-leverage dummy	
	Coefficient		Coefficient		Coefficient	
γ_K	3.41	**	2.96	**	2.85	**
γ_L	-1.35	**	-1.65	**	-1.88	**
$-\gamma_K a_K$	1.07	**	1.29	**	1.81	**
$-\gamma_L a_L$	1.19	**	1.44	**	2.00	**
C_0					-1.72	**
C_1			-0.21	**	-0.32	**
C_2			-1.01	**	-1.31	**
C_3			0.11	**	0.06	*
R-squared	0.106		0.125		0.146	
N of obs.	3,800		3,800		3,800	

Note 1. Standard errors are heteroscedastically robust (Huber-White estimator), with ** and * denoting significance at the 5% and 10% levels, respectively.
2. The results of the year dummies and industry dummies are omitted from the table.

ratio and lower tangibility. The estimates of the enterprise asset size coefficient C_3 are positive and significant at every capital size level, as in the baseline model estimation results for all samples, suggesting the easing of borrowing constraints from the effects of size, although no tendency for the value to increase as share capital size becomes smaller is observed.

Regarding the estimation results' coefficient of determination, the value decreases as the size of share capital decreases, indicating that the explanatory power of the investment function decreases. This tendency does not change even when control variables are added, such as those relating to funding constraints. As discussed in Section II, in estimating the investment function based on q theory by enterprise size, the goodness of fit would be better for smaller enterprises for the reason that their business structures are simple and easier to understand through a single investment function, and that perfect competition, an underlying assumption of q theory, is nearly established. However, such possibilities are not supported by these results. On the other hand, concerning the possibility of lumpy investment, which is considered a reason why the goodness of fit would be worse for smaller enterprises, this is not contradicted by the results, in which the estimate of parameter γ_K relating to tangible fixed assets other than land increases as the size of share capital shrinks.[12] Thus, we verify this issue in detail in the next section.

IV-4. Possibility of lumpy investment

The adjustment of capital stock carried out in a lumpy form will be efficient if the adjustment cost includes a fixed cost portion, which would be borne every time a fine adjustment is made. As a result, when carrying out adjustments, large scale investment is carried out in one fell swoop. However, if there are funding constraints, a sufficient investment scale may not be possible. If this is the case, when applying the investment function based on q theory, the estimation of parameter γ_K relating to tangible fixed assets other than land will be smaller in enterprises with funding constraints than in enterprises without. Therefore, as was done in many previous studies, after dividing the sample according to whether the firm paid dividends as an indicator of the existence or non-existence of funding constraints, estimations were made from equation (24). When investment behavior may be distorted due to insufficient funds from paying dividends, shareholders should not want dividends to be paid for the sake of maximizing enterprise value. Therefore, the sample that pays dividends is considered not to have funding constraints, and the sample that does not pay dividends is considered to have them.

Table 7 shows the estimation results. In the sample, no more than 120 micro enterprises paid dividends throughout the entire period. Hence, the estimations are not conducted for them, as the degree of freedom is insufficient. The estimates of the tangibility coefficient C_2

[12] The large parameter γ_K estimate may also reflect the fact that, within the framework of the smooth, convex adjustment cost function, there is more friction for the adjustment by small enterprises. If this is so, no systemic reduction in the coefficient of determination should occur.

Table 7. Difference between dividend paying samples and non-dividend paying samples (FY 2004 to 2013)

Results for dividend paying samples (i.e., financially unconstrained), by capital size

	Major enterprises	Medium-sized enterprises	Small enterprises
γ_K	2.56 **	2.66 **	3.20 **
γ_L	-2.73 **	-2.81 **	-3.35 **
$-\gamma_K a_K$	3.93 **	4.36 **	3.55 **
$-\gamma_L a_L$	3.93 **	4.45 **	3.70 **
C_0	-1.56 **	-1.76 **	-1.89 **
C_1	-0.04	-0.15 **	0.01
C_2	-4.32 **	-4.11 **	-3.54 **
C_3	-0.01	-0.04 **	-0.05 **
R-squared	0.564	0.565	0.546
N of obs.	23,153	21,292	7,024

Results for non-dividend paying (i.e., financially constrained) samples, by capital size

	Major enterprises	Medium-sized enterprises	Small enterprises	Micro enterprises
γ_K	1.18 **	1.66 **	2.29 **	2.85 **
γ_L	-1.00 **	-1.65 **	-2.00 **	-1.91 **
$-\gamma_K a_K$	0.76 *	1.35 **	1.26 **	1.67 **
$-\gamma_L a_L$	0.51	1.28 **	1.56 **	1.86 **
C_0	-0.84 **	-1.13 **	-1.32 **	-1.67 **
C_1	-0.03	0.02	0.07 **	-0.30 **
C_2	-1.58 **	-2.18 **	-2.12 **	-1.16 **
C_3	0.14 **	0.13 **	0.06 **	0.07 *
R-squared	0.180	0.230	0.221	0.134
N of obs.	9,542	18,515	22,144	3,680

Note 1. Standard errors are heteroscedastically robust (Huber-White estimator), with ** and * denoting significance at the 5% and 10% levels, respectively.
2. The results of the year dummies and industry dummies are omitted from the table.

are negative and significant both for the sample paying a dividend and the sample not paying one, but the absolute value of the latter is clearly smaller. The estimates of the enterprise asset size coefficient C_3 are negative and significant or not significant for the sample paying a dividend but positive and significant for the sample not paying a dividend. These results indicate that the paying (or not) of a dividend functioned appropriately as an indicator of funding constraints.

The estimates of parameter γ_K relating to tangible fixed assets other than land are positive and significant in all of the cases, and the characteristic whereby greater capital implies a smaller γ_K is common to both the sample that pays and the sample that does not pay a dividend, but the level is clearly smaller in the sample that does not pay (or, the funding constraints sample). However, this does not necessarily mean a good fit with the smooth, convex adjustment cost function because the coefficient of determination of the sample not paying a dividend is clearly lower than that paying a dividend. These results indicate that, regardless of the share capital size, at least some part of the investment behavior is lumpy, that the degree of lumpiness increases as the size of share capital decreases, and that some part of the lumpy investment behavior is constrained by the imperfect nature of the capital market. This is consistent with what can be forecast from theory.

Therefore, in our framework of the smooth adjustment cost function, we ascertain as straightforwardly as possible the situation concerning lumpy investment/disinvestment by dividing the investment rate relating to tangible fixed assets other than land into certain categories and estimating the investment function for each of these categories. We divide the sample into eight categories at 5% intervals, from an investment rate of 0% up to 40%, and, together with the negative sample, estimate the investment rate from equation (24) and compare the estimation performances. As lumpy behavior is to be constrained when there are funding constraints, only the sample paying dividends is targeted.

As is shown in Table 8, in the three categories of investment rates of 0% to 5%, 5% to 10%, and 10% to 15%, parameter γ_K relating to tangible fixed assets other than land is positive and significant despite having a slightly higher value than in the baseline case (Table 3). By contrast, for the categories of 15% to 20% and above, while the signs are positive, they are not significant, and the estimates become unstable. In addition, when the investment rate is negative, the estimates of parameter γ_K relating to tangible fixed assets other than land are not significant (the sign is negative). In other words, regarding investment in tangible fixed assets other than land, the smooth, convex adjustment cost function framework may not be

Table 8. Difference by the level of investment rate for tangible fixed assets other than land (dividend paying samples, FY 2004 to 2013)

	$Z_K<0$	$0 \leqq Z_K<0.05$	$0.05 \leqq Z_K<0.1$	$0.1 \leqq Z_K<0.15$	$0.15 \leqq Z_K<0.2$
γ_K	-0.478	5.201 **	7.261 **	5.633 **	0.091
γ_L	-2.140 **	-2.913 **	-2.970 **	-4.411 **	-3.043 **
$-\gamma_K a_K$	3.204 **	3.528 **	3.519 **	3.635 **	4.732 **
$-\gamma_L a_L$	3.337 **	3.715 **	3.811 **	4.096 **	4.699 **
C_0	-1.525 **	-1.512 **	-1.569 **	-1.673 **	-1.857 **
C_1	0.173	0.068	-0.049	-0.161 *	-0.458 **
C_2	-3.966 **	-3.507 **	-3.668 **	-4.061 **	-4.573 **
C_3	-0.004	-0.059 **	-0.036 **	-0.040 **	-0.025
R-squared	0.437	0.479	0.544	0.580	0.605
N of obs.	3401	12203	11610	8640	5568

	$0.2 \leqq Z_K<0.25$	$0.25 \leqq Z_K<0.3$	$0.3 \leqq Z_K<0.35$	$0.35 \leqq Z_K<0.4$
γ_K	0.302	5.224	1.537	5.169
γ_L	-3.989 **	-3.421 **	-2.932 **	-3.972 **
$-\gamma_K a_K$	4.548 **	4.150 **	5.852 **	3.395
$-\gamma_L a_L$	4.334 **	5.661 **	5.668 **	4.740 **
C_0	-1.866 **	-2.056 **	-2.016 **	-2.007 **
C_1	-0.260	-0.104	-0.021	0.717 *
C_2	-4.646 **	-5.916 **	-5.416 **	-5.171 **
C_3	-0.015	-0.004	-0.045	0.019
R-squared	0.627	0.647	0.672	0.673
N of obs.	3244	2051	1366	953

Note 1. Standard errors are heteroscedastically robust (Huber-White estimator), with ** and * denoting significance at the 5% and 10% levels, respectively.
2. The results of the year dummies, industry dummies, and capital size dummies are omitted from the table.

applicable to the comparatively large positive investment rate of over 15% and to negative investment. This result is generally consistent with the studies that have empirically analyzed lumpy investment, such as Power (1999), who regarded investment rates of 20% or above as large - scale investment (an investment spike).

V. Conclusions and future research issues

This paper used survey slips of the Financial Statements Statistics of Corporations by Industry (FSSCI) from fiscal 2004 to fiscal 2013 and estimated Multiple q model that incorporated the heterogeneity of two types of capital goods—tangible fixed assets other than land and land—to verify the extent to which the investment behavior of enterprises of various sizes, ranging from major enterprises to small enterprises and micro enterprises, could be explained within the q theory framework. To this end, while considering the imperfect nature of the capital market, we estimated the investment function using the Multiple q model under various settings. The results of the analysis can be summarized as follows.

First, in contrast to prior studies that used data from the securities reports of listed enterprises, our dataset was mostly comprised of non - listed enterprises, including small enterprises and micro enterprises. Therefore, our analyses were innovative in terms of the diversity of enterprise sizes even though various restrictions were placed on the data due mainly to the sampling survey and the limitation in surveyed items. However, the main results of the analysis were generally consistent with those of the prior studies. (i) Within the Single q framework that does not consider the heterogeneity of capital goods, a model that considers land to be a capital good with a specific adjustment cost is preferable to a model that excludes land; (ii) concerning investment behavior that includes land in capital goods, significant heterogeneity was found between land and tangible fixed assets other than land, and the Multiple q model that explicitly considers this was found to be preferable to the Single q model; (iii) however, on adding to the Multiple q model control variables that are inherently redundant in q theory such as the imperfect nature of the capital market, they gained significant explanatory power, indicating that even when considering the heterogeneity of capital goods, a large part of enterprises' investment behaviors is left unexplained by q theory.

Second, regarding the control variables, much of the interest - bearing debt ratio's apparent impact on investment behavior is due to differences in investment behaviors between zero - leverage enterprises and enterprises with debt, and the apparent impact of tangibility on investment behavior is due to the measurement error of the "q" ratio from the growing importance of intangible assets as a quasi - fixed production factor. These findings offer new topics for future research on capital investment.

Third, regarding the differences in investment behavior according to share capital size, one of the main concerns of this paper, the coefficient of determination suggested that the smaller the company, the worse the fit with the investment function while the estimation values of the coefficient of tangible fixed assets other than land was significantly higher than for major enterprises (in other words, smaller enterprises experience greater friction in the adjustment of capital stock). These findings suggest the existence of lumpy investment that cannot be handled by the *q* theory framework, which is observed charcteristically in smaller enterprises. In fact, estimation results after dividing the sample into two subsamples—payment or non-payment of dividends as an indicator of funding constraints—found that, regardless of share capital size, at least some part of investment behavior is lumpy, that the degree of lumpiness increases as the size of share capital decreases, and that some part of lumpy investment behavior may be constrained by the imperfect nature of the capital market.

Fourth, to ascertain the lumpy investment conditions, the sample was restricted to enterprises paying a dividend (enterprises without funding constraints), and this sample was then divided into investment rate levels relating to tangible fixed assets other than land. The estimation results indicated that an investment rate in the range of 0% to 15% was applicable to the smooth, convex adjustment cost function.

Finally, we discuss potential issues for future research. Regarding funding constraints, clear evidence to support the intuition that funding constraints become more serious as share capital size decreases was not confirmed from the variables or the estimation methods adopted in this paper. Whether this means that no relationship between capital size and funding constraints exists or that there is a relationship that cannot be ascertained due to problems with the analytical methods should be addressed. In addition to the issue of funding constraints, it will also be necessary to verify the relationship between a zero-leverage condition and investment behavior using a more appropriate analytical framework.

As suggested by the coefficient of tangibility, the importance of explicitly handling intangible assets as capital goods is something that many researchers are already paying attention to, but a considerable divergence separates the economic concept of intangible assets and the intangible assets that are recorded on enterprises' balance sheets. It will probably not be easy to overcome this problem using data in FSSCI, but it is an issue worth addressing. Elucidating lumpy investment, which is also an important research issue, will be the feasible task on a line extending from the current framework. Studies have already extended the linear investment function based on the Multiple *q* model to the nonlinear framework, including lumpy investment, of Asako and Tonogi (2010) and Asako, Nakamura, and Tonogi (2016), who analyzed listed enterprises. Applying this framework to the FSSCI after dealing appropriately with the data constraints is a promising research task.

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