KIER DISCUSSION PAPER SERIES

KYOTO INSTITUTE
OF
ECONOMIC RESEARCH

Discussion Paper No.1043

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Evidence from
Japan's Two Lost Decades and Financial Crises

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October 2020

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KYOTO, JAPAN

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Abstract

To reveal the cause of Japan's recent weak physical investment, this study estimates and compares the Euler equations for physical investment, R&D investment, and employment. We construct an unbalanced panel from Japanese firms' microdata from 1994 to 2014. The estimation results suggest that firms face weak financial constraints in the sense that their borrowing amount is not restricted, but their internal funds are insufficient. To address such constraints, firms first allocate their cash flows and cash reserves to buffer their employment and then incur R&D investment rather than protect physical investment. We suggest the following reason for this result: employment and R&D investment are more productive and/or impose larger adjustment costs than physical investment, and thus, firms prioritize the stabilization of employment and R&D over funding physical investment. This study also shows that young, small-sized, and manufacturing firms are likely to

*Corresponding author: Hirokazu Mizobata; Email: mizobata@kansai-u.ac.jp. This study received funding from the Japan Society for the Promotion of Science (JSPS) (KAKENHI Grant Number 26285068). This grant enabled us to obtain questionnaire information pertaining to the Basic Survey of Japanese Business Structures and Activities. We thank Yasuo Goto, the principal investigator of the project. We also acknowledge financial support from the JSPS Core-to-Core Program (A. Advanced Research Networks), KAKENHI Grant Number 20H00076, and the International Joint Research Center of Advanced Economic Theory, Kyoto University. We are grateful to the participants of the INCAS Annual Conference (FU Berlin, 2018) and Monetary Economic Workshop (Ryukoku University, 2016) for their comments and suggestions.

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suffer from weak financial constraints. Furthermore, even during financial crises, firms rely only on internal funding and are not restricted by external funding in the same way as they are during usual times.

JEL Classification: D25, G31, G32

Keywords: physical investment, research and development investment, employment, adjustment cost, financial constraint, Euler equation

1 Introduction

Japan's physical investment (or fixed investment) has remained stagnant since the 1990s. The economic stagnation period after the collapse of the Japanese asset price bubble in 1991 to 2010 is referred to as the "two lost decades." Despite the relatively long economic expansions during this period, physical investment growth was generally slower than before. This weak investment has continued from 2010 until now. In particular, the recovery of physical investment after the global financial crisis in 2008 was slower than that of corporate profit, which showed resilience. Weak physical investment during a long expansion is uncommon, as there are usually enough internal and external funds in a good economic environment.

This unusual state of Japan's physical investment is explained mainly from three non-exclusive viewpoints. The first point is the existence of investment adjustment costs. Convex adjustment costs make investment sluggish compared to the economic recovery. The second point is financial constraints. Even in the current low interest rate era, external financing, such as bank borrowing or corporate bond issuance, may hit the ceiling, reflecting the uncertain business conditions of firms. Similarly, as external finance carries higher interest rate premiums than internal finance, the investment may be constrained by internal funding, such as cash flows. Alternatively, firms may face the constraint of not being able to increase enough retained earnings for future borrowing constraints. External and internal financial constraints arising from such factors restrain investment. The third point is the allocation of funds among multiple types of investment. Firms generally decide the amount of physical investment simultaneously with the amount of other kinds of investment. Research and development (R&D) investment is typical of such investment. For example, decreases in physical investment may be induced by a shift of funds to R&D expenditure, and overall investment may expand. This may occur because the marginal profitability of physical capital declines more than that of R&D capital.

Our main purpose is to obtain insights into the dominant source of the recent weak capital investment in Japan. To this end, it is useful to consider firms' dynamic decision-making behavior on multiple stock types. In addition, if employment incurs adjustment costs, which is plausible in Japan, it varies with rigidity and its determination becomes dynamic, like other stocks.[1] A firm's optimal dynamic stock decision is described by the Euler equations. Thus, for our purpose, it is suitable to estimate regression equations of physical investment, R&D investment, and employment induced by the Euler equations.

The pioneers of estimating investment by Euler equation considering corporate financial structure are Whited (1992) and Bond and Meghir (1994). Whited (1992) considers the investment decision with an external upper limit of borrowing, and estimates a non-linear Euler equation. Bond and Meghir (1994) examine structures that generate financial hierarchy, such as tax systems and transaction costs, and investigate conditions under which the level of liabilities affects the Euler equation. Subsequently, the authors test the implications of financial constraints using the Euler equations in a linear form.

Several variants of these two studies follow. Among others, Hall (1995) estimates the Euler equations of investment and R&D employing a model close to that of Whited (1992) but explicitly considers the financing phase of stock issuance, which is not included in the abovementioned two models. Gilchrist and Himmelberg (1998) solve Euler equations embedding financial constraints and linearly approximate them, and then construct a vector autoregression model that forecasts future fundamentals and financial state variables. Brown and Petersen (2015) extend Bond and Meghir's (1994) estimation equations by adding some finance variables that do not appear in the Euler equations without financial constraints to examine their significance. In addition, the authors estimate both capital and R&D investment from the same viewpoint as our third point outlined above to explain the unusual physical investment contraction. We extend Brown and Petersen's

[1]The change in the labor force as a production factor corresponding to investment (e.g., a change in capital stock or R&D stock) is the number of employees hired or dismissed. We use the term "employment" as a concept that corresponds to investment in the sense of flow. Meanwhile, the term "employment stock" is used when referring to the number of employees.

(2015) approach to include the employment Euler equation, since labor adjustment costs are non-negligible in Japan.

Our study contributes to the literature that investigates the weak physical investment problem. Previous studies have dealt with this problem by employing the extended Q-type investment function, rather than the Euler equation. Nakamura (2017) addresses Japan's weak physical investment from three aspects: managerial entrenchment, precautionary saving, and inefficient internal capital market. He uses Japanese listed company data and estimates the Q-type investment equation to show that weak investment is brought about by managerial entrenchment and precautionary saving. Weak physical investment is also observed in the US. Gutiérrez and Philippon (2017) analyze this phenomenon in the US using a wide range of aggregate-, industry-, and firm-level data. The authors estimate the Q-type investment equation with several core variables that support four hypotheses: financial constraints, changes in the nature of investment, decreased competition, and tighter corporate governance. The authors show that the rise of intangible investment explains one-third of the drop in physical investment, while decreased competition and changes in corporate governance explain the rest. Our study has a common research interest with these studies but differs in that we comprehensively and consistently analyze the firm's dynamic decision-making from the viewpoint of fund allocation among different production factors.

The rest of this paper is organized as follows. Section 2 provides an overview of Japanese physical and R&D investment as well as employment at the aggregate level. Section 3 presents the investment model with financial constraints and provides empirical implications. Section 4 describes the data characteristics. Section 5 introduces the basic estimation results and compares them by splitting the sample based on firms' characteristics. In addition, this section examines the impact of financial crises. Section 6 concludes.

2 Overview of investment and employment behavior

This section presents an overview of aggregate investment and employment behavior in Japan since the middle of the 1990s based on data used in our analysis. The data are from the Basic Survey of Japanese Business Structures and Activities (BSBSA) conducted by the Ministry of Economy, Trade and Industry (METI).[2] We

[2]Section 4 describes the data and our sample selection scheme.

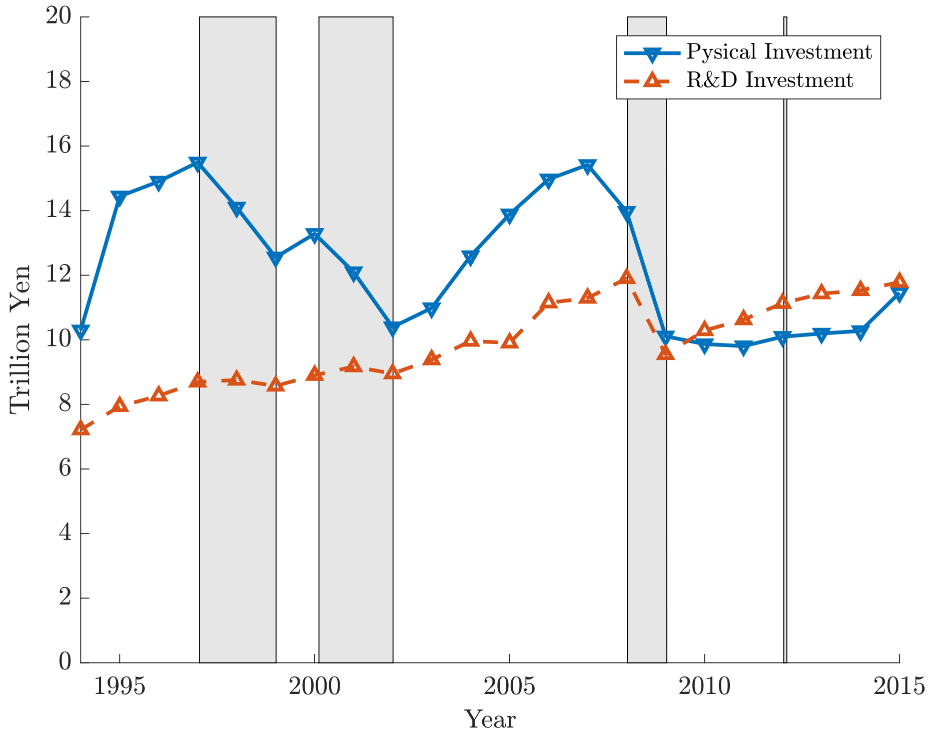

Figure 1: Aggregate capital and R&D investment

aggregate the amounts of physical and R&D investment and the number of employees defined in Section 4.

Figure 1 compares aggregate amounts of physical and R&D investment (in nominal terms). The shaded areas indicate the recession period officially set by the Japanese government. The figure shows that, prior to the 2010s, physical investment was well above the level of R&D investment. However, while physical investment fluctuated greatly and sensitively according to business cycles, R&D investment was growing steadily. Subsequently, after the global financial crisis of 2008, physical investment in Japan stagnated, as mentioned in Section 1, but R&D investment continued to grow shortly after declining during the crisis. Consequently, R&D investment has exceeded physical investment since 2010.

Figure 2 shows the growth rate of physical and R&D investment alongside that

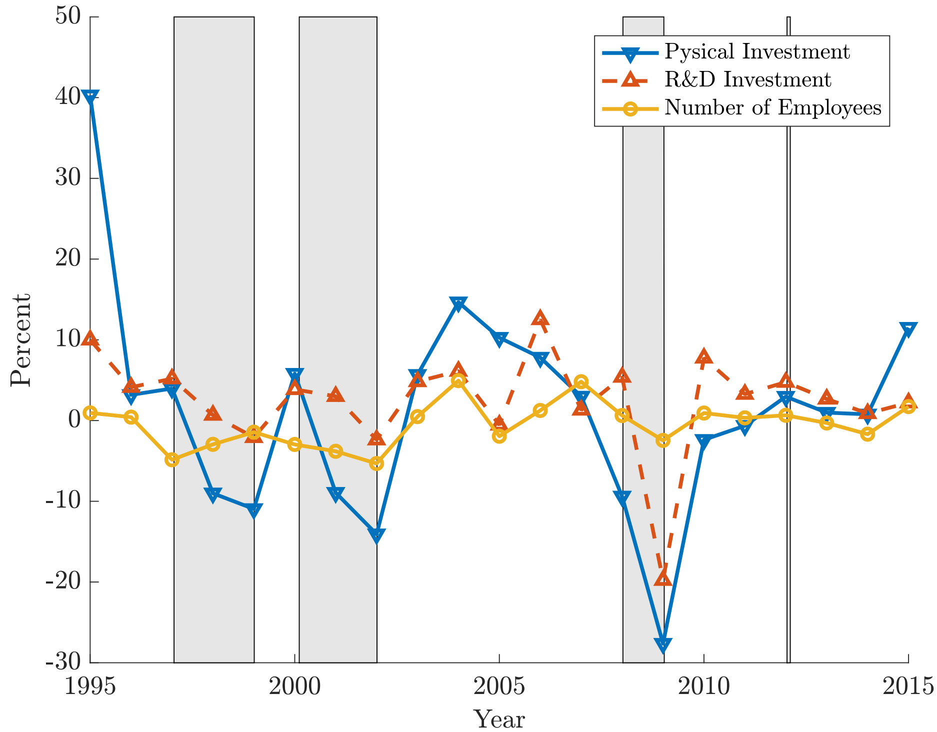

Figure 2: Dynamics of investment and employment

of the aggregate number of employees.[3] Employment is more stable than the other two investment variables; that is, the labor force is not a production factor that can be adjusted flexibly. Firms cannot always hire or dismiss workers freely, since they face, for example, recruitment costs and legal or implicit dismissal costs. In addition, firms may invest in human capital, which is a sunk cost. Thus, employment adjustments also impose costs, making a firm's decision about employment dynamics like that of physical and R&D investment.

Between the two series of physical and R&D investment, physical investment is more volatile. This feature is observed markedly in recessions. In a recession, the growth rate in physical investment drops sharply to a negative value, whereas that in R&D investment remains positive or near zero, except for a large decrease just after the 2008 financial crisis.

[3] These employees are regular and non-regular employees, as explained in Section 4.

Figure 2 indicates that, overall, firms adjust these three variables contrastively. Employment is stable against negative economic shocks. R&D investment responds to negative shocks but recovers quickly. Conversely, physical investment declines significantly due to negative shocks and remains sluggish. The large volatility of physical investment suggests that the adjustment cost of physical investment is relatively small. However, the long slump in physical investment after the 2008 financial crisis, as opposed to R&D investment, cannot be explained by small adjustment costs, suggesting that some other sources exist.

In the following sections, we investigate the reasons for the different behavior based on firms' dynamic decisions. We also compare the patterns of production factor adjustment among different firms according to their characteristics, such as age, size, payout, debt level, and industry.

3 Background Model and Implications

3.1 The Setting

We consider the firm's dynamic optimization problem for three production factors under financial constraints. In this section, we first describe this model, and then derive the estimable form of the firm's optimal first-order conditions. Each firm maximizes the expected present value of future dividends,

$$V_t = E_t \left[\sum_{j=0}^{\infty} \beta_{t,t+j} D_{t+j} \right], \tag{1}$$

where V_t denotes the firm's market value at time t, $E_t[\cdot]$ denotes the expectation operator conditional on information available at time t, $\beta_{t,t+j}$ denotes the firm's discount factor (product of the reciprocal of investors' gross required rate of return) from time t to $t+j$, and D_t is the dividend paid to shareholders at time t.

The firm's dividend at time t is defined as

$$\begin{aligned} D_t \equiv P_t \left(F(\mathbb{K}_{t+1}, N_{t+1}) - \sum_{i=1}^{2} \psi_i(I_{it}, K_{i,t+1}) - \phi(H_t, N_{t+1}) \right) - \sum_{i=1}^{2} P_{it} I_{it} - W_t N_{t+1} \\ + NB_t - r_t B_t. \end{aligned} \tag{2}$$

The function F represents a production function, and the functions ψ_i and ϕ are the adjustment cost functions. The vector $\mathbb{K} = (K_1, K_2)$ represents a stock vector of capital. The variable N is the employment stock. The subscript i refers to a function or variable relating to physical capital when $i = 1$, and R&D capital when $i = 2$. A stock variable with time notion t indicates its beginning-of-the-period value at time t. This specification of production timing is the same as in Bond and Meghir (1994).[4] The variable P is the output price. The variable P_i is the price of investment goods, and the amount of investment is I_i. The variable W denotes the wage rate, and the variable H is changes in the number of employees. The variable B is outstanding debt with interest rate r, and the associated flow variable is NB.[5]

The law of motion for K, N, and B is

$$K_{i,t+1} = K_{it} + I_{it}, \quad i \in \{1, 2\}, \tag{3}$$

$$N_{t+1} = N_t + H_t, \tag{4}$$

$$B_{t+1} = B_t + NB_t. \tag{5}$$

Here, we ignore the depreciation of capital or exogenous job separation (due to, e.g., retirement age), as these factors provide no additional insights into the analysis in our framework.

The financial constraints are summarized as

$$D_t \geq 0, \tag{6}$$

$$B^*_{t+1} \geq B_{t+1}. \tag{7}$$

Conditions (6) and (7) introduce financial constraints in a manner commonly used in the literature, including by Whited (1992) and Whited and Wu (2006). The constraint (6) prevents firms from issuing new shares. In other words, the marginal cost of issuing shares is prohibitively expensive. As Gilchrist and Himmelberg

[4]Here, the notation of time is different to that of Bond and Meghir (1994), who use the notation t for the end-of-period t stock value, while we use t for the beginning-of-period t stock value. Hall (1995) argues that the timing at which investment becomes capitalized and contributes to production affects the specifications of the Euler equations. She argues that in an adjustment cost framework, it is more reasonable to assume that the investment is available for production in the first period than to assume that it does not become productive until the next period. This is because the existence of adjustment costs allows for a diminishing marginal product in the first period.

[5]Brown and Petersen (2015) assume that firms have positive cash holdings (or retained earnings), which can be used to relax financial constraints in the future. We make the same assumption by allowing a negative value of outstanding debt.

(1998) note, a binding non-negativity constraint on dividends, or the assumption that shareholders prefer dividends to investment, is required for debt issuance as a marginal financing source. The condition (7) restricts the quantity of debt outstanding. Hence, if firms raise an insufficient amount of money, severe financial conditions might give rise to a situation in which firms must give up some investment or employment in a bad economic condition.[6]

Inserting Equations (2)–(5) into Equation (1), we obtain the following Euler equations for the variables K_i, N, and B:

$$P_{it} + P_t\left(\psi_{i,I_{it}} + \psi_{i,K_{i,t+1}}\right) = P_t F_{K_{i,t+1}} + E_t\left[\beta_{t,t+1}\left(\frac{1+\lambda_{t+1}}{1+\lambda_t}\right)\left(P_{t+1}\psi_{i,I_{i,t+1}} + P_{i,t+1}\right)\right],\ i \in \{1,2\}, \quad (8)$$

$$W_t + P_t\left(\phi_{H_t} + \phi_{N_{t+1}}\right) = P_t F_{N_{t+1}} + E_t\left[\beta_{t,t+1}\left(\frac{1+\lambda_{t+1}}{1+\lambda_t}\right)P_{t+1}\phi_{H_{t+1}}\right], \quad (9)$$

$$1+\lambda_t = E_t\left[\beta_{t,t+1}(1+\lambda_{t+1})(1+r_{t+1})\right] + \gamma_t, \quad (10)$$

where variable λ and γ are the Lagrange multipliers regarding the non-negativity constraint on dividends (6) and the constraint on new debt issues (7), respectively. The term F_x is the marginal product of raising variable x, and the terms $\psi_{i,x}$ and ϕ_x are the marginal costs of adjusting variable x. The left-hand side of Equation (8) is the marginal purchase and adjustment costs associated with the current investment in physical or R&D capital. The right-hand side of Equation (8) represents the marginal profits of the current investment, which consist of the marginal product and the expected marginal investment costs that can be reduced in the next period. The next-period values are discounted by the one-period discount factor and the relative shadow cost of the internal finance. Equation (9) is similar to Equation (8); the only difference is that the cost of purchasing marginal investment goods is incurred once while wages for marginal hiring are paid in each period. Equation (10) is the first-order condition for debt, which links the shadow costs of internal finance to those of external finance.

[6] As an alternative way to incorporate financial frictions implicitly, Gilchrist and Himmelberg (1998) assume an external financing premium that depends on outstanding debt and other factors. Meanwhile, Bond and Meghir (1994) introduce a borrowing constraint into the model more explicitly by considering taxation and bankruptcy costs. However, these different assumptions on financial frictions do not make an essential difference in the final form of the estimation equations.

3.2 Empirical Implications

To obtain the empirical implications from the model, we categorize the situations depending on whether the constraints (6) and (7) bind. This process leaves the following three possible cases.[7]

Regime 1. $D_t > 0,\ B^*_{t+1} > B_{t+1}$ **(No Financial Constraints)**

In this regime, the firm pays positive dividends to shareholders and can afford to issue new debt. The firm finances its investment and employment sufficiently. The sources of finance can be cash flows, cash holdings (or retained earnings), and/or borrowing when the expected interest rates on all assets or liabilities are equal, as we assume in the model in Subsection 3.1. Capital structure does not matter. Furthermore, the firm does not predict financial constraints in the future.[8] In this case, any variables concerned with a firm's financing decisions do not affect the investment and employment levels. We call this regime "no financial constraints." In this regime, all investment and employment are at the desired level for the firm, and the low physical investment is a result of its low profitability.

Regime 2. $D_t = 0,\ B^*_{t+1} > B_{t+1}$ **(Weak Financial Constraints)**

In this regime, the firm pays no dividends to shareholders and can afford to issue new debt. If there are no hierarchies for financing in a perfect capital market, this regime is trivial. In other words, new debt allows the firm to achieve desirable levels of investment and employment while maintaining zero dividend conditions.

However, in reality, this regime may have essential implications. Unlike the assumption of the model in Subsection 3.1, corporate debt and savings are not really perfectly substitutable financing tools owing to bankruptcy costs and taxation system (Bond and Meghir, 1994), as well as monitoring costs and moral hazard costs (Gilchrist and Himmelberg, 1998). If debt is a more costly financing tool than retained earnings, this regime may address the situation when the firm prepares

[7]Strictly speaking, there are four possible cases depending on whether constraints (6) and/or (7) bind. However, we focus on three cases here, as the situation in which the firm pays positive dividends and faces debt constraint rarely occurs. We can understand this logic intuitively by checking the optimal condition (10): a firm borrows to the limit because of the lower interest rate relative to the required rate of return.

[8]Solving a stochastic difference equation (10) forward shows that λ_t is the (weighted) sum of expected future values of γ if the solution exists.

insufficient net revenues and retained earnings to finance all its desired investment and employment but finds it optimal not to issue new debt up to the borrowing limit. This outcome may occur simply because the firm uses a combination of prioritized financing tools to achieve desirable investment and employment levels. Another possibility is that the firm cannot achieve the desired investment and employment with internal funds alone, but does not issue new debt, because the high cost of external funds is not worth the further investment or employment. Alternatively, the firm predicts severe financial distress in the future, and currently saves as much as possible.[9] In any case, firms' investment or employment would expand if additional cash flows or cash holdings were available. We call this regime "weak financial constraints."

In this regime, physical investment, R&D investment, and employment are constrained by the availability of the firm's internal funds. Note that the weights, $(1+\lambda_{t+1})/(1+\lambda_t)$, that cause the distortion are the same across the three Euler equations, but the degree of investment or employment deviation from the desired level varies depending on marginal conditions.[10] The low physical investment could be caused by the allocation of limited internal funds across investment and employment.

Regime 3. $\boldsymbol{D_t = 0,\ B^*_{t+1} = B_{t+1}}$ **(Strict Financial Constraints)**

In this regime, the firm again exhausts its net revenues to finance its investment and employment but has sufficiently attractive investment and employment opportunities remaining, even considering that borrowing is more costly. Borrowing to the maximum level in this period means that the firm cannot issue new debt in the future without repayment; however, the firm finds it optimal to borrow as much as it can. The financial crisis may be categorized into this regime, for example, as the upper bound is significantly lowered. In this case, in addition to the availability

[9] In other words, the firm increases the size of negative NB_t until $D_t = 0$ in Equation (2).

[10] In this regime, Equation (10) indicates that the relative shadow costs of internal finance in the next period to those in the current period are equal to the ratio of (gross) debt interest rate to the required rate of return. If the required rate of return and the debt interest rate are the same (this assumption is natural in Regime 1, at least, in the long run), the shadow costs λ are adjusted to be equal in two consecutive periods. In this case, Euler equations in this regime are indistinguishable from the no-financial-constraint regime. For this regime to be meaningful, the interest rate on debt should be higher than the required rate of return, in which case the shadow costs of internal finance is time dependent. In fact, Whited and Wu (2006) use the estimated value of λ as a financing constraint index.

of internal funds, additional availability of new debt issues affects investment and employment activity. As Equation (10) indicates, the Euler equations are affected by debt outstanding through λ. We call this regime "strict financial constraints." In this regime, the firm allocates constrained external and internal funds across investments and employment according to marginal conditions, similar to the case of Regime 2.

Next, we show the relationship between the abovementioned three regimes and our estimation formula. In Regime 1, the investment and employment Euler equations (8)–(9) reduce to the basic form of those without financial constraints (i.e., $\lambda_t = \lambda_{t+1} = 0$). On the other hand, in Regimes 2 and 3, investment and employment are affected by the unobserved positive variables, λ_t and λ_{t+1}, and the basic Euler equations are misspecified. In these regimes, observable variables, such as cash flows, cash holdings, and new debt issues, affect the determination of investment and employment levels.

Many researchers derive non-linear investment Euler equations with financial constraints similar to Equations (8)–(9), and then linearize them with some model-dependent assumptions for estimation (e.g., Hall, 1995; Love, 2003; Brown et al., 2009; Hall and Lerner, 2010; Brown and Petersen, 2015). We follow this standard formula in the literature. For the determination of each of the production factors, we consider the following baseline empirical specifications that are often used in the literature, which is close to Brown and Petersen (2015).

$$\begin{aligned}CAP_{j,t} =& \beta_1^C CAP_{j,t-1} + \beta_2^C CAP_{j,t-1}^2 + \beta_3^C Sale_{j,t} + \beta_4^C Sale_{j,t-1} \\ &+ \beta_5^C CF_{j,t} + \beta_6^C CF_{j,t-1} + \beta_7^C \Delta CH_{j,t} + \beta_8^C \Delta CH_{j,t-1} \\ &+ \beta_9^C DebtIssue_{j,t} + \beta_{10}^C DebtIssue_{j,t-1} + d_t^C + f_j^C + \epsilon_{j,t}^C,\end{aligned} \tag{11}$$

$$\begin{aligned}RD_{j,t} =& \beta_1^R RD_{j,t-1} + \beta_2^R RD_{j,t-1}^2 + \beta_3^R Sale_{j,t} + \beta_4^R Sale_{j,t-1} \\ &+ \beta_5^R CF_{j,t} + \beta_6^R CF_{j,t-1} + \beta_7^R \Delta CH_{j,t} + \beta_8^R \Delta CH_{j,t-1} \\ &+ \beta_9^R DebtIssue_{j,t} + \beta_{10}^R DebtIssue_{j,t-1} + d_t^R + f_j^R + \epsilon_{j,t}^R,\end{aligned} \tag{12}$$

$$
\begin{aligned}
EMP_{j,t} =& \beta_1^E EMP_{j,t-1} + \beta_2^E EMP_{j,t-1}^2 + \beta_3^E Sale_{j,t} + \beta_4^E Sale_{j,t-1} + \zeta_1 Wage_{j,t} + \zeta_2 Wage_{j,t-1} \\
&+ \beta_5^E CF_{j,t} + \beta_6^E CF_{j,t-1} + \beta_7^E \Delta CH_{j,t} + \beta_8^E \Delta CH_{j,t-1} \\
&+ \beta_9^E DebtIssue_{j,t} + \beta_{10}^E DebtIssue_{j,t-1} + d_t^E + f_j^E + \epsilon_{j,t}^E,
\end{aligned} \tag{13}
$$

The subscripts t and j of each variable are indexes of year and individual firm, respectively. The term CAP is the amount of physical investment, and RD is the amount of R&D investment. Investment equations (11) and (12) have symmetrical functional forms. A proxy variable for a firm's output is sales amount, *Sale*. The term EMP is the net employment change (net hiring), and employment equation (13) additionally includes wages per capita, *Wage*. All variables are normalized by the beginning-of-the-period stock of total assets in both Equations (11) and (12). In Equation (13), EMP is normalized by the beginning-of-the-period number of workers, while other variables except *Wage* are the same as those in (11) and (12).[11]

The Euler equations in the no-financial-constraint regime are explained by only real variables, and the financing variables described later in this subsection do not appear in these equations. In other words, the model structure suggests that current and lagged finance variables do not appear in an estimation equation merely because they represent expected future profitability. This implication is the essence of the Euler-equation approach (Bond et al., 2003; Brown et al., 2009).

The Euler equations can be expressed in a linear form under some reasonable assumptions. The assumptions for linearization vary across studies, which may affect the interpretation of the coefficients in the estimation equations, but do not make essential differences. Here, we obtain some implications of the parameters from the following settings. First, we assume that the production function F has a Cobb–Douglas form, $F(\mathbb{K}_{t+1}, N_{t+1}) = AK_{1,t+1}^{\alpha_1} K_{2,t+1}^{\alpha_2} N_{t+1}^{\delta}$, where $\delta = 1 - \alpha_1 - \alpha_2$. Second, the adjustment cost functions ψ_i and ϕ have symmetric quadratic

[11] This normalization deviates from the specification of the derived Euler equation, where the variables are deflated by the stock amounts corresponding to each type of investment (see the appendix). However, such normalization is widely adopted in the field of estimating investment functions based on Euler equations, such as Brown and Petersen (2015). One reason, related to R&D, is that it is difficult to measure the R&D stock owing to the absence of a long-term time series of R&D expenditure and the difficulty of estimating the depletion rate of R&D (Brown et al., 2009). Another reason is that the existence of firms with very small physical capital stock may make the estimation results unstable, and deflating stock variables by the same deflator may reduce heteroscedasticity (Whited and Wu, 2006).

forms, $\psi_i(I_{it}, K_{i,t+1}) = (a_i/2)(I_{it}/K_{i,t+1} - b_i)^2 K_{i,t+1}$ for $i = 1, 2$, and $\phi(H_t, N_{t+1}) = (c/2)(H_t/N_{t+1} - g)^2 N_{t+1}$. Subsequently, as shown in the appendix, the current period's investment is expressed as a linear function of the lagged values of investment, its square, and output. The current period's hiring is a linear function of the lagged values of hiring, its square, output, and real wages. In the no-financial-constraint regime, this functional form should hold, and other finance variables have no effects.

The appendix shows that the Euler equations with no financial constraint suggest the signs or sizes of some coefficients in reduced-form equations (11)–(13). We can show that β_1^k $(k = C, R, E)$ corresponds to the gross real required rate of return, and β_2^k is the negative half of that rate. Thus, $\beta_1^k > 1$ and $\beta_2^k < 0$ are expected. The coefficient of lagged output is shown to be the negative value of the product of the gross real required rate of return and some positive structural parameters; thus, $\beta_4^k \leq 0$. In the hiring equation, the coefficient of lagged wages is the product of some positive structural parameters; thus, $\zeta_2 \geq 0$. In the quadratic adjustment cost function, the size of adjustment costs is represented by the structural parameter a_i or c. Although we do not estimate these parameters directly, the estimated coefficient of the reduced-form equation indicates the size of the adjustment cost. In other words, the coefficient β_4^k or ζ_2 reflects a_j or c, and the absolute value of the coefficient is smaller as the size of the adjustment cost increases. The remaining coefficients should be zero in the no-financial-constraint regime if the model holds.

We also include current output in each equation and current real wages in (13) to allow a more general lag structure of production. The lag structure of the underlying Euler equation is often extended to avoid an estimation equation being too strongly dependent on the assumptions of a particular model. From the same perspective, we do not rigorously check the constraints in the coefficients just examined, but rather focus on the sign conditions that might hold if the non-essential assumptions of the model change.

In the weak and strict financial-constraint regimes, finance variables influence the Euler equations through a shadow cost of internal finance λ. Since λ is unobservable, several studies (e.g., Whited, 1992) assume that it is a linear function of observable firm characteristics, especially financial conditions. Instead of directly estimating the non-linear equation with λ function assigned, Brown and Petersen (2015) add variables that may affect financial constraints in a linear form to the estimation equations.[12] Based on the model in Subsection 3.1, we add current and lagged values of cash flows (CF), changes in cash holdings (ΔCH), and funds from new debt issues ($DebtIssue$) to the Euler equation with no financial constraint.

In the strict financial-constraint regime, it is expected that investment and employment are positively correlated to cash flows and debt issues, since relaxing those constraints means adding available funding. Conversely, investment and employment are expected to correlate negatively to the changes in cash holdings. The negative correlation reflects funding for investment and employment through the release of cash holdings. On the other hand, in the weak financial-constraint regime, as the firm can issue additional debt if it so desires, finance variables related to debt issuance do not influence its investment or employment decisions. Only cash flows and changes in cash holdings matter. By testing the empirical significance of these variables, we can identify which regime the firms are in.

Finally, the variables d_t^k and f_j^k capture a time-specific effect and a firm-specific effect, respectively, in each equation.

4 Data and Summary Statistics

4.1 Data source and sample selection

We use data from the BSBSA conducted by the METI. The BSBSA is an annual survey that contains data on the diversification, globalization, and informatization of Japanese firms, and it is generally used by the METI to inform its economic policy-making. The survey's scope covers firms with 50 or more employees and paid-up capital or investment of more than 30 million yen. The industries covered include mining, manufacturing, wholesale and retail trade, food services, and many other service industries. The survey collects basic corporate finance data and detailed information on various business activities, such as R&D and overseas promotions. All targeted firms receive a questionnaire from the METI and report the data for the most recent fiscal year. Although the BSBSA does not include data from micro-enterprises, it includes a large range of firms and has a large sample size. The collection rate is high (e.g., 84.3% in 2016) and the size of the cross-sectional samples ranges from 25,000 to 30,000 firms every year.

[12]This treatment is interpreted as a linear approximation of the non-linear terms around their stationary solutions, as in Love (2003) and Gilchrist and Himmelberg (1998).

Table 1: Sample selection

	Observations excluded	Remaining observations
Original sample		572,708
Outliers	6,269	566,439
CAP, R&D, EMP are missing or zero	449,537	116,902
CAP, R&D, SALE, ASSET ≤ 0	0	116,902
Sales growth ≥ 100	473	116,429
5 years' continuous data	16,596	99,833
Missing lagged variables	26,520	73,313

Notes. "CAP," "R&D," "EMP," "SALE," and "ASSET" mean physical investment, R&D investment, net increase in number of employees, sales amount, and total asset amount, respectively. "Outliers" excludes the 1% tails in all key variables. The category "CAP, R&D, EMP are missing or zero" drops the observations that report missing data or zero values for these variables. The category "5 years' continuous data" requires firms to have at least 5 continuous years of observations. Finally, the category "Missing lagged variables" excludes observations that do not have the lagged values necessary to estimate the dynamic Euler equations.

We construct an unbalanced panel using the BSBSA data from 1994 to 2014. We focus on manufacturing and non-manufacturing firms except those from primary, regulated, and financial industries. Our measure of physical investment is the purchase of tangible fixed assets, and that of R&D investment is the sum of own and outsourced R&D expenses. Employment is defined as the net increase in employment stock. Employment stock corresponds to the total number of paid officers. Here, the paid officers are defined by regular and non-regular employees with employment contracts that exceed 1 month, or those employees who worked for 18 days or more in the last 2 months of the fiscal year.

We select the sample based on the following criteria. (1) We trim outliers in all key variables at the 1% level. (2) We focus on firms engaged in all activities, including physical investment, R&D investment, and employment. (3) We drop any firm-year observations if physical investment, R&D investment, sales, or total assets are negative, or if sales growth is greater than 100%. (4) We require firms to have at least 5 years of continuous observations. (5) We eliminate any firm-year observations whose 1-year lagged values of physical investment, R&D investment, or employment are missing. After imposing these restrictions, the sample consists of 8,821 firms with 73,313 firm-year observations. To the best of our knowledge, this sample size is the largest among studies that investigate the relationships between firms' real economic activities and their financial constraints.

Table 2: Firm count by industry

Industry	Industry code	Firm count	Observation	Share (%)
Food and beverages	5	876	7,578	10.3
Textile	6	211	1,654	2.3
Pulp and paper	7	137	1,182	1.6
Chemicals	8	895	8,487	11.6
Petroleum and petroleum products	9	396	3,572	4.9
Pottery and glass	10	275	2,459	3.4
Steel	11	156	1,531	2.1
Non-ferrous metals	12	204	1,800	2.5
Fabricated metals	13	502	4,142	5.6
Machinery	14	1,040	8,613	11.7
Electrical machinery	15	1,170	9,436	12.9
Transportation equipment	16	586	5,687	7.8
Instruments	17	274	2,073	2.8
Wood and furniture	19,20	115	951	1.3
Printing and publishing	21	93	811	1.1
Leather and rubber	22,23	113	972	1.3
Other manufacturing	24	186	1,552	2.1
Wholesale and retail trade	28,29	1,062	7,538	10.3
Information and communications	34,35,36	66	363	0.5
Business services	38	153	925	1.3
Non-business services	39	298	1,850	2.5
Other services	32,37	13	137	0.2
Full sample	All	8,821	73,313	100.0

Notes. As the BSBSA determines the firm's industry by its major sales product, the firm's industry has changed over time. We adopt the industry from the first time that the firm entered the database. The industry code in this table describes the number of minor industries reported in Japan's National Accounts in 2014.

Table 1 depicts the change of the samples in each step. The second criterion that the firm engages in all activities decreases the sample size sharply with approximately 450,000 observations deleted. Most of these observations report no R&D or zero R&D data. The fraction of the aggregate R&D investment explained by the deleted observations is relatively small (about 33% of the original sample). Furthermore, we calculate the average size of capital and R&D investment for the deleted observations and find that this value is much less than that of our sample: the expenditure of capital investment amounts to only about 25% of our sample, while that of R&D is only about 7% of our sample.

Table 2 presents the industrial distribution of 8,821 firms in our sample. The top five industry groups with the biggest share are electrical machinery, wholesale

Table 3: Summary statistics for benchmark sample

Industry	Physical Investment	Share	R&D Investment	Share	Employ-ment Stock	Share
Food & beverages	1,260	6.6	425	2.5	28.1	8.2
Textile	661	0.8	431	0.5	3.6	1.0
Pulp & paper	3,054	2.5	315	0.3	4.3	1.2
Chemicals	2,249	13.2	2,168	14.1	30.6	8.9
Petroleum & petroleum products	1,658	4.1	556	1.5	10.8	3.1
Pottery & glass	1,197	2.0	389	0.7	4.3	1.2
Steel	5,419	5.7	1,129	1.3	9.7	2.8
Non-ferrous metals	2,189	2.7	1,079	1.5	7.3	2.1
Fabricated metals	886	2.5	300	1.0	11.7	3.4
Machinery	1,221	7.3	1,226	8.1	29.7	8.6
Electrical machinery	3,146	20.5	4,396	31.8	47.9	13.9
Transportation equipment	4,616	18.2	5,696	24.9	63.0	18.3
Instruments	836	1.2	1,166	1.9	6.9	2.0
Wood & furniture	592	0.4	171	0.1	2.6	0.8
Printing & publishing	3,723	2.1	1,033	0.6	4.2	1.2
Leather & rubber	2,699	1.8	2,258	1.7	5.0	1.5
Other manufacturing	789	0.8	1,008	1.2	3.8	1.1
Wholesale & retail trade	1,057	5.5	819	4.7	29.9	8.7
Information & communications	1,208	0.3	311	0.1	6.0	1.7
Business services	1,381	0.9	504	0.4	9.3	2.7
Non-business services	510	0.7	704	1.0	23.7	6.9
Other services	889	0.1	215	0.0	1.7	0.5
Full sample	1,971	100.0	1,777	100.0	344.1	100.0

Notes. Each value in the columns of physical investment and R&D investment shows the average of the corresponding variable in each industry. The column headed "Share" refers to the fraction of the corresponding variable in the full sample (unit is percent). All monetary values are nominal and in units of million yen. The number of employees is measured at the end of 2014 and is in units of 10,000 people.

and retail trade, machinery, chemicals, and food and beverages. Most of the observations fall into main high-tech industries in Japan. This sample characteristic is highly dependent on our sample selection, which drops non-R&D or zero R&D data.

4.2 Summary statistics

Table 3 reports summary statistics of our main economic variables, physical investment, R&D investment, and employment stock, from 1996 to 2014. Each entry is the average or the share of the corresponding variable in our benchmark sample.

Table 3 shows that the sizes of physical investment and R&D investment are

Table 4: Sample characteristics by year (1996–2014)

Year	CAP	RD	EMP	CF	ΔCH	$DebtIssue$
1996	0.050	0.0206	−0.002	0.056	0.019	0.013
1997	0.051	0.0206	−0.0002	0.053	0.005	0.003
1998	0.044	0.0200	−0.023	0.045	−0.022	−0.022
1999	0.039	0.0201	−0.017	0.049	0.014	0.004
2000	0.041	0.0199	−0.011	0.050	0.017	0.018
2001	0.038	0.0185	−0.028	0.040	−0.031	−0.029
2002	0.033	0.0188	−0.016	0.046	−0.004	−0.016
2003	0.035	0.0195	0.0001	0.053	0.018	0.003
2004	0.039	0.0198	0.006	0.058	0.021	0.005
2005	0.041	0.0195	0.013	0.060	0.024	0.012
2006	0.044	0.0199	0.017	0.061	0.030	0.021
2007	0.042	0.0191	0.019	0.060	0.008	−0.005
2008	0.040	0.0188	0.007	0.044	−0.030	−0.026
2009	0.029	0.0183	−0.002	0.046	−0.0003	−0.013
2010	0.032	0.0178	0.005	0.058	0.022	0.002
2011	0.033	0.0178	0.002	0.056	0.026	0.010
2012	0.035	0.0182	0.001	0.057	0.003	−0.007
2013	0.036	0.0184	0.005	0.061	0.022	0.010
2014	0.038	0.0182	0.007	0.062	0.025	0.012
Average	0.039	0.0191	−0.001	0.053	0.009	−0.0003

Notes. Each entry refers to the average value of key variables in the estimation equation (Equations (11)–(13)).

relatively large in high-tech industries, such as transportation equipment, electrical machinery, chemicals, and machinery. In the previous subsection, we confirm that the category of wholesale and retail trade has a large number of observations, while Table 3 shows that the sizes of physical investment and R&D investment in this group are not as large as those of other industries. Meanwhile, employment stock shows a slightly different aspect. In addition to wholesale and retail trade, service industries, such as business and non-business services, have a large share of employees. There are about 650,000 workers employed in these industries or 20% of all observations. Finally, comparing the mean of physical investment and R&D investment in the full sample shows that both investment types are of similar size (nearly 2 billion yen).

Table 4 reports the mean of the key variables used in the estimation for each year. These regression variables are as follows. First, CAP and RD are the same as described in Subsection 4. Second, EMP is calculated by the net increase in employment stock (i.e., number of employees) during period t scaled by employment stock at the beginning of period t. Variables CF, ΔCH, and $DebtIssue$ are financing variables. We construct CF as the sum of after-tax income and depreciation, ΔCH as the net increase in liquidity assets during period t, and $DebtIssue$ as the increase in total debt during period t, whose values are all scaled by the beginning of period t total assets.

Table 4 provides the following three findings. (1) Consistent with the literature, RD shows significantly stable movements in these 20 years, but CAP shows very volatile movements. Specifically, the difference between high and low values of the RD investment rate is approximately 0.003, while that of CAP is 0.022. (2) EMP declined at the end of the 1990s, the so-called "job seekers' ice age" in Japan, but recovered after 2003 and showed stable movements thereafter. (3) The financing variables CF, ΔCH, and $DebtIssue$ worsened in 1998, 2001, and 2008; these years coincide with the Japanese financial crises reported by the Economic and Social Research Institute of the Cabinet Office in Japan.

5 Estimation and results

5.1 Estimation method

We estimate Equations (11)–(13) by using the system generalized method of moments (GMM) approach developed by Arellano and Bover (1995) and Blundell and Bond (1998). We estimate each of the equations by both differences and levels, using lagged levels as instruments for differences, and lagged differences as instruments for levels. We calculate two-step GMM estimates using lagged levels dated $t-3$ and $t-4$ as instruments for differences and lagged differences dated $t-2$ for levels.[13] In the two-step GMM, the standard covariance matrix yields downward bias in a small sample. To correct this bias, we calculate Windmeijer's (2005) suggested covariance matrix.[14]

Our estimation method largely depends on the validity of the assumption that the lagged values used as instruments are not correlated with the expectation er-

[13] We follow the recommendations of Roodman (2009), who addresses the problem of too many instruments. One suggestion is to limit the lag depth, and the other is to collapse the instrument set. A combination of these two techniques makes the instrument count invariant to T, the end of the estimation period.

[14] Our estimation uses the xtabond2 command of Stata.

rors. To assess this instrument validity, we report Hansen J-test statistics with the null that the over-identifying restrictions are valid. Furthermore, we report difference-in-Hansen test statistics to check the validity of the instruments for the regression in levels. Finally, to check the validity of the dynamic panel estimation setting, we report m1 and m2 statistics for first- and second-order autocorrelation for the first-differenced residuals.

5.2 Main results

Table 5 expresses the estimation results of Equations (11)–(13). We use the full sample and report the result for each adjustment of production factors: physical investment (CAP), R&D investment (RD), and employment (EMP).

Before examining the coefficients of each parameter, we first assess the test statistics to check the validity of our estimation method. Since both the Hansen and difference-in-Hansen test statistics do not reject the null, the lagged instrumental variables we use can be considered as exogenous. Next, m1 statistics clearly reject the null that the residuals of the first differences are serially uncorrelated with order 1 while m2 statistics do not reject the null that these residuals are serially uncorrelated with order 2. Thus, we can consider that our dynamic panel estimation setting is valid.

Next, we discuss the key estimation results. First, we check the estimation results for the coefficients of the lagged dependent variable and its square in the physical and R&D investment regressions. The coefficients of the lagged dependent variables in both equations are significantly different from 0 at the 5% level. The point estimates of both coefficients are positive and slightly less than 1. According to the model in Section 3, the coefficient of the lagged dependent variable corresponds to the gross real required rate of return and should be more than 1. Although the point estimates do not satisfy this condition, the 95% confidence interval includes values slightly over 1. Meanwhile, the coefficients of the squares of the lagged dependent variables in both equations are significant at the 5% level and negative, as the model suggests. However, the size of their absolute values largely exceeds those suggested by the model, that is, half the coefficient of the lagged dependent variable. The reason could be that the adjustment cost functions do not have monotonous curvatures and might not be captured accurately by a quadratic function. These estimation results do not strictly satisfy the coefficient constraints

Table 5: Baseline estimation

Dependent variable	*CAP*	*RD*	*EMP*
Lagged	0.808^{**}	0.931^{***}	0.053
	[0.350]	[0.093]	[0.321]
Lagged^2	-2.846^{**}	-2.100^{**}	-1.103
	[1.367]	[1.005]	[0.994]
Sale	0.191^{**}	0.043^{*}	0.208
	[0.083]	[0.022]	[0.233]
$Sale(-1)$	-0.167^{**}	-0.040^{**}	-0.151
	[0.070]	[0.019]	[0.203]
Wage	-	-	-0.069
	-	-	[0.055]
$Wage(-1)$	-	-	0.052
	-	-	[0.040]
CF	0.278	0.129	3.495^{***}
	[0.426]	[0.117]	[1.198]
$CF(-1)$	0.172	-0.012	-1.674^{*}
	[0.409]	[0.099]	[0.872]
ΔCH	-0.581^{*}	-0.156^{**}	-1.690^{**}
	[0.299]	[0.072]	[0.862]
$\Delta CH(-1)$	0.079	0.025	0.045
	[0.214]	[0.036]	[0.353]
DebtIssue	0.242	0.044	0.845
	[0.250]	[0.077]	[0.643]
$DebtIssue(-1)$	-0.009	-0.018	-0.145
	[0.269]	[0.051]	[0.421]
m1	-3.99^{***}	-4.61^{***}	-3.17^{***}
m2	0.02	1.59	1.04
Hansen J-test (p-value)	0.575	0.901	0.931
Diff-in-Hansen test (p-value)	0.360	0.807	0.861
Obs	73,313	73,313	73,313
Firms	8,821	8,821	8,821
Sum *CF*s	0.451^{*}	0.116^{**}	1.821^{***}
Chi-squared test (p-value)	0.096	0.031	0.005
Sum ΔCHs	-0.502	-0.130^{*}	-1.645^{**}
Chi-squared test (p-value)	0.213	0.087	0.047
Sum *DebtIssue*s	0.234	0.026	0.700
Chi-squared test (p-value)	0.525	0.721	0.255

*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$

Notes. The table shows the estimates of Equations (11)– (13). Estimation is by system GMM with lagged levels dated $t-3$ and $t-4$ used as instruments for differences, and lagged differences dated $t-2$ used as instruments for levels. The regression sample is the full sample in Table 3. Robust standard errors are reported in brackets. The term (-1) means the lag for one period. *Lagged* means the one-period lagged dependent variable in each equation, that is, $CAP(-1)$, $RD(-1)$ or $EMP(-1)$. The variable *Sale* is the amount of sales divided by the beginning-of-period total assets and the variable *Wage* is wage per capita defined as the ratio of total annual salary payment to the end-of-period number of employees.

of the background Euler equations. However, as shown in the process of deriving estimable equations in Subsection 3.2, our estimation equations deviate from the underlying Euler equations from some practical points of view. Considering this, we conclude that our assumption regarding the adjustment cost functions of both types of investment are satisfactory overall.

Second, for the employment regression, we do not reject that both coefficients of the lagged dependent variable and its square are 0 at the usual significance level. A straightforward interpretation of this result is that employment does not require any adjustment costs. Since non-regular workers are considered to be hired or dismissed with small costs, marginal employment adjustments can be made with few costs with these workers in the normal business cycle. This interpretation is consistent with the widely accepted understanding in Japan that firms use non-regular labor as an adjustment margin. However, it should be noted that employment did not dramatically decrease even in the financial crisis period, as shown in Figure 2. This, in turn, suggests that when the reduction of the non-regular employment stock with low adjustment costs reaches the limit, it is difficult to dismiss regular employees, as dismissal incurs extremely high adjustment costs. If there are two types of workers with different adjustment costs, the employment adjustment cost function is discontinuous and cannot be captured by the symmetric convex function, as we assume.

Third, the coefficient of lagged sales is negative, as the model suggests, and significant for physical and R&D investment. The size of the coefficient of lagged sales in the physical investment equation is larger than that of the corresponding coefficient in the R&D equation. This finding suggests that the size of the adjustment costs of physical capital is smaller than that of R&D capital. However, current sales are positively significant for these two investment types, which is not what the model suggests directly. In reality, the effect of sales on investment is not discrete but occurs continuously from the previous to the current period. The inverse sign of the coefficient of current sales may reflects the complex process in which sales are reflected in the profit and then influence investment. The coefficients of lagged sales and lagged wages are insignificant, which again suggests misspecification of the quadratic form of the employment adjustment cost function.

Fourth, the coefficients on finance variables CF, ΔCH, and $DebtIssue$ impact investment and employment. For the investment equations, the coefficients on the variable CF or $CF(-1)$ are insignificant. For the employment equation, CF is significant at the 1% level and positive, and $CF(-1)$ is significant at the 10% level and negative. The results of the chi-square test show that for all equations, the total effect of current and lagged cash flow is positive and statistically significant at least at the 10% level. The coefficients of ΔCH are significantly estimated at the 5% or 10% levels for all equations and are all negative, and the total effects of current and lagged changes in cash holdings are significant and negative for R&D and employment equations. Finally, we find that the estimated coefficients of $DebtIssue$ and $DebtIssue(-1)$ are insignificant for all equations, and the total effects of these variables are also not significant.

We interpret the abovementioned results regarding finance variables in the following way. (1) Debt issues have no impact on investment or employment. Additional debt has no direct relationship to both investment and employment decisions, indicating that firms do not face strict financial constraints. (2) Increases in cash flows have a positive effect on investment and employment over time. A cash-flow increase means there are additional internal funds available, which ease investment and employment constraints. Therefore, we understand that firms are in the regime of weak financial constraints. They prefer internal to external finance, the former being constrained, to accommodate investment and employment. (3) The negative coefficient of changes in cash holdings suggests that firms use internal savings to increase investment and employment, resulting in a decrease in their internal cash reserves. However, it is worth noting that the significance levels of both coefficients of cash flows and changes in cash holdings are low in the physical investment equation. In other words, the firm may allocate its internal funds to buffer its R&D investment and employment from the financial constraints rather than protecting physical investment. This finding is consistent with that of Brown and Petersen (2015) on physical and R&D investment. We also find that Japanese firms may protect their employees as well as their R&D investment at the expense of physical investment.

When considering intra-firm fund allocation, it should be noted that in the Euler equations under financial constraints (8) and (9), terms in the next period are weighted *equally* by the relative shadow cost of internal finance. However, the elasticities of investment or hiring to internal funding differ, since marginal productivity and marginal adjustment costs vary among those variables. While the additional funds are allocated more to factors with greater marginal productivity, factors with high marginal adjustment costs require more additional funds for smoothing. Brown and Petersen (2015) refer to large adjustment costs of R&D as the cause of the firm's buffering of R&D investment. The authors argue that R&D expenditure consists mainly of wage payments to scientists and engineers, and there are multiple types of adjustment costs associated with firing and rehiring these skilled workers. In Japan, this explanation is applied to regular workers generally, although the adjustment cost function of production workers might be discontinuous and asymmetric, as argued earlier in this subsection.

The estimation results in this subsection lead to the following implications regarding the recent slump in physical investment in Japan. Convex adjustment costs are marginally greater for R&D investment than for physical investment . In addition, employment incurs discontinuously high marginal adjustment costs. These factors concentrate stock adjustments on physical investment. This interpretation is consistent with the volatility of physical investment being greater than that of R&D investment and that of employment, as shown in Table 4 and Figure 2. However, the low adjustment costs alone are insufficient to explain why physical investment recovered more slowly than R&D investment did after the 2008 financial crisis. In addition, the decline in the average (or long-term) level of physical investment since the 1990s cannot be explained by its low adjustment costs. These facts have to do with the finding that Japanese firms have weak financial constraints. Under this circumstance, the firm has to allocate constrained internal funds among multiple stock types, and must spend additional funds on more marginally profitable production factors. Marginal profitability positively depends on marginal productivity and marginal savings in adjustment costs. Thus, the firm uses limited funds to keep high-productivity stock types stable, and to save money with low productivity and cheap adjustments. In other words, the results suggest that the stagnation of physical investment is a consequence of not only its low productivity but also financial constraints and the relatively high adjustment costs of R&D and employment stock. If there is no financial constraint, low investment is the result of the firm's optimizing behavior in a given market and technology environment. Conversely, the existence of financial constraints in fact means that not only physical investment but also R&D investment and employment are at sub-optimal levels. This is suggested as the reason for the high cost of external funds.

5.3 Sample splits by firm characteristics

In this subsection, we divide our sample into two groups that may have different characteristics regarding financial constraints. We separate our sample based on age, capital size, payout ratio (dividend paid to total assets), debt ratio (sum of short-term and long-term debt to total assets), and industry. Age, capital size, and industry may offer more attractive splitting criteria to sort firms because these variables are more exogenous than the other criteria. Although the payout ratio and the debt ratio are more endogenous, we include them in the criteria, since these ratios are considered as proxies for financial distress, which are closely related to our model implications.

To sort firms based on age or capital size, we first find the median value for these variables; then, we consider firms as young or small if their age or capital size, respectively, is lower than the median values. To sort firms based on the payout ratio or the debt ratio, we first calculate the payout ratio and the debt ratio for each firm. Subsequently, we consider firms as low-payout firms or low-debt firms if their average values are less than those of the median value. Finally, we categorize firms into two groups, manufacturing and non-manufacturing, based on the industry to which the firm belongs.

Table 6 describes the means and standard deviations by firm characteristics. First, young firms conduct more physical investment, while mature firms conduct more R&D investment. However, the means of both types of investment are close in value. On average, young firms reduce the number of employees and mature firms increase the number of employees, although the means are close to 0. Second, on average, large firms have more physical investment, R&D investment, and employment than small firms do, even with similar values of finance variables.[15] The difference between firm sizes is relatively large in R&D investment. Third, from the classification of finance variables, high-payout firms or low-debt firms tend to invest more in R&D capital and employment stock, with more cash flows or cash reserves obtained. However, the difference in mean is unclear for physical investment. Finally, from the industry classification, firms in the manufacturing sector conduct more capital and R&D investment, while firms in the non-manufacturing

[15]This characteristic of Japanese firms is also shown in Arikawa et al. (2011) and Sasaki (2016). However, in the US, it is well known that young firms conduct more physical and R&D investment. For example, Brown et al. (2009) show that fixed investment of young firms becomes one and a half times as large, while R&D investment becomes double that of mature firms.

Table 6: Descriptive statistics by firm characteristics

	Full	Young	Mature	Small	Large	Low payout	High payout	High debt	Low debt	Mfg.	Non-mfg.
RD											
mean	0.0191	0.0190	0.0194	0.0157	0.0225	0.0155	0.0240	0.0164	0.0219	0.0201	0.0131
sd	0.022	0.023	0.022	0.020	0.024	0.019	0.024	0.020	0.024	0.023	0.019
CAP											
mean	0.039	0.041	0.037	0.036	0.041	0.038	0.040	0.039	0.038	0.041	0.025
sd	0.045	0.049	0.042	0.046	0.045	0.046	0.043	0.047	0.043	0.046	0.037
EMP											
mean	−0.001	−0.007	0.005	−0.002	−0.0002	−0.001	0.003	−0.004	0.001	−0.002	0.006
sd	0.086	0.081	0.091	0.088	0.085	0.085	0.083	0.091	0.081	0.086	0.089
CF											
mean	0.053	0.060	0.046	0.053	0.053	0.047	0.063	0.046	0.060	0.054	0.046
sd	0.048	0.051	0.043	0.046	0.050	0.045	0.047	0.047	0.047	0.048	0.047
ΔCH											
mean	0.009	0.014	0.004	0.011	0.007	0.008	0.013	0.006	0.012	0.009	0.011
sd	0.083	0.090	0.074	0.085	0.081	0.079	0.082	0.087	0.079	0.082	0.087
$DebtIssue$											
mean	−0.0002	0.001	−0.002	−0.0002	−0.0002	−0.0003	0.001	−0.0001	−0.0003	−0.0004	0.001
sd	0.085	0.093	0.076	0.088	0.082	0.084	0.080	0.094	0.075	0.085	0.086
Obs	73,313	37,495	35,818	36,099	37,214	29,766	29,794	36,668	36,645	62,966	10,347
Firms	8,821	5,156	3,665	4,896	3,925	3,346	2,978	4,772	4,049	7,229	1,592

Notes. Except for the grouping by payout ratio, the sum of firms becomes 8,821. The sum of firms in high and low payout ratio groups becomes 6,324, which suggests that about 2,500 firms are non-listed.

sector employ more workers, on average.

Table 7 shows the estimation results for the Euler equation (11)-(13) by firm characteristics. The upper panel of the table shows the result of the physical investment Euler equation, the middle panel shows that of the R&D investment, and the bottom panel shows that of employment. As suggested in Subsection 5.2, our main concern should be the state of financial constraints and their effects on investment and employment. Thus, we focus on the total effects of finance variables, that is, the sum of the coefficients of current and lagged finance variables, together with the p-values from the chi-squared test that the sum of the coefficients equals zero.

We first examine the significance of the sum of the debt issuance coefficients of all equations for all categories to observe whether firms in a category are under strict financial constraints. Except for the employment equation of firms with high debt ratios, the sum of the coefficients of the debt issues is insignificant in all cases, even at the 10% level. Therefore, in general, firms are not restricted by external funding. This finding is consistent with the result in Subsection 5.2.

Next, we examine the effects of internal finance variables. Table 7 shows that whether the coefficients of those variables are significantly estimated depends on

Table 7: Estimation results by sample splits

1: Physical investment regression by sample splits

	Age		Size		Payout		Debt		Industry	
	Young	Mature	Small	Large	Low	High	High	Low	Mfg..	Non-mfg.
CF	0.406	0.278	0.451	0.195	0.732	0.348	0.328	0.217	0.453	0.127
p-value	0.097	0.465	0.304	0.366	0.116	0.217	0.155	0.509	0.244	0.828
ΔCH	−0.479	−0.202	−0.334	−0.187	−0.864	−0.414	−0.345	0.026	−0.411	−0.147
p-value	0.121	0.730	0.552	0.503	0.111	0.296	0.263	0.957	0.443	0.804
DebtIssue	0.436	0.049	0.073	0.029	0.547	0.236	0.310	−0.267	0.130	0.200
p-value	0.150	0.923	0.881	0.904	0.304	0.551	0.243	0.619	0.786	0.756
m1	−5.09	−3.38	−3.11	−6.25	−1.62	−3.60	−3.04	−3.31	−4.09	−1.99
m2	0.62	0.30	0.51	0.17	0.11	−0.11	0.83	−1.08	0.16	1.11
Hansen J-test (p-value)	0.144	0.444	0.905	0.687	0.553	0.908	0.447	0.822	0.669	0.212
Diff-Hansen test (p-value)	0.080	0.725	0.771	0.582	0.476	0.768	0.333	0.634	0.481	0.117
Obs	37,495	35,818	36,099	37,214	29,766	29,794	36,668	36,645	62,966	10,347
Firms	5,156	3,665	4,896	3,925	3,346	2,978	4,772	4,049	7,229	1,592

2: R&D investment regression by sample splits

	Age		Size		Payout		Debt		Industry	
	Young	Mature	Small	Large	Low	High	High	Low	Mfg.	Non-mfg.
CF	0.067	0.071	0.154	0.097	0.181	0.099	0.041	-0.003	0.091	0.005
p-value	0.334	0.263	0.030	0.265	0.114	0.264	0.605	0.964	0.063	0.958
ΔCH	−0.048	−0.063	−0.158	−0.072	−0.221	−0.175	−0.060	0.018	−0.108	0.090
p-value	0.582	0.562	0.094	0.417	0.063	0.115	0.496	0.890	0.142	0.367
DebtIssue	−0.021	0.023	0.073	−0.007	0.079	0.146	0.062	−0.064	0.011	−0.108
p-value	0.802	0.830	0.352	0.900	0.320	0.180	0.407	0.707	0.871	0.430
m1	−5.14	−3.54	−4.34	−2.94	−2.29	−3.35	−2.16	−2.79	−5.21	−2.39
m2	1.31	1.46	1.73	1.90	0.98	1.10	1.55	1.280	2.17	0.63
Hansen J-test (p-value)	0.853	0.403	0.296	0.656	0.845	0.997	0.920	0.796	0.808	0.882
Diff-Hansen test (p-value)	0.707	0.807	0.149	0.444	0.846	0.989	0.832	0.624	0.852	0.753
Obs	37,495	35,818	36,099	37,214	29,766	29,794	36,668	36,645	62,966	10,347
Firms	5,156	3,665	4,896	3,925	3,346	2,978	4,772	4,049	7,229	1,592

3: Employment regression by sample splits

	Age		Size		Payout		Debt		Industry	
	Young	Mature	Small	Large	Low	High	High	Low	Mfg.	Non-mfg.
CF	1.843	0.612	1.132	0.690	0.640	1.243	2.180	0.436	1.300	1.530
p-value	0.034	0.476	0.091	0.141	0.464	0.028	0.021	0.281	0.028	0.260
ΔCH	−1.719	0.760	−0.946	−0.421	−0.187	−1.471	−2.174	−0.093	−1.261	−0.272
p-value	0.089	0.529	0.264	0.467	0.840	0.076	0.040	0.895	0.089	0.879
DebtIssue	1.311	−1.021	0.460	0.393	−0.645	0.647	1.347	0.241	0.451	−0.376
p-value	0.138	0.283	0.470	0.381	0.336	0.424	0.039	0.734	0.365	0.842
m1	−2.80	−1.51	−2.59	−2.10	−2.20	−1.46	−2.25	−2.93	−3.58	−1.36
m2	1.48	0.02	0.49	0.89	1.37	0.31	−0.09	1.44	1.29	−0.48
Hansen J-test (p-value)	0.970	0.942	0.196	0.096	0.981	0.938	0.728	0.845	0.457	0.994
Diff-Hansen test (p-value)	0.911	0.870	0.313	0.043	0.942	0.935	0.585	0.720	0.365	0.994
Obs	37,495	35,818	36,099	37,214	29,766	29,794	36,668	36,645	62,966	10,347
Firms	5,156	3,665	4,896	3,925	3,346	2,978	4,772	4,049	7,229	1,592

Notes. The top panel shows the result of the physical investment Euler equation, the middle panel shows that of the R&D investment Euler equation, and the bottom panel shows that of the employment Euler equation. Except for the grouping by payout ratio, the sum of firms in each group becomes 8,821. The sum of firms in the high and low payout ratio groups becomes 6,324, which suggests that about 2,500 firms are non-listed.

the firm characteristics. Comparing young and mature firms by Columns 1 and 2 in each panel of Table 7, we find that no coefficients of the internal (or external, as just mentioned) finance variables are significant for mature firms, indicating that they are not financially constrained. However, for young firms, cash flows and/or changes in cash holdings show significant effects at the 5% to 10% levels in the physical investment and employment equations. As debt issuance by young firms is not restricted, they are weakly financially constrained. These findings on young firms are in line with the baseline results in Subsection 5.2. However, unlike the baseline results, for young firms, internal finance variables affect physical investment and employment rather than R&D investment. Equipment and labor expansion may be more profitable than R&D during the growth stage of a firm. On the one hand, for the difference depending on firm size, Column 4 of Table 7 shows that there are no internal and external financial constraints among the large-scale firms. On the other hand, for small-scale firms, Column 3 reveals that internal finance affects both R&D investment and employment, which is similar to the scale-wide results in Subsection 5.2.

The results classified by financial status are shown in Columns 5 to 8 of Table 7. Cash holdings are used to sustain R&D investment in the low-payout firms while the high-payout firms use cash flows and cash holdings for employment (Columns 5 and 6, respectively). This finding is consistent with the interpretation in Subsection 5.2 that low-payout firms, which are considered to have relatively tight cash flows, preferentially use internal reserves for R&D investment. However, high-payout firms, not low-payout firms, use internal financing for employment. The reason is not clear, but it may be that a firm with relatively few investment opportunities returns profits to both shareholders and workers (to the latter, by employment protection). Columns 7 and 8 report the results when firms are classified by debt ratio. Employment in firms with high debt is affected by both internal and external finance. It is a convincing argument that firms with a high debt ratio are in the strict financial-constraint regime, and that this regime can be observed only when the debt-ratio splitting criterion is used. However, it is unclear why only employment stock suffers from financial constraints. It is possible that, in such firms, there are few opportunities for profitable physical and R&D investment and thus, only employment is affected by limited funds.

Finally, Column 9 of Table 7 shows that in the manufacturing sector, internal finance affects R&D investment and employment; these findings are similar to the industry-wide results in Subsection 5.2. Conversely, as shown in Column 10, in the non-manufacturing sector, no finance variables affect the changes in any factor stock types.

The main conclusions of the comparative analysis by firm attributes in this subsection are summarized as follows. (1) The financial-constraint regime varies across firm characteristics. As shown in the literature, for example, Brown and Petersen (2015), firms that are more likely to face financial constraints due to ex-ante criteria (i.e., young, small-sized, and manufacturing) indeed suffer from financial constraints, which are internal. (2) There are more significant coefficients of finance variables, and their significance levels are higher (p-values are smaller) roughly in the following order: employment, R&D investment, and physical investment. (3) Young, small-sized, and/or manufacturing firms tend to allocate their cash flows and cash holdings to buffering their R&D investment and employment rather than to protect their physical investment.

5.4 Financial crises and difference-in-difference estimation

In this subsection, we confirm whether financially constrained firms are more affected by their financial positions during crisis periods (e.g., the Asian financial crisis, the US dot-com bubble recession, and the 2008 global financial crisis) than non-crisis periods. During financial crises, both firms and banks seriously suffer because of their large decrease in operating incomes and damage to the balance sheet, which influence the firms' financial decisions through both the supply and demand channels. We investigate these effects by using the difference-in-difference estimation technique of Guney et al. (2017). Specifically, we construct a crisis dummy variable that takes the value one during the following periods: 1998–1999, 2001–2002, and 2008–2009. We then interact this dummy with the finance variables, such as cash flows, changes of cash holdings, and debt issues. The estimation methods are basically the same as those in Subsections 5.2 and 5.3.

Table 8 shows these results. We find that the point estimates for coefficients of regressors except finance variables take close values to those in Table 5 in the physical and the R&D investment equations. Similar to the result of Table 5, these coefficients are insignificant in the employment equation. Furthermore, most results for the sum of the coefficients of cash flows, changes in cash holdings, and debt issues are similar to those in Table 5.

Table 8: Difference-in-difference estimation for the effects of financial crises

Dependent variable	*CAP*		*RD*		*EMP*	
$INV(-1)$	0.751**	[0.346]	0.929***	[0.098]	0.301	[0.245]
$INV^2(-1)$	−2.311	[1.526]	−1.983*	[1.074]	0.311	[1.096]
$Sale$	0.119	[0.095]	0.014	[0.027]	0.079	[0.183]
$Sale(-1)$	−0.099	[0.095]	−0.015	[0.023]	−0.056	[0.159]
$Wage$	-	-	-	-	−0.014	[0.044]
$Wage(-1)$	-	-	-	-	0.008	[0.031]
CF	0.315	[0.573]	0.176	[0.142]	1.107	[1.229]
$CF(-1)$	−0.062	[0.708]	−0.062	[0.139]	0.350	[1.192]
$CF * Crisis$	−0.789	[1.694]	−0.078	[0.341]	3.601	[3.375]
$CF(-1) * Crisis$	0.769	[1.806]	0.086	[0.329]	−3.372	[3.263]
ΔCH	−0.210	[0.323]	−0.052	[0.074]	−0.524	[0.622]
$\Delta CH(-1)$	0.114	[0.274]	−0.011	[0.054]	−0.768	[0.517]
$\Delta CH * Crisis$	0.036	[0.757]	−0.248	[0.361]	−2.812	[2.463]
$\Delta CH(-1) * Crisis$	−0.272	[0.749]	0.068	[0.153]	1.482	[1.416]
$DebtIssue$	−0.012	[0.270]	0.011	[0.061]	0.191	[0.531]
$DebtIssue(-1)$	−0.105	[0.313]	0.016	[0.064]	0.846	[0.575]
$DebtIssue * Crisis$	0.084	[0.748]	0.202	[0.332]	2.437	[2.438]
$DebtIssue(-1) * Crisis$	0.378	[0.749]	−0.104	[0.207]	−1.857	[1.593]
m1	−4.74***		−2.05**		−2.30**	
m2	0.69		1.44		1.47	
Hansen J-test	0.325		0.878		0.653	
Diff-Hansen	0.324		0.788		0.506	
Obs	73313		73313		73313	
Firms	8821		8821		8821	
Sum CF (p-value)	0.252	(0.454)	0.114	(0.120)	1.456	(0.024)
Sum ΔCH (p-value)	−0.096	(0.854)	−0.063	(0.533)	−1.292	(0.103)
Sum $DebtIssue$ (p-value)	−0.117	(0.761)	0.027	(0.741)	1.036	(0.125)
Sum $CF * Crisis$ (p-value)	−0.020	(0.944)	0.008	(0.935)	0.229	(0.712)
Sum $\Delta CH * Crisis$ (p-value)	−0.235	(0.698)	−0.180	(0.555)	−1.330	(0.515)
Sum $DebtIssue * Crisis$ (p-value)	0.463	(0.408)	0.098	(0.657)	0.580	(0.757)

*** $p < 0.01$; ** $p < 0.05$; * $p < 0.1$

Notes. The table shows the estimates of (11) to (13) with the crisis dummies. A term with "$*Crisis$" indicates the cross-term of the relevant variable and the crisis dummy. Estimation is by system GMM with lagged levels dated $t-3$ and $t-4$ used as instruments for differences, and lagged differences dated $t-2$ used as instruments for levels. The regression sample is the full sample in Table 3. Robust standard errors are reported in brackets.

Despite these similarities, the significance of the estimates worsens, as shown in Table 8. This is because the coefficients of additional regressors are not significant. All the interaction terms between the crisis dummies and finance variables are insignificant, and their sums are also insignificant. This phenomenon is known as an over-specification problem (see Davidson and Mackinnon, 2004), in which regressors that do not belong in a true model generally increase the variance of the estimates on the regressors that do belong. We interpret this result as Japanese firms relying on their internal funds in the same way, that is, being weakly financially constrained, during both financial crisis and non-crisis periods.[16]

6 Conclusion

To reveal the major causes of the different behaviors of physical investment, R&D investment, and employment, we estimate the modified Euler equations for the determination of these production factors by using the microdata of Japanese firms. Our results have implications for the analysis of long-term slack physical investment from Japan's two lost decades and financial crises.

The main estimation results are summarized as follows. First, Japanese firms face weak financial constraints in the sense that borrowing amount is not restricted, but internal finance is not sufficient. Second, firms first allocate their cash flows and/or cash holdings to buffer employment, and then incur R&D investment rather than protecting physical investment. Third, the following reason for this internal financing order is suggested. The marginal profit from R&D investment or employment is larger than that from physical investment. Subsequently, this larger marginal profit of R&D investment or employment may stem from its larger productivity or larger adjustment cost savings. This reason is consistent with the greater stability and resilience observed for R&D and employment than that for physical investment in aggregate levels.

We also examine the differences in firms' decision making regarding physical investment, R&D investment, and employment among different firm characteristics and find several results, which are summarized as follows. First, firms that are more likely to face financial constraints due to ex-ante criteria (young, small-

[16]Note that the BSBSA data are annual, not quarterly, like those of, for example, Duchin et al. (2010). If we were able to use quarterly data, we might capture the impact of the financial crisis more accurately in a narrow timeframe. Such information losses may lead to our regression results, that the financial crisis dummies have less explanatory power.

sized, and manufacturing) indeed suffer from weak financial constraints. Second, a comparative analysis based on several characteristics of firms does not change the finding that firms subject to weak financial constraints prioritize the allocation of funds in the following order: employment, R&D investment, and physical investment.

Finally, we examine whether financial constraints are tighter during financial crisis periods (e.g., the Asian financial crisis, the US dot-com bubble recession, and the 2008 global financial crisis) than non-crisis periods. The results show that firms rely on internal funds and are not restricted by external funds even during the financial crises, in the same way as they are in normal times.

This study reveals several characteristics of the factor adjustment behavior of Japanese firms since the mid-1990s by the estimation of Euler equations based on firm microdata. The Euler equation approach provides insights based on structural parameters. These insights help to understand the weakness of Japanese physical investment in recent years. However, it should be mentioned that this study does not identify the structural parameters but infers them from the estimated reduced-form coefficients. This indirect method is commonly used in this field because the identifications of structural parameters are joint hypothesis tests with restrictive assumptions of the structural model, such as functional forms. We estimate reduced-form equations that seem slightly ad hoc but with a structural model as the background. Therefore, it is not possible to distinguish clearly between the productivity and the size of adjustment costs, which constitute factor profitability. In future research, we aim to identify the parameters of interest without imposing restrictive conditions as far as possible, and to confirm the insights found in this study.

In addition, we show that estimating and comparing multiple Euler equations of the production-factor stock yields quite different implications for financial constraints than just examining a single Euler equation. This fact may be relevant not only in Japan, but also in countries where employment adjustments are costly (e.g., European countries where trade unions have power).

Appendix

The Euler equation for investment $i \in \{1,2\}$ with no financial constraint is

$$P_{it} + P_t \left(\psi_{i,I_{it}} + \psi_{i,K_{i,t+1}}\right) = P_t F_{K_{i,t+1}} + E_t \left[\beta_{t,t+1}(P_{t+1}\psi_{i,I_{i,t+1}} + P_{i,t+1})\right], \tag{A1}$$

as explained in Subsection 3.1. To obtain the empirical specification, we assume the following forms of production and adjustment cost functions.

$$F(\mathbb{K}_{t+1}, N_{t+1}) = AK_{1,t+1}^{\alpha_1} K_{2,t+1}^{\alpha_2} N_{t+1}^{\delta}. \tag{A2}$$

$$\psi_i(I_{it}, K_{i,t+1}) = \frac{a_i}{2}\left(\frac{I_{it}}{K_{i,t+1}} - b_i\right)^2 K_{i,t+1}. \tag{A3}$$

Then, rearranging Equation (A1) and shifting time back by one period yields

$$\begin{aligned} &E_{t-1}\left[\beta_{t-1,t}\left\{P_t\left(\frac{I_{it}}{K_{i,t+1}} - b_i\right) + \frac{1}{a_i}P_{it}\right\}\right] \\ =& P_{t-1}\frac{I_{i,t-1}}{K_{it}} - \frac{1}{2}P_{t-1}\left(\frac{I_{i,t-1}}{K_{it}}\right)^2 - P_{t-1}\frac{\alpha_i}{a_i}\frac{Y_{t-1}}{K_{it}} + P_{t-1}\left(\frac{b_i^2}{2} - b_i\right) + \frac{1}{a_i}P_{i,t-1}, \end{aligned} \tag{A4}$$

where $Y_{t-1} = F(\mathbb{K}_t, N_t)$.

Linearly introducing the expectational errors realized at time t, ϵ_t, into (A4) yields

$$\begin{aligned} \frac{I_{it}}{K_{i,t+1}} =& z_{t-1,t}\frac{I_{i,t-1}}{K_{it}} - \frac{z_{t-1,t}}{2}\left(\frac{I_{i,t-1}}{K_{it}}\right)^2 - z_{t-1,t}\frac{\alpha_i}{a_i}\frac{Y_{t-1}}{K_{it}} \\ &- \frac{1}{a_i}z_{t-1,t}\left(\beta_{t-1,t}\frac{P_{it}}{P_{t-1}} - \frac{P_{i,t-1}}{P_{t-1}}\right) + z_{t-1,t}\left(\frac{b_i^2}{2} - b_i\right) + b_i + \epsilon_t, \end{aligned} \tag{A5}$$

where

$$z_{t-1,t} = \frac{1}{\beta_{t-1,t}}\frac{P_{t-1}}{P_t}, \tag{A6}$$

is the gross real required rate of return. Our basic Euler equations are close to those induced by Bond and Meghir (1994) with slightly different assumptions.

Assuming that the fourth and subsequent terms on the right-hand side of (A5) are included in the time-specific effect d and the firm-specific effect f, the basic

Euler equation for investment i is obtained as

$$\frac{I_{it}}{K_{i,t+1}} = z_{t-1,t}\frac{I_{i,t-1}}{K_{it}} - \left(\frac{z_{t-1,t}}{2}\right)\left(\frac{I_{i,t-1}}{K_{it}}\right)^2 - \left(\frac{\alpha_i z_{t-1,t}}{a_i}\right)\frac{Y_{t-1}}{K_{it}} + d_t^i + f_j^i + \epsilon_{jt}^i. \quad \text{(A7)}$$

In this derivation, we assume that the final goods market is perfectly competitive. However, the assumption of imperfect competition with the constant price-elasticity demand function of final goods, as in Bond and Meghir (1994), affects Equation (A7) only through the firm-specific effect, and the implications for the coefficients in our estimation equations do not change.

Similarly, we obtain the Euler equation for employment as

$$\begin{aligned}\frac{H_t}{N_{t+1}} &= z_{t-1,t}\frac{H_{t-1}}{N_t} - \left(\frac{z_{t-1,t}}{2}\right)\left(\frac{H_{t-1}}{N_t}\right)^2 - \left(\frac{\delta z_{t-1,t}}{c}\right)\frac{Y_{t-1}}{N_t} \\ &+ \left(\frac{z_{t-1,t}}{c}\right)\frac{W_{t-1}}{P_{t-1}} + d_j^E + f_t^E + \epsilon_{jt}^E. \quad \text{(A8)}\end{aligned}$$

where the labor adjustment cost function is $\phi(H_t, N_{t+1}) = (c/2)(H_t/N_{t+1} - g)^2 N_{t+1}$. We estimate the equations individually by system GMM without explicitly considering the coefficient constraints across these Euler equations.

References

[1] Arellano, M., & Bover, O. (1995) "Another look at the instrumental variable estimation of error-components models," Journal of Econometrics, 68, 29–51.

[2] Arikawa, Y., Kawanishi, T., & Miyajima, H. (2011) "Debt, ownership structure, and R&D investment: Evidence from Japan," RIETI Discussion Paper Series, 11-E-013.

[3] Blundell, R., & Bond, S. (1998) "Initial conditions and moment restrictions in dynamic panel data models," Journal of Econometrics, 87, 115–143.

[4] Bond, S., Elston, J. A., Mairesse, J., & Mulkay, B. (2003) "Financial factors and investment in Belgium, France, Germany, and the United Kingdom: A comparison using company panel data," Review of Economics and Statistics, 85, 153–165.

[5] Bond, S., & Meghir, C. (1994) "Dynamic investment models and the firm's financial policy," Review of Economic Studies, 61, 197–222.

[6] Brown, J. R., Fazzari, S. M., & Petersen, B. C. (2009) "Financing innovation and growth: Cash flow, external equity, and the 1990s R&D boom," Journal of Finance, 64, 151–185.

[7] Brown, J. R., & Petersen, B. C. (2015) "Which investments do firms protect? Liquidity management and real adjustments when access to finance falls sharply," Journal of Financial Intermediation, 24, 441–465.

[8] Davidson, R., & MacKinnon, J. G. (2004) "Econometric theory and methods (International edition)," Oxford University Press.

[9] Duchin, R., Ozbas, O., & Sensoy, B. A. (2010) "Costly external finance, corporate investment, and the subprime mortgage credit crisis," Journal of Financial Economics, 97, 418–435.

[10] Gilchrist, S., & Himmelberg, C. P. (1998) "Investment, fundamentals and Finance," in NBER Macroeconomic Annual, MIT Press, Cambridge, Mass. 223–274.

[11] Guney, Y., Karpuz, A., & Ozkan, N. (2017) "R&D investments and credit lines," Journal of Corporate Finance, 46, 261–283.

[12] Gutiérrez, G., & Philippon, T. (2017) "Investmentless growth: An empirical investigation," Brookings Papers on Economic Activity, 48, 89–190.

[13] Hall, B. H. (1995) "Firm investment with liquidity constraints: What can Euler equations tells us?" Working paper, UC Berkeley.

[14] Hall, B. H., & Lerner, J. (2010) "The financing of R&D and innovation," in Handbook of the Economics of Innovation, Vol. 1, North-Holland, 609–639.

[15] Love, I. (2003) "Financial development and financing constraints: International evidence from the structural investment model," Journal of Financial Intermediation, 24, 441–465.

[16] Nakamura, J. I. (2017) "Why does capital investment by Japanese firms remain sluggish? A reexamination from secular stagnation perspective," Economic Analysis, 193, 51–82.

[17] Roodman, D. (2009) "A note on the theme of too many instruments," Oxford Bulletin of Economics and Statistics, 71, 135–158.

[18] Sasaki, T. (2016) "Financial cash flows and research and development investment," Pacific-Basin Finance Journal, 39, 1–15.

[19] Whited, T. M. (1992) "Debt, liquidity constraints, and corporate investment: Evidence from panel data," Journal of Finance, 47, 1425–1460.

[20] Whited, T. M., & Wu, G. (2006) "Financial constraints risk," Review of Financial Studies, 19, 531–559.

[21] Windmeijer, F. (2005) "A finite sample correction for the variance of linear efficient two-step GMM estimators," Journal of Econometrics, 126, 25–51.