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Interest Rate Sensitivity of Capital Investment in Japan:
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Abstract

This paper examines the interest rate sensitivity of capital investment in Japan. We first summarize recent global trends using macro-level statistics from advanced economies. Using firm-level financial survey data for Japanese firms, we then demonstrate how structural changes surrounding Japanese firms, such as the increase in intangible asset investment and overseas capital investment, affect interest rate sensitivity, employing a method called Panel LP-IV (Local Projection Instrumental Variables). The analysis yields several key findings: first, the interest rate sensitivity of capital investment has shown a declining trend in recent years globally. Second, intangible asset investment has a low interest rate sensitivity; consequently, firms with a higher proportion of intangible assets in their aggregate capital investment are less sensitive to interest rate changes compared to firms with a lower proportion. Last but not least, declining growth expectations and increasing labor shortages can additionally depress interest rate sensitivity. While firms with a higher overseas investment ratio showed a lower interest rate sensitivity for tangible asset investment domestically compared to firms with a lower overseas investment ratio, this difference is not statistically significant.

JEL classification code: E22, E43, G31

Keywords: Capital investment, Interest rate sensitivity, Intangible assets, Overseas capital investment, Labor shortage, Growth expectations

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1. Introduction

Understanding the interest rate sensitivity of an economy—how a rise (or fall) in interest rates affects the behavior of economic agents and, consequently, how much economic variables like GDP change—is crucial for an economic assessment. In Japan, since the latter half of the 1990s, monetary policy has deviated from conventional nominal short-term interest rate operations, with nominal short-term interest rates remaining near zero for much of the period. This unconventional monetary policy ended in March 2024, after which Japan reverted to one that relies short-term interest rate operations.[1] In this context, re-examining interest rate sensitivity has become increasingly important.

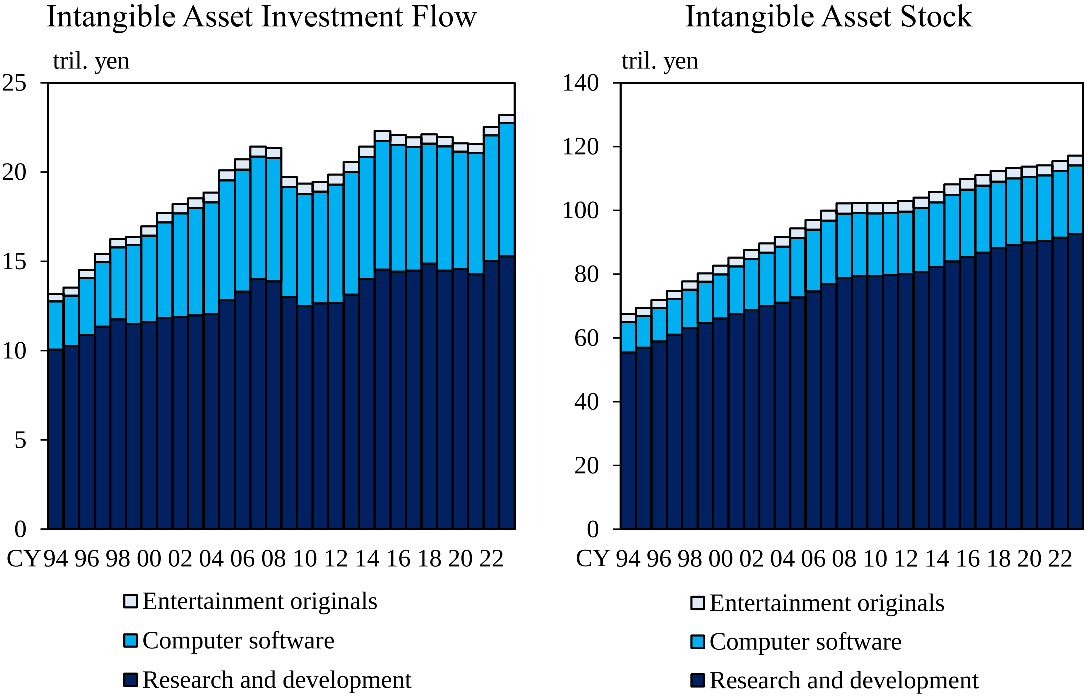
This paper focuses on the interest rate sensitivity of capital investment, a component of GDP by demand side. When firms undertake capital investment, they typically need to raise funds. Assuming inflation remains constant, such financing activities are thought to be negatively (positively) affected by rising (falling) interest rates. Therefore, examining the interest rate sensitivity of capital investment is important for forecasting investment trends. However, it is unlikely that the interest rate sensitivity of capital investment has remained constant over time, not only in Japan but also globally. Looking back over the past several decades, digitalization and the accompanying increase in intangible asset investment, for instance, changed the nature of capital investment compared to periods when tangible asset investment accounted for the majority of this investment.[2] Furthermore, Japan's business environment has been continuously evolving, with increased overseas expansion of business activities by Japanese firms and the progression of a declining birthrate and aging population.[3] This paper aims to explore the changes in interest rate sensitivity of capital investment and its underlying factors, focusing on these structural changes.

Reviewing existing literature, particularly in the U.S., there is a discussion that the interest rate sensitivity of capital investment has weakened, due to the increase in intangible assets such as software investment (Caggese and Pérez-Orive (2022), Döttling and Ratnovski (2023)). If the portion of capital investment that shows a smaller decline in response to interest rate hikes (i.e., low interest rate sensitivity) or the portion of capital investment that increases in response to interest rate hikes grows, due to the rise in the proportion of

[1] For a review of monetary policy during this period, refer to Bank of Japan (2024b).
[2] Corrado et al. (2022) comprehensively addresses how recent advancements in digitalization and the accompanying increase in intangible assets have influenced firms and the economy.
[3] For a comprehensive discussion of Japan's economic and price situation during this period, refer to Fukunaga et al. (2024).

intangible assets in total capital investment, the overall interest rate sensitivity of capital investment diminishes.

Figure 1: Intangible Asset Investment in Japan

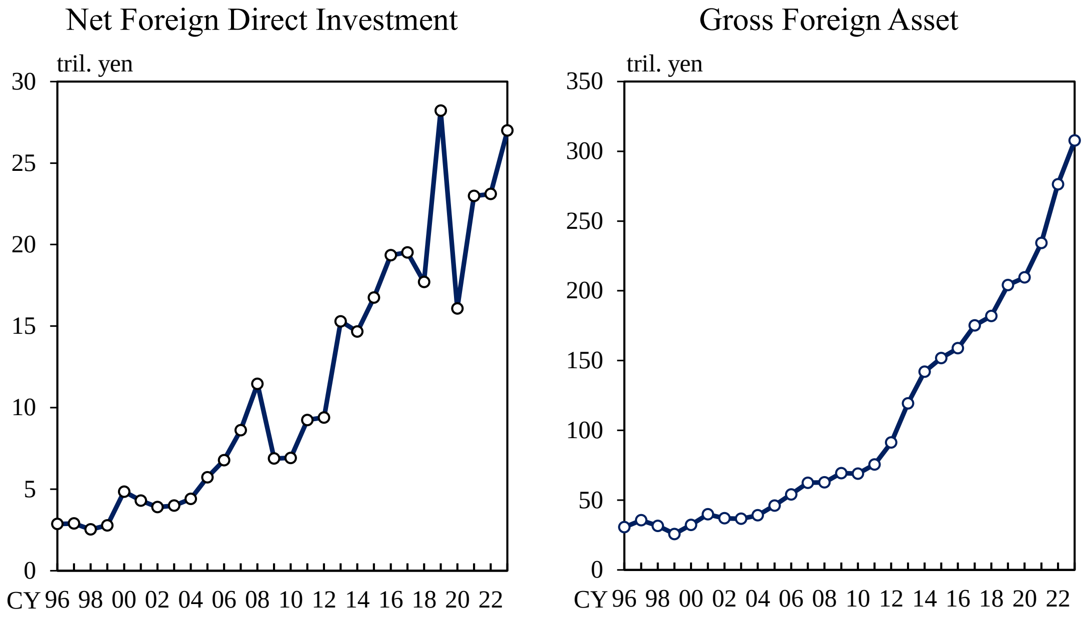


Note: Investment by private non-financial corporations. Real values.
Source: Cabinet Office.

Looking at Japanese data, intangible asset investment in Japan has also shown robust growth, resulting in an accumulation of intangible asset stock, primarily in research and development (R&D) activities and software investment (Figure 1). Drawing on the discussion from the U.S., it is possible that this increase in intangible asset investment has led to a decrease in the interest rate sensitivity of capital investment in Japan as well. This paper investigates whether the increase in intangible asset investment has indeed contributed to dampening the interest rate sensitivity of capital investment in Japan, using panel analysis along with survey data from the "Basic Survey of Japanese Business Structure and Activities," conducted by the Ministry of Economy, Trade and Industry. Given that interest rate changes stemming from monetary policy do not necessarily translate one-to-one to firms' cost of capital, we employ a method called Panel LP-IV (Local Projection Instrumental Variables, detailed in Section 4) to evaluate the relationship between monetary policy shocks and capital investment. This method allows us to observe the response of capital investment to interest rate fluctuation shocks from monetary policy, while avoiding the endogeneity between interest rates and capital investment. This is one of our paper's original contributions not found in previous research.

Another major structural change in Japan during this period is the increase in Foreign Direct Investment (FDI). Indeed, Figure 2 shows that Japan's FDI, both in terms of flow and stock, has continued to increase markedly. To our knowledge, there is no existing research that directly examines the possibility that such FDI, particularly the increase in overseas capital investment ("greenfield investment"), might depress the interest rate sensitivity of domestic capital investment. Studies that have indirectly examined this using Tobin's Q, i.e., observing the response of domestic capital investment to Tobin's Q in domestically based firms with overseas operations, have yielded mixed results (Gutiérrez and Phlippon (2017), Döttling et al. (2017), Kang and Piao (2015)). In this paper, we expand the above panel data by linking the survey data from the "Basic Survey on Overseas Business Activities" (also conducted by the Ministry of Economy, Trade and Industry), to include overseas local subsidiary capital investment (hereinafter, overseas capital investment). We then examine whether the increase in overseas capital investment significantly affects the interest rate sensitivity of capital investment in Japan.

Figure 2: Foreign Direct Investment in Japan



Note: Net Foreign Direct Investment is the amount obtained by subtracting foreign direct investment recovery from foreign direct investment execution.
Source: Ministry of Finance.

This paper also examines the relationship between declining growth expectations, rising labor shortages, and the interest rate sensitivity of capital investment. To date, the impact of these factors on interest rate sensitivity has not been analyzed in previous research. Building on the above panel data, this paper incorporates these factors into its estimations to confirm what additional effects declining growth expectations and rising labor shortages have on the interest rate sensitivity of capital investment.

The structure of this paper is as follows: Section 2 reviews previous research on factors influencing capital investment. Section 3 constructs panel data by collecting macro data from advanced economies to examine whether there have been global changes in capital investment's interest rate sensitivity before analyzing that of Japan. Section 4 uses survey data from the Ministry of Economy, Trade and Industry's "Basic Survey of Japanese Business Structure and Activities" to examine the possibility that the increase in intangible assets is dampening the interest rate sensitivity of capital investment. Section 5 analyzes the possibility that more indirect factors, such as declining growth expectations and labor shortages, are depressing the interest rate sensitivity of capital investment. Section 6 uses survey data from the Ministry of Economy, Trade and Industry's "Basic Survey on Overseas Business Activities," in addition to the "Basic Survey of Japanese Business Structure and Activities," to explore the possibility that increased overseas capital investment is reducing the interest rate sensitivity of domestic capital investment. Section 7 concludes.

2. Literature Review

This section reviews prior literature concerning the interest rate sensitivity of capital investment.[4]

Regarding the determinants of capital investment, a seminal study is Tobin (1969), which introduced the so-called Tobin's Q theory. This theory uses the ratio Q, representing firm value relative to the replacement cost of its capital stock. Under Tobin's Q theory, interest rate sensitivity of capital investment is interpreted as a factor influencing capital investment through the firm's cost of capital. Specifically, a rise in interest rates tends to suppress capital investment by lowering Tobin's Q. Other than this, Jorgenson's acceleration principle (Jorgenson (1963)) is also often used in capital investment analysis. This principle posits that rising interest rates suppress capital investment by increasing user costs and worsening economic conditions, thereby viewing interest rate sensitivity as one of the factors governing such effects. These traditional approaches to capital

[4] In addition to interest rates, other factors influencing capital investment that have been widely discussed include the cash flow levels of firms (Fazzari et al. (1988)), borrowing constraints (Hoshi et al. (1991)), economic uncertainty (Dixit and Pindyck (1994)), firms' cash holdings (Denis and Sibilkov (2010)), and firm age and size (Gnewuch and Zhang (2025)). While this paper does not look at these factors in depth, it is important to note the possibility that these other factors may have contributed to the recent interest rate sensitivity of capital investment.

investment analysis have well explained capital investment in empirical analyses using Japanese data (Hayashi and Inoue (1991), Nagahata and Sekine (2002), Tsuchiya (2021)). This paper's approach builds upon these theoretical studies to analyze the recent relationship between interest rates and capital investment more directly.

Following the Global Financial Crisis, capital investment recovery was sluggish despite the generally accommodating financial conditions maintained across major economies (IMF (2015)). Baldi and Lange (2019) examine the interest rate sensitivity of capital investment in the U.S. and four European countries (UK, France, Germany, and Italy) using VAR models. They report that while capital investment significantly reacted to central bank policy changes before the 1980s in all these countries, it showed little reaction thereafter. Although not directly addressing capital investment, Ahmed et al. (2024), conducted by BIS staff, analyzes recent changes in the interest rate sensitivity of GDP. Using panel data from 18 advanced economies, including Japan, and the local projection method (Jordà (2005)), they found that GDP reacted significantly to interest rate shocks during high interest rate periods, but the impact of central bank interest rate operations on GDP was mostly insignificant during recent low interest rate periods. Building on these prior studies, this paper will construct panel data using country-specific data to examine whether similar trends are observed for capital investment in advanced economies (OECD member countries).

One study that offers insights into the background of this decline in interest rate sensitivity is Gutiérrez and Philippon (2017). Using high-granularity firm- and industry-level data for the U.S., they analyzed the relationship between Tobin's Q and capital investment since the 2000s. They reported that capital investment growth has been sluggish despite high Tobin's Q in recent years, suggesting a decline in interest rate sensitivity. They pointed out the background factors to this, including the expansion of intangible asset investment and globalization, in addition to shortsighted investment decisions driven by intensifying competition among firms and their profit-seeking behavior.

Among these, intangible asset investment is frequently cited in both theoretical and empirical analyses as a reason for the recent decline in interest rate sensitivity. Döttling and Ratnovski (2023) report that the effects of monetary policy are less likely to propagate to intangible assets because they have small collateral value and high depreciation rates. Caggese and Pérez-Orive (2022), who conducted a theoretical study of intangible asset investment, point out that the low collateral value of intangible assets makes it difficult for firms to raise funds through borrowing, thereby incentivizing firms to invest using their own cash. They argue that when interest rates rise, the returns on cash holdings increase, which could paradoxically lead to an increase in intangible asset investment (i.e., the sign of interest rate sensitivity changes). David and Gourio (2023) analyzed the relationship between monetary policy and capital investment using the local projection method with U.S. data and reported that intangible asset investment has lower sensitivity to monetary policy compared to tangible asset investment.

Regarding the impact of globalization, on the other hand, while some research points to the difficulty of managing collateral for assets located in other countries through foreign direct investment influencing investment decisions (e.g., De Maeseneire and Claeys (2012)), to the best of our knowledge, no theoretical research analyzes the relationship between domestic interest rate trends and domestic and overseas investment decisions directly. Empirically, Gutiérrez and Philippon (2017) indicate that in the U.S., capital investment by multinational corporations does not react to Tobin's Q, whereas their analysis for Europe found no such evidence (Döttling et al. (2017)), suggesting mixed results. Furthermore, Kang and Piao (2015), a somewhat dated study by IMF staff, conducted a similar analysis using Japanese data and reported that capital investment by Japanese firms with overseas operations does not react to Tobin's Q.[5] Moreover, regarding the background of sluggish domestic capital investment compared to improved cash flow, a survey conducted by the Bank of Japan (2024a) targeting Japanese firms noted that many large firms responded that they "prioritized overseas business."

These two factors, as mentioned, are distinctive characteristics surrounding Japanese firms in recent years. This paper will analyze the changes in interest rate sensitivity, taking these factors into account in greater detail using corporate financial data.

Furthermore, significant changes surrounding Japanese firms that occurred concurrently with the decline in interest rate sensitivity include factors such as declining growth expectations, reflected in demand forecasts, and an intensifying labor shortage. Regarding the impact of these factors on capital investment, research on growth expectations suggests that medium-term demand outlooks influence capital investment (Kang (2014), Kato and Kawamoto (2016), Ogawa et al. (2019)). Bank of Japan (2024a) also reported that many firms cited declining growth expectations as a reason for limiting domestic capital investment. As for labor shortages, it has been pointed out that they encourage firms to intensify efforts to substitute labor with capital, thereby promoting capital

[5] This study also notes that the coefficient for Tobin's Q might become significant if overseas listed stock price information, which reflects the interest rates of the investing country, is used.

investment (Chikamatsu et al. (2024)). However, there is no prior research on how these factors affect interest rate sensitivity, which this paper aims to investigate.

3. Global Trends

This section begins by examining global trends in the interest rate sensitivity of capital investment using a simple panel analysis. We construct panel data by aggregating annual macro data from various advanced economies and estimate the average interest rate sensitivity of capital investment in these countries.

3-1. Estimation Framework

In this section, we conduct a panel estimation including fixed effects and time effects, with the capital investment-to-capital stock ratio (I/K ratio) as the dependent variable and cost of capital, year-on-year stock price index change, real GDP growth rate, and exchange rate against the dollar as explanatory variables.[6]

The estimation equation is as follows:

$$\frac{I_{i,t}}{K_{i,t-1}} = \beta_1 r_{i,t-1} + \boldsymbol{\beta X_t} + u_i + y_t + \epsilon_{i,t}$$

$\frac{I_{i,t}}{K_{i,t-1}}$: Capital investment-to-capital stock ratio (%)

$r_{i,t-1}$: Cost of capital (= Nominal long-term interest rate - Inflation rate + Depreciation rate).

$\boldsymbol{X_t}$: Control variables (year-on-year stock price index change, real GDP growth rate, exchange rate against the dollar).

u_i: Fixed effects

y_t: Time effects

$\epsilon_{i,t}$: Error term

Here, the nominal long-term interest rate (10-year) was used to calculate the cost of capital. This is because using nominal short-term interest rates would result in less information, given the periods of near-zero interest rates in Japan and Europe.[7] While it

[6] For model selection, the Hausman test result suggested that a fixed effects model was appropriate.

[7] It could be argued that using medium-term interest rates rather than long-term interest rates is more appropriate in relation to capital investment. However, this paper uses long-term interest rates across the

would be preferable to use medium- to long-term inflation expectations for real value calculation, consumer price inflation rate is used due to data constraints. Control variables include the stock price index, real GDP growth rate, and the exchange rate against the dollar. The stock price index is converted into year-on-year series and used as a proxy for the market value of capital, consistent with Tobin's Q theory. Real GDP growth rate was added to remove country-specific business cycle. The exchange rate is a variable that can influence the decision of whether to invest domestically or overseas, and a depreciation of the domestic currency is expected to boost domestic capital investment.[8]

To analyze changes in interest rate sensitivity over time, a rolling estimation was employed using a backward 15-year window, starting from 2004. The end of the estimation period was set to 2019 to exclude the impact of the COVID-19 pandemic.

3-2. Data Used for Analysis

The analysis covers a total of 22 OECD member countries for which the necessary data is available. Capital investment and GDP data were obtained from the World Bank's World Development Indicators (WDI). Capital stock and exchange rate data were sourced from the Penn World Table (PWT), published by the Groningen Growth and Development Centre. With the exception of Japan, long-term interest rate series published by the IMF or OECD were used for interest rate data. For Japan, JGB interest rate information published by the Ministry of Finance was used. Stock price data, published by the OECD, were converted to year-on-year changes.

All capital investment, capital stock, and GDP data were converted to real values using each country's capital investment deflator, capital stock deflator, and GDP deflator, respectively. These deflators were obtained from PWT.

3-3. Estimation Results

Figure 3 (left panel) presents the results of the rolling estimation for interest rate sensitivity (parameter related to the cost of capital). The results indicate that as an average trend across advanced economies, the interest rate sensitivity of capital investment generally remained stably negative, albeit with fluctuations, until around 2013. Thereafter, interest rate sensitivity gradually weakened, becoming statistically insignificant recently.

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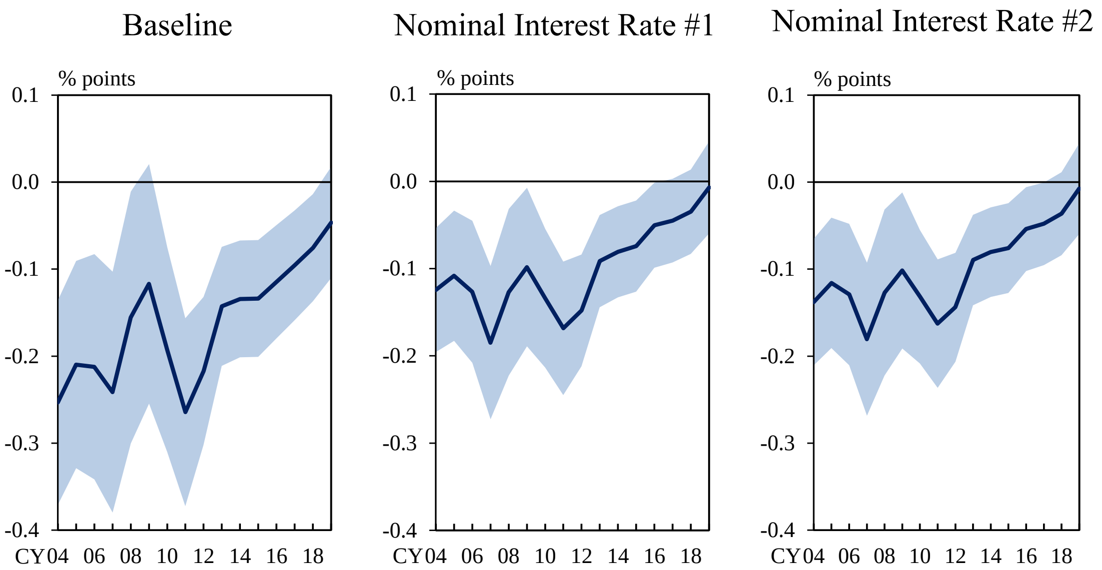
countries due to data constraints requiring the use of indicators of the same maturity across target countries. In the analysis focusing on Japan in Section 4 and subsequent sections, medium-term interest rates are used to emphasize their correspondence with capital investment.

[8] For the exchange rate, the rate against the U.S. dollar was used because the real variables used in the estimation are denominated in dollars.

The coefficients of the control variables satisfy the sign conditions.

As a robustness check, additional analyses are conducted: (1) as biases may exist arising from the conversion to real value (I/K ratio, cost of capital), we verified whether similar results could be obtained using nominal variables. Specifically, we re-estimated the model using the nominal I/K ratio as the dependent variable, replacing the explanatory variable for cost of capital with the nominal long-term interest rate, and real GDP growth rate with the nominal GDP growth rate. Furthermore, (2) due to concerns about endogeneity between interest rates and exchange rates (e.g., exchange rates reacting to interest rates if UIP condition holds, or business cycle fluctuations due to interest rate operations affecting exchange rates), we also conducted an estimation that excluded the exchange rate from the explanatory variables of the regression. The estimation results (Figure 3, middle and right panels) show that in all specifications, the interest rate sensitivity of capital investment has declined in recent years, suggesting that the average trend of declining interest rate sensitivity in advanced economies is a reasonably robust finding.[9]

Figure 3: Average Interest Rate Sensitivity in Advanced Economies



Note: Sensitivity to a +1%pt change in interest rates. In Nominal Interest Rate #1, real variables in the estimation equation are replaced with nominal variables for estimation. In Nominal Interest Rate #2, the exchange rate is excluded from the explanatory variables in the formulation of Nominal Interest Rate #1. Shaded areas indicate 95% CI.
Source: Groningen Growth and Development Centre; IMF; OECD; World Bank; Ministry of Finance.

The international panel analysis confirmed that, on average across advanced economies, the interest rate sensitivity of capital investment has weakened. This trend is evident from

[9] In addition, it could be pointed out that capital investment deflators, rather than consumer prices, should be used for real value calculations. In regards to this, even when consumer prices were replaced with capital investment deflators for estimation, the qualitative results remained unchanged.

both the upper and lower bounds of the confidence intervals in the estimation results, implying that this situation in advanced economies is applicable to Japan as well. In the following sections, we will analyze the background factors contributing to this weakening interest rate sensitivity, based on prior research, from three perspectives: (1) the increase in intangible asset investment, (2) declining growth expectations and rising labor shortages, and (3) increased overseas capital investment.

4. Panel Analysis Using the Basic Survey of Japanese Business Structure and Activities

In this section, we analyze the impact of recent structural changes, specifically the increase in intangible asset investment, on the interest rate sensitivity of capital investment in Japan, using the "Basic Survey of Japanese Business Structure and Activities" (fiscal years 1994-2022) conducted by the Ministry of Economy, Trade and Industry.

The "Basic Survey of Japanese Business Structure and Activities" is a survey undertaken by the Ministry of Economy, Trade and Industry. It commenced in 1992 (for fiscal year 1991 results) to capture corporate activities and has been conducted annually since 1995 (for fiscal year 1994 results). The survey targets a wide range of industries, including manufacturing, mining, wholesale and retail trade, and food-related services, specifically firms with 50 or more employees and capital or investment of 30 million yen or more. In the most recent 2023 survey, over 40,000 companies were surveyed, with the relatively high response rate of about 90 percent. The survey items cover a broad range of information to capture corporate activities, including not only basic balance sheet (B/S) and profit and loss statement (P/L) information, but also R&D investment, import/export amounts, inter-firm transaction information, and information on subsidiaries and affiliates. Given its broad coverage and rich survey items, the "Basic Survey of Japanese Business Structure and Activities" survey data is considered suitable for this paper's objective of analyzing the impact of structural changes surrounding Japanese firms, such as the prevalence of intangible assets, on firms' capital investment behavior.

4-1. Estimation Method: Panel LP-IV

Prior research that estimated capital investment functions for Japanese firms, such as Tsuchiya (2021) and Nishioka and Goto (2024), used the cost of capital calculated from each firm's balance sheet as an interest rate-related variable. While the main objective of this paper is to investigate the relationship between exogenous interest rate fluctuations due to monetary policy changes and capital investment, it is worth mentioning that changes in interest rates due to monetary policy do not necessarily move in parallel with the cost of capital for firms. This is because it is natural to assume that the lending rates firms face include a credit spread, and this spread can also fluctuate when interest rates change. Furthermore, there is an endogeneity problem between interest rates and capital investment (e.g., monetary policy being determined based on capital investment data, and capital investment being determined by interest rates), which also needs to be addressed. Therefore, to identify the impact of exogenous interest rate fluctuations more directly, this paper adopts a different approach from these previous studies.

Specifically, following Jordà et al. (2020), we employ a method called Panel LP-IV. This method extends the local projection (LP) method proposed by Jordà (2005) to panel data and incorporates the instrumental variables (IV) method to address the endogeneity of explanatory and dependent variables. This method has also been adopted in prior research, such as Cloyne et al. (2023), when analyzing firms' capital investment behavior. The advantages of using this method include the flexibility of its formulation, allowing for the direct measurement of capital investment's interest rate sensitivity with appropriate control variables. Moreover, by using exogenous monetary policy shocks as instrumental variables, the endogeneity problem between capital investment and interest rates can be mostly mitigated.[10]

[10] Stock and Watson (2018) point out that a benefit of using monetary policy shocks as instrumental variables, rather than directly as explanatory variables, is that impulse responses are calculated as sensitivity per unit of an endogenous variable—here, the medium-term interest rate—making them easier to interpret. This paper does not identify the transmission channels through which interest rate fluctuations caused by monetary policy shocks affect capital investment behavior.

The estimation equation is as follows:

$$\Delta_h \frac{I_{i,t+h}}{K_{i,t+h}} = \beta_1^h \Delta R_t + \beta_2^h ROA_{i,t} + \beta_3^h CASH_{i,t}/A_{i,t} + \beta_4^h DEBT_{i,t}/A_{i,t} + \beta_5^h \log(A_{i,t}) + \boldsymbol{\beta}^h \boldsymbol{X_t} + u_i + \epsilon_{i,t}$$

$\Delta_h \frac{I_{i,t+h}}{K_{i,t+h}}$: Change in capital investment-to-capital stock ratio

ΔR_t: Period-over-period change in medium-term interest rate

$ROA_{i,t}$: Return on assets (= Operating income / Total assets)

$\log(A_{i,t})$: Logarithm of total assets

$CASH_{i,t}/A_{i,t}$: Liquidity ratio (= Current assets / Total assets)

$DEBT_{i,t}/A_{i,t}$: Debt ratio (= Total liabilities / Total assets)

$\boldsymbol{X_t}$: Other control variables

u_i: Fixed effects

$\epsilon_{i,t}$: Error term

Here, h represents the number of years for the horizon to measure the response. For example, β_1^2 indicates the response of the I/K ratio two years ahead to the interest rate change of the current period. Among the dependent variables, capital stock (K)[11] is defined as the sum of tangible asset stock and intangible asset stock. For tangible assets, we used "tangible assets (excluding land)" as reported in the "Basic Survey of Japanese Business Structure and Activities." Intangible assets surveyed in the "Basic Survey of Japanese Business Structure and Activities" are limited to goodwill, etc., thus capturing only a part of intangible asset investment. Therefore, following Peters and Taylor (2017), we add up R&D expenses and selling, general, and administrative expenses (e.g., human capital investment) using the perpetual inventory method (see the Appendix for details), and defined the sum using intangible assets surveyed in the "Basic Survey of Japanese Business Structure and Activities" as intangible asset stock. For capital investment (I) in the numerator, as it is not directly surveyed in the "Basic Survey of Japanese Business Structure and Activities," it is calculated based on the following assumptions: tangible

[11] For stock variables, the average of the previous and current fiscal year-end values is used.

asset investment is defined, following prior research such as Tsuchiya (2021), as the difference in capital stock from the previous period plus depreciation. In this process, it is assumed that the depreciation reported by firms generally corresponds to tangible assets (i.e., firms do not recognize most of the depreciation of intangible assets), and the full amount of depreciation is recorded as tangible asset investment. Note that if fixed assets are sold or impaired, capital investment in this estimation may take negative values.[12] Intangible asset investment is also calculated by adding depreciation to the stock difference. Stock value is calculated by the perpetual inventory method as described above, and depreciation is calculated by multiplying the stock amount by the depreciation rate used in calculating the stock value. The depreciation rate is set to the value used in Peters and Taylor (2017) (see the Appendix for details).

To verify the effect on I/K ratio by the type of investments, we also calculated I/K ratio for tangible asset, and I/K ratio for intangible asset.

Regarding the explanatory variables, firstly, for interest rates, we obtain data on 3- to 5-year interest rates from the Ministry of Finance's JGB interest rate data and use their simple average.[13, 14] Furthermore, following Cloyne et al. (2023), we use monetary policy shocks as instrumental variables for the period-over-period change in the calculated medium-term interest rate. We employ monetary policy shocks that are estimated by Kubota and Shintani (2022). While they extract monetary policy shocks for multiple interest rate series, this paper uses the monetary policy shock for the 1-year Euroyen interest rate futures, which has a maturity similar to the medium-term interest rate used in our estimation, as instrumental variables.[15] Besides event studies like Kubota and Shintani (2022), there are several methods for identifying monetary policy shocks, including VAR-based methods. From the perspective of using monetary policy shocks as instrumental variables for daily interest rate data, the measurements in their study, which capture interest rate fluctuations during the period 10 minutes before to 20 minutes after

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[12] Additionally, for periods where "tangible assets (excluding land)" are not reported in the "Basic Survey of Japanese Business Structure and Activities," data is interpolated using the most adjacent data, which also means that capital investment could take negative values if land sales occur during these periods.
[13] The Bank of Japan's large-scale macroeconomic model, Q-JEM, also uses similar data (Hirakata et al. (2019)).
[14] While this paper uses medium-term interest rates as the interest rate affecting capital investment, capital investment is likely influenced by the overall shape of the yield curve, not just medium-term interest rates. However, to reflect information on the entire yield curve, adding multiple maturity interest rates as explanatory variables would raise concerns about multicollinearity. Therefore, this paper adopts medium-term interest rates as representative interest rates affecting capital investment.
[15] The F-value for the instrumental variable used in this estimation is 86 (>10), suggesting that a weak instrumental variable problem is not applicable.

the Bank of Japan's monetary policy announcements based on high-frequency data, are appropriate variables for this purpose.[16, 17]

Control variables are set referencing Tsuchiya (2021) and Cloyne et al. (2023). Specifically, ROA (Return on Assets) is included as a proxy for firm value and the cost of capital replacement. The liquidity ratio is used as a variable related to liquidity. Additionally, the debt ratio is used as a variable representing the soundness of the firm's balance sheet. The logarithm of total assets is also included as a control variable. This is used to control for investment behavior where smaller firms, which are typically premature, actively undertake capital investment to expand their businesses. Furthermore, to control for common business cycle factors affecting capital investment behavior across firms at each point in time, explanatory variables include the output gap (one-period lag), the *Tankan* lending attitude DI (one-period lag), and dummy variables (Global Financial Crisis dummy, Great East Japan Earthquake dummy).

To avoid distortion of estimation results due to outliers, firms with at least one outlier that falls outside the upper or lower 0.25 percentiles in the change of the dependent variable I/K ratio (total, tangible, intangible), measured 1 year ahead to 5 years ahead, are excluded from the estimation. The sample size after this treatment is approximately 10,000 firms.

4-2. Trends and Distribution of Variables Used in Estimation

This section provides an overview of the time-series trends and distributions of the variables used in the estimation (fiscal years 1999-2017). Looking at the time-series data for the inter-firm average of each variable in Figure 4, the overall I/K ratio is approximately 20 percent. Breaking down the I/K ratio, tangible assets increased partly thanks to the effects of monetary easing after a dip due to the financial crisis in fiscal year 2009, while intangible assets remained relatively stable. This is consistent with the hypothesis that intangible assets have lower interest rate sensitivity. As for the intangible asset ratio (intangible assets as a proportion of total capital stock), it followed a gradual upward trend, reaching slightly less than 70 percent towards the end of the estimation period. ROA generally hovered around 3-4 percent, though it declined to about 2 percent

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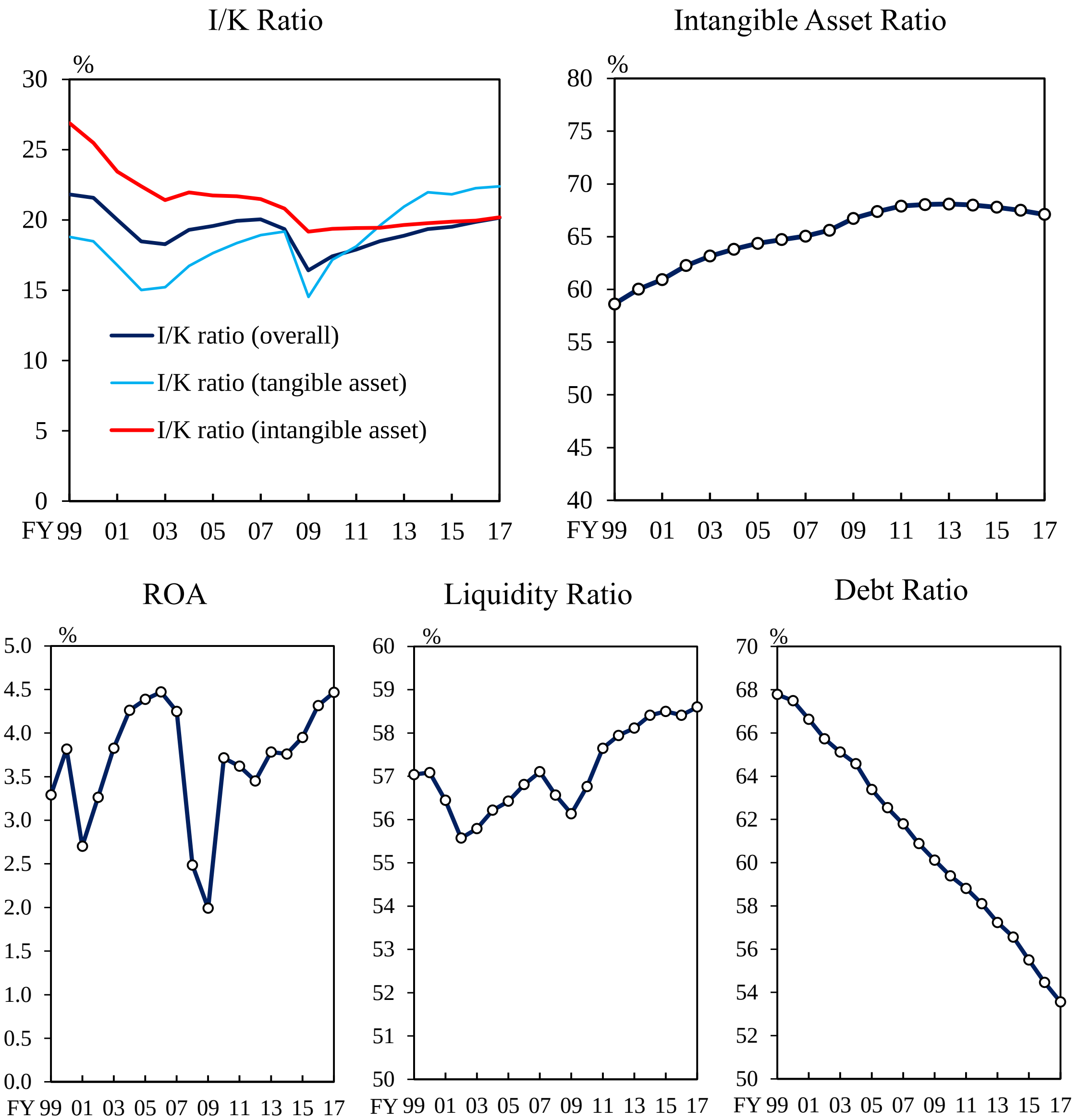
[16] For converting daily monetary policy shocks to annual data, this paper used a simple sum of the shocks. This approach refers to prior research such as Cloyne et al. (2023).

[17] As a robustness check, estimations were also conducted using monetary policy shocks based on VAR with quarterly macroeconomic data as instrumental variables. The estimation results showed similar qualitative results for the overall interest rate sensitivity of tangible and intangible asset investment, but the difference between tangible and intangible assets was not as clear as presented in this section. This difference is likely due to the difference in the frequency of monetary policy shock identification as mentioned in the main text.

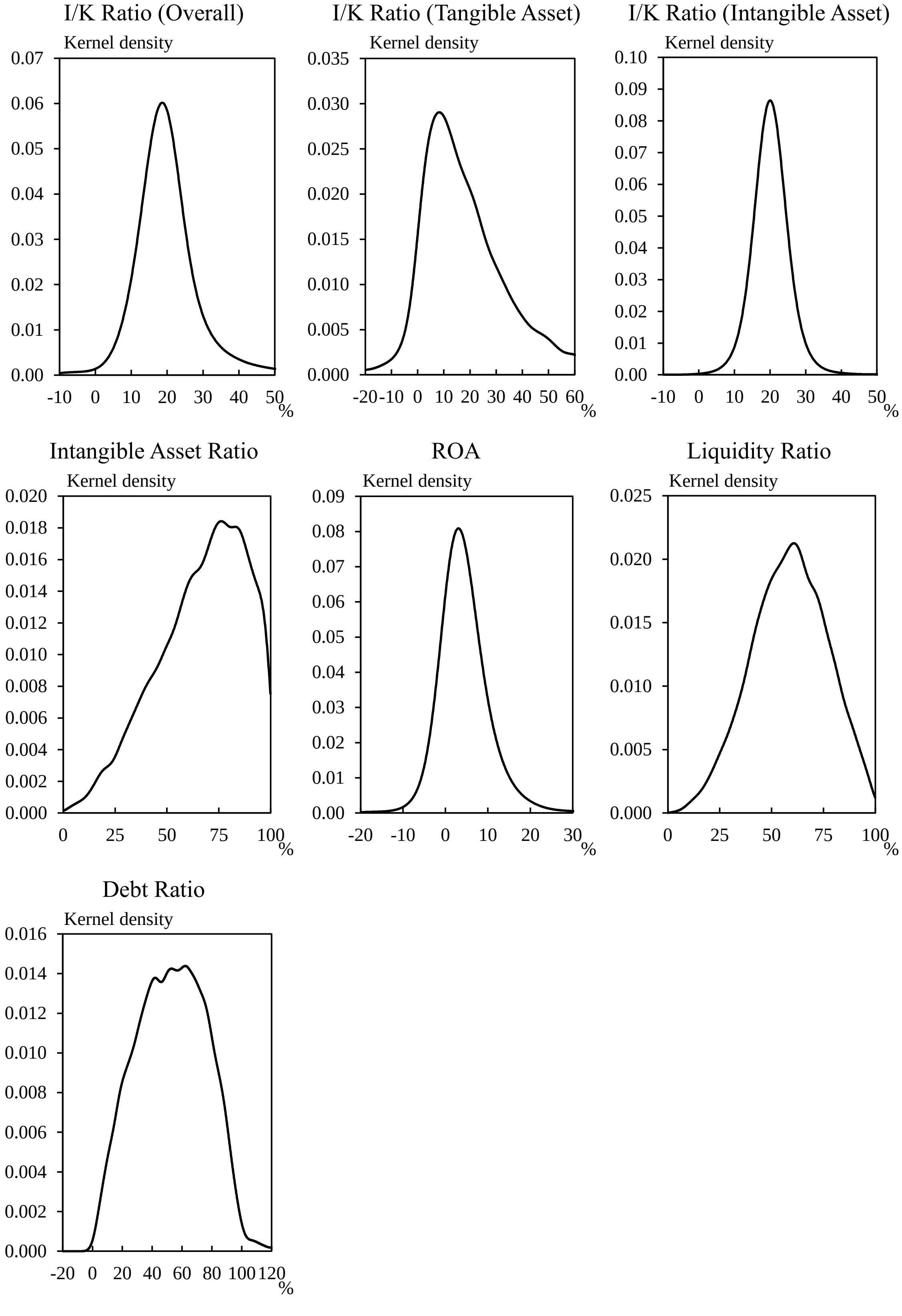
in fiscal year 2009. Meanwhile, the liquidity ratio remained stable in the upper 50 percent range, while the debt ratio continued a gradual declining trend. This suggests that the firms analyzed in this paper, which include a significant number of large corporations, have been gradually deleveraging since the burst of the bubble economy and the 1997 financial crisis.

Figure 4: Time-Series Trends of Variables Used for Estimation



Source: Ministry of Economy, Trade and Industry.

Figure 5: Cross-Sectional Distribution of Variables Used for Estimation



Note: Distribution as of FY2017.
Source: Ministry of Economy, Trade and Industry.

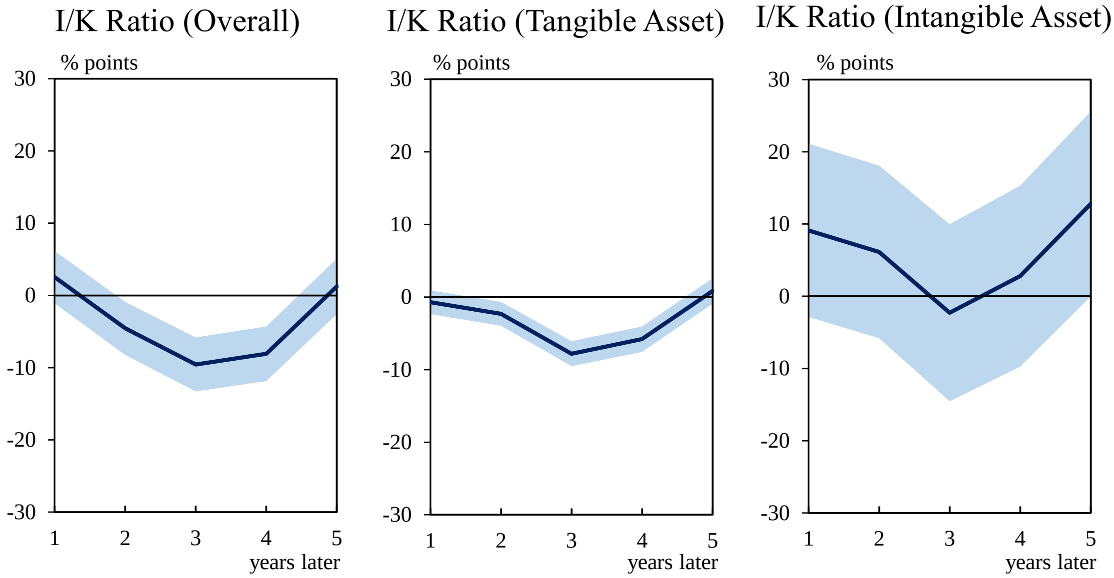
As for the dispersion of each variable (Figure 5), as a sample-based check, we discuss the distributions by performing kernel density estimation for individual data in fiscal year 2017. For the overall I/K ratio, the distribution peaks at approximately 20 percent, with a heavy right tail. When separated into tangible and intangible assets, the distribution of the tangible asset I/K ratio generally peaks at about 10 percent, also with a heavy right tail. A small portion of the samples show negative values, confirming the existence of a number of firms that underwent impairment or disposal in a single year. For the intangible asset I/K ratio, the peak of the distribution is higher than that for tangible assets (approximately 20 percent) and considering prior research which indicates a high depreciation rate for intangible assets, firms were relatively more aggressive in investing in intangible than tangible assets. Meanwhile, the intangible asset ratio shows very large dispersion. Specifically, while many firms have an intangible asset ratio of around 70-80 percent, a considerable number of firms also have a ratio below 50 percent, suggesting that the quantity of intangible asset stock clearly differs depending on the business type and industry characteristics of the firm. For ROA, most firms are concentrated roughly between -10 percent and +20 percent, and many deficit-making firms with ROA below 0 percent are included in the sample. Both the liquidity ratio (current assets / total assets) and the debt ratio (total liabilities / total assets) show very large dispersion, and the sample also includes firms with a debt ratio exceeding 100 percent, indicating over-indebtedness.

4-3. Impulse Response

For the estimation equation explained in Section 4-1, estimations are conducted with the overall I/K ratio, tangible asset I/K ratio, and intangible asset I/K ratio as dependent variables, respectively. Furthermore, for the I/K ratio, estimations are also conducted on samples grouped by firms with high and low intangible asset ratios. By comparing these impulse responses, we will examine the impact of the level of intangible asset ratio on the interest rate sensitivity of capital investment.

Figure 6 shows the impulse response to a 1 percentage point increase in the medium-term interest rate. The left panel illustrates the response of total capital investment, including both tangible and intangible assets, for all firms. The results show that in response to an interest rate hike shock, capital investment significantly decreases, peaking 3-4 years later. Subsequently, the middle and right panels of Figure 6 present the estimation results when the dependent variables are the tangible asset I/K ratio and the intangible asset I/K ratio, respectively. The impulse responses imply that, similar to prior research of other countries, the tangible asset I/K ratio significantly decreases in response to an interest rate hike, whereas the intangible asset I/K ratio shows a wide error band, and the response was not significant.[18, 19]

Figure 6: Impulse Response to Medium-Term Interest Rate Shock (All Firms)



Note: Shaded areas indicate 95% CI.
Source: Ministry of Economy, Trade and Industry; Kubota and Shintani (2022); Bank of Japan.

Next, we grouped the firms based on their intangible asset ratio (proportion of intangible assets in total fixed asset stock)—above or below the median—and conducted estimations using the I/K ratio as the dependent variable. The impulse responses imply that firms with a low intangible asset ratio experienced a more pronounced decrease in capital investment in response to an interest rate hike than firms with a high intangible asset ratio (Figure 7). This result is consistent with the previous finding that intangible assets are not sensitive to interest rates.[20]

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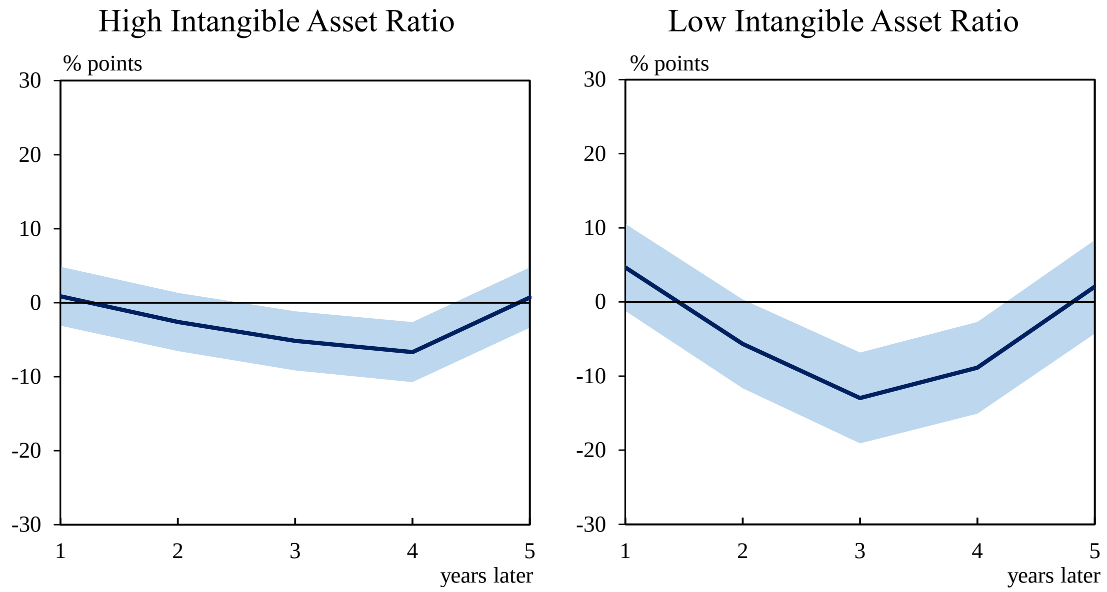
[18] The influence of control variables on the I/K ratio generally yielded expected results. Specifically, an increase in ROA and liquidity ratio boosted capital investment one to two years later, while an increase in the debt ratio depressed capital investment. The coefficient for asset size was also negative, indicating a relationship where larger firms invest less relative to their business scale.

[19] In this analysis, the analysis is limited to samples for which changes in the I/K ratio (1 year ahead, 2 years ahead, …, 5 years ahead) are available at each point in time, so problems with survival bias in impulse responses due to sample size reduction in later periods are considered small.

[20] To verify the time-series robustness of this estimation, the sample was divided into two time-series subsamples for analysis. The estimation results confirmed that the qualitative relationship where firms with lower intangible asset ratios show greater interest rate sensitivity than firms with higher ratios was also observed in the subsamples, confirming robustness. Furthermore, the interest rate sensitivity for the overall I/K ratio was lower in the latter subsample compared to the former, which is consistent with the observation in Section 3.

Figure 7: Impulse Response to Medium-Term Interest Rate Shock
(by Intangible Asset Ratio)



Note: Shaded areas indicate 95% CI.
Source: Ministry of Economy, Trade and Industry; Kubota and Shintani (2022); Bank of Japan.

In the above analysis, all depreciation expenses reported by firms in the "Basic Survey of Japanese Business Structure and Activities" were assumed to be related to tangible assets. Considering the possibility that the reported depreciation data might also include depreciation of intangible assets, a robustness check was conducted with proportionally allocated depreciation expenses to tangible and intangible asset stock values. Figure 8 presents the results of this analysis. The results remain unchanged qualitatively compared with those in Figure 6 and Figure 7, suggesting that the increase in intangible asset stock depresses capital investment's interest rate sensitivity is reasonably robust.[21]

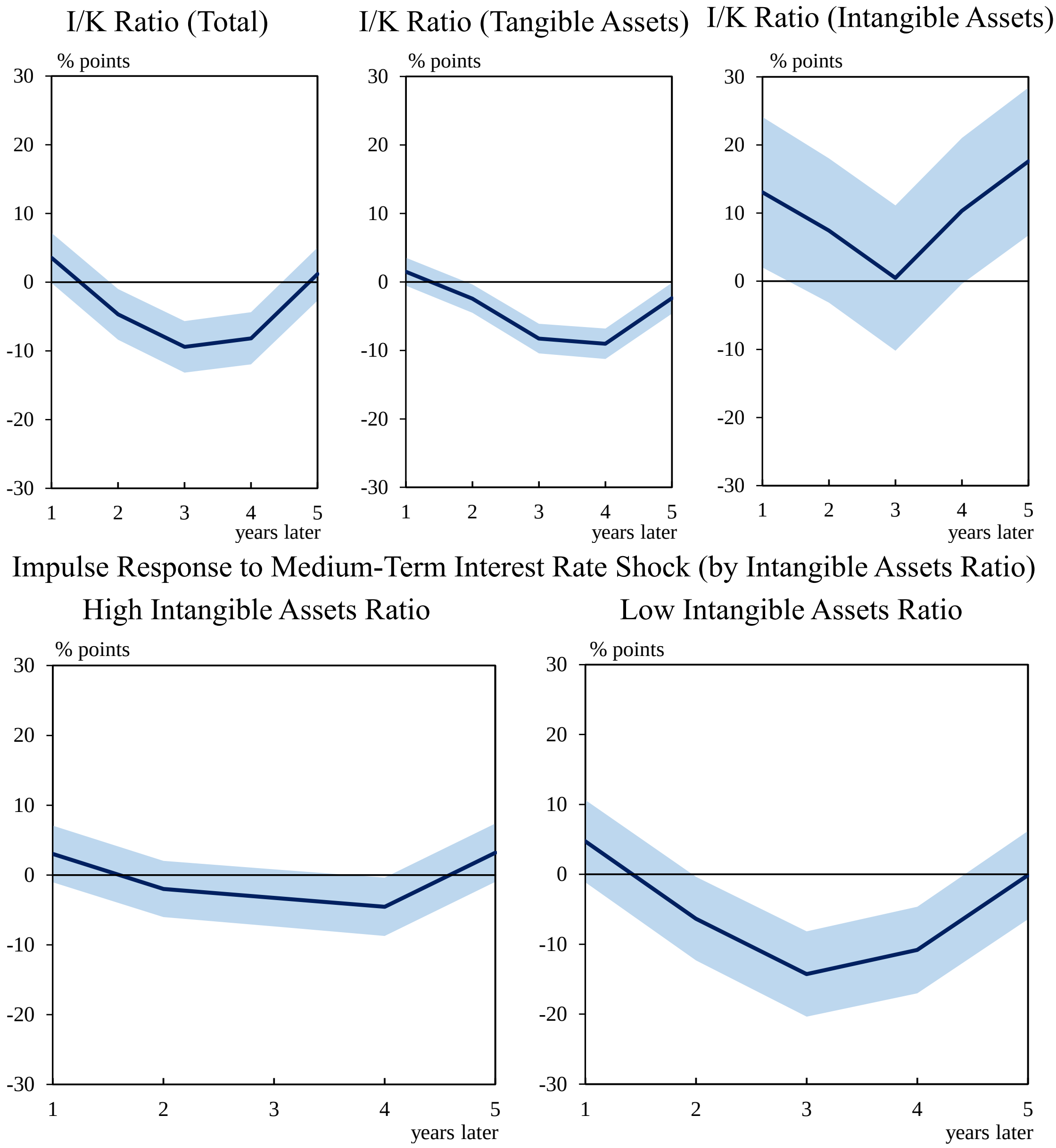
Furthermore, compared with the results of Cloyne et al. (2023)[22], which looked at capital investment in the U.S., the response of overall capital investment in this paper is larger. This might be related to an overestimation due to the data compilation. Specifically, the capital investment series used in the estimation is based on a definition that includes sales and disposals of fixed assets due to data constraints, thus allowing for negative capital investment. In this regard, if impairment losses occur due to a deterioration in firms' business conditions or a decline in capital value during a period of rising interest rates, negative capital investment could become significant. As a result, the impulse response to an interest rate hike may be overestimated. Therefore, when evaluating the impulse

[21] Similar robustness checks were conducted for the analyses in subsequent sections, confirming that the qualitative results and implications remain unchanged.
[22] Cloyne et al. (2023) report that a 1 percentage point increase in interest rates depresses the I/K ratio by approximately 3 percentage points.

response, the absolute value needs to be considered with a certain margin. In this analysis, therefore, the discussion primarily focuses on the relative differences in impulse responses between grouping such as the level of intangible asset ratio.

Figure 8: Robustness Check

Impulse Response to Medium-Term Interest Rate Shock (All Firms)



Note: Shaded areas indicate 95% CI.
Source: Ministry of Economy, Trade and Industry; Kubota and Shintani (2022); Bank of Japan.

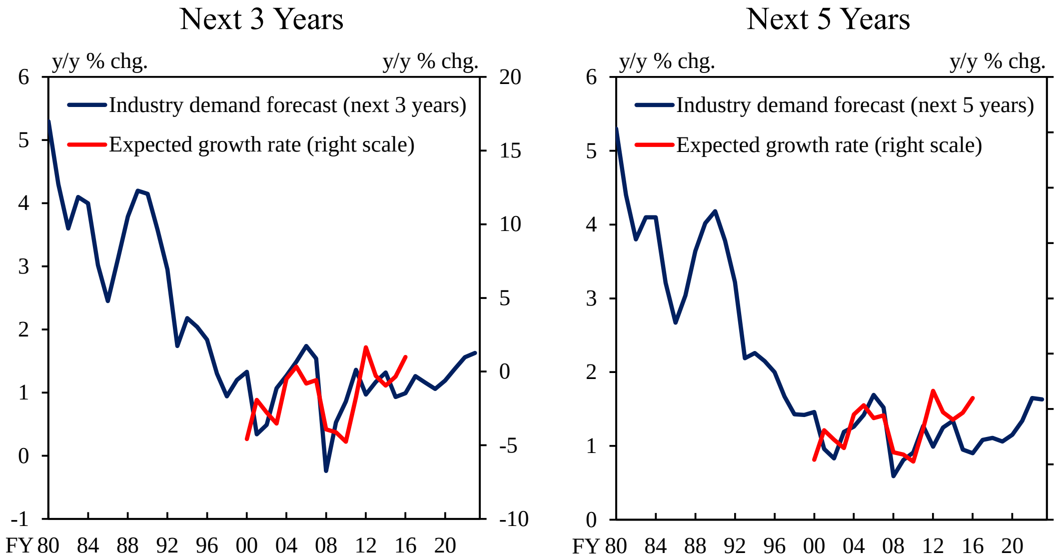
5. Additional Analysis Using the Panel LP-IV Framework

This section utilizes the Panel LP-IV framework from the previous section to group firms based on criteria different from the intangible asset ratio and then examines differences in impulse responses. Specifically, the analysis focuses on "declining growth expectations" and "labor shortages," which are considered to have an impact on corporate behavior amidst recent changes in the Japanese economy.

5-1. Growth Expectations

According to Kang (2014), who analyzed Japanese firms using financial survey data, medium- to long-term demand outlooks significantly influence capital investment. When examining industry demand growth rate forecasts from the "Annual Survey of Corporate Behavior"[23] composed by the Cabinet Office (Figure 9), both 3-year and 5-year forecasts have shown a declining trend, despite a slight recent uptick. Extending Kang (2014), such a decline in growth expectations could depress capital investment. However, Kang (2014) does not mention the relationship between growth expectations and the interest rate sensitivity of capital investment. This section will consider the impact of declining growth expectations on the interest rate sensitivity of capital investment.

Figure 9: Industry Demand Forecast (Annual Survey of Corporate Behavior) and Growth Expectations



Note: Expected growth rate is the median of individual firms' expected growth rates calculated following Fukunaga et al. (2023).
Source: Ministry of Economy, Trade and Industry; Cabinet Office.

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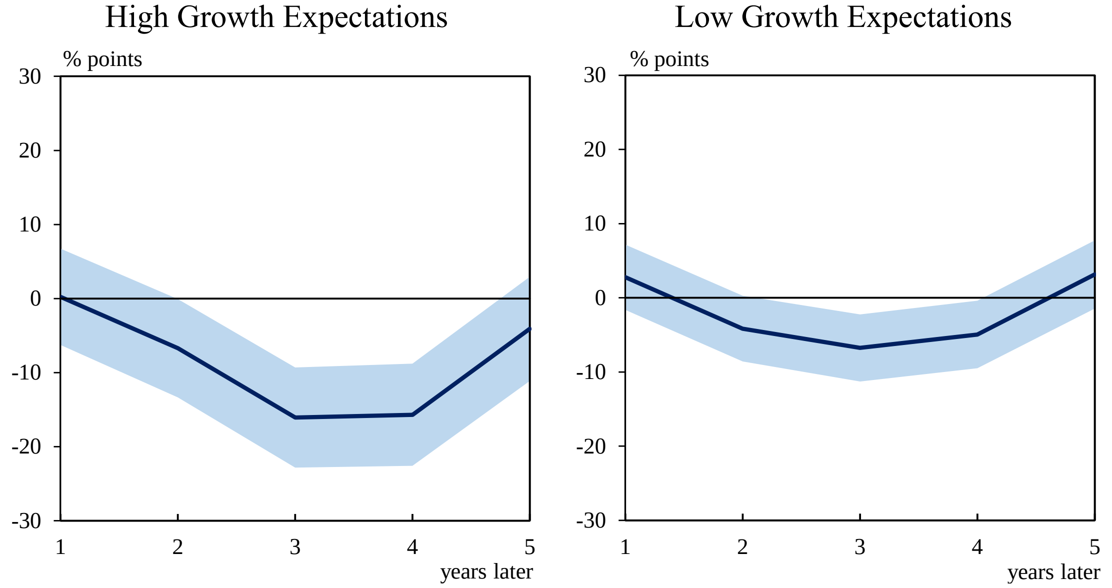
[23] This survey was launched in 1961, targeting listed companies for ongoing surveys on their outlook and action plan for future business conditions and industry demand. As of fiscal year 2024, the number of companies surveyed is over 3,000.

When grouping firms by high or low growth expectations, data representing firm-specific growth expectations are needed. However, such items are not surveyed in the "Basic Survey of Japanese Business Structure and Activities." Therefore, first, we simply group firms using the "Annual Survey of Corporate Behavior." Specifically, we use the industry-specific demand growth rate forecasts published in that survey (average for fiscal years 2010-2023). The dataset created in this paper based on the "Basic Survey of Japanese Business Structure and Activities" also includes firm industry information, allowing for linkage with the Annual Survey of Corporate Behavior data. We then use this industry information to link the demand growth rate forecasts for each firm's industry to the dataset and perform Panel LP-IV estimation by grouping firms into those whose demand forecast exceeds the average expected growth rate for all industries and those whose forecast falls below it.

Figure 10: Impulse Response to Medium-Term Interest Rate Shock (by Growth Expectations <Annual Survey of Corporate Behavior>)



Note: Shaded areas indicate 95% CI.
Source: Ministry of Economy, Trade and Industry; Cabinet Office; Kubota and Shintani (2022); Bank of Japan.

Figure 10 compares the impulse responses to a 1 percentage point increase in the medium-term interest rate after grouping firms as described. Firms in industries with higher growth expectations relative to the all-industry average show interest rate-sensitive capital investment, whereas firms in industries with lower growth expectations show less sensitivity. If Tobin's Q is determined by stock prices, which is the discounted present value of corporate earnings, then declining growth expectations not only reduce Tobin's Q directly but also reduce interest rate sensitivity through an increase in the discount rate, further affecting Tobin's Q. This paper measures the latter channel. One interpretation of this latter channel is that for firms with low growth expectations, demand is expected to be insufficient to actively undertake capital investment, so capital investment does not fluctuate whether interest rates rise or fall. However, this method might capture industry characteristics in addition to the level of growth expectations, and it is necessary to eliminate the influence of such industry characteristics on the analysis results.[24]

To more precisely measure the impact of growth expectations on interest rate sensitivity without using industry information, we calculated firm-specific growth expectations following Fukunaga et al. (2023) and then grouped firms according to the magnitude of their calculated growth expectations. Their research calculates expected growth rates of individual firms from their capital investment behavior. Specifically, assuming that a firm's capital coefficient (real capital stock / real value added)[25] fluctuates along a trend growth rate, and that firms undertake capital investment to maintain this trend, the expected growth rate of individual firms was reverse-calculated.[26] Here, the trend growth rate is defined as the 3-year backward moving average of the capital coefficient's growth rate. Comparing the estimated growth expectations with the results from the "Annual Survey of Corporate Behavior" (Figure 9) confirms that the calculated growth expectations generally align with firms' demand forecasts.

As with the previous section, Figure 11 presents the impulse responses to a 1 percentage point increase in the medium-term interest rate, grouped by the calculated high and low growth expectations. This also yields the same implication as Figure 10: firms in the high growth expectation group are interest rate sensitive, while those in the low growth expectation group are not.[27]

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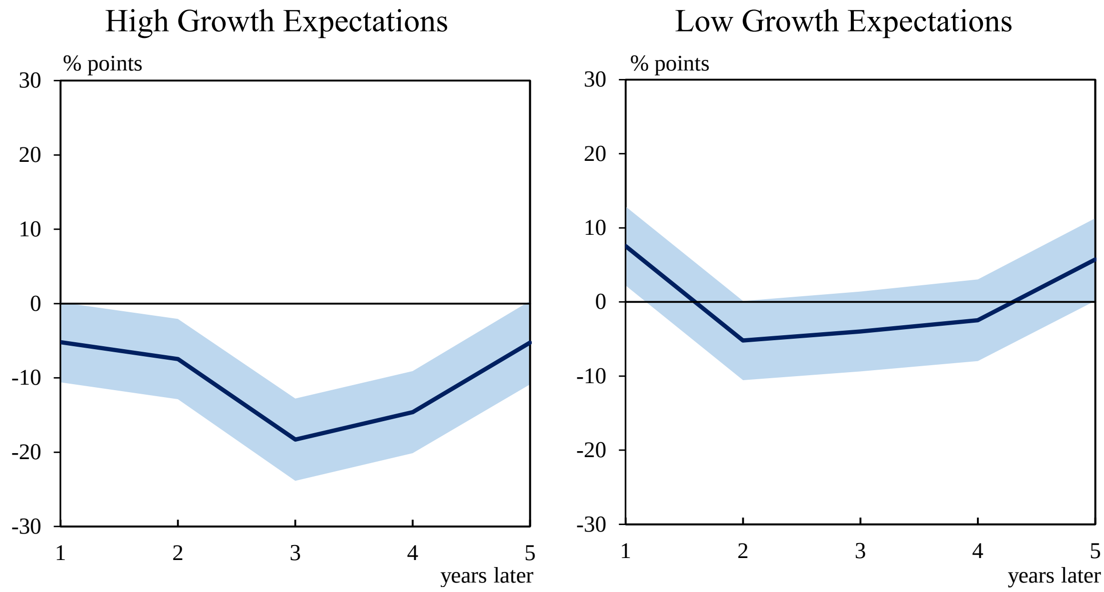
[24] For example, the information and communication industry, which is considered to have high growth expectations, includes many relatively young firms, and there is a possibility that factors other than growth expectations, such as borrowing constraints, are captured.

[25] Real value added = operating profit + labor costs + personnel expenses + rent + taxes and public charges + interest and discount paid + depreciation.

[26] Let real capital stock be K_t, and the growth rate of the capital coefficient (real capital stock/real GDP) be γ_t. If $\overline{\gamma_t}$ is the 3-year backward moving average of γ_t, then the expected growth rate can be calculated as $g_t = \frac{K_t - K_{t-1}}{K_{t-1}} - \overline{\gamma_t}$. For details on the derivation of the formula, refer to Fukunaga et al. (2023).

[27] Cloyne et al. (2023) point out that younger firms are more sensitive to interest rates in their capital investment. While their paper discusses younger firms in the context of borrowing constraints, given that younger firms generally have higher growth expectations, their results can be interpreted as consistent with this paper's findings.

Figure 11: Impulse Response to Medium-Term Interest Rate Shock
(by Growth Expectations <Authors' Estimates>)



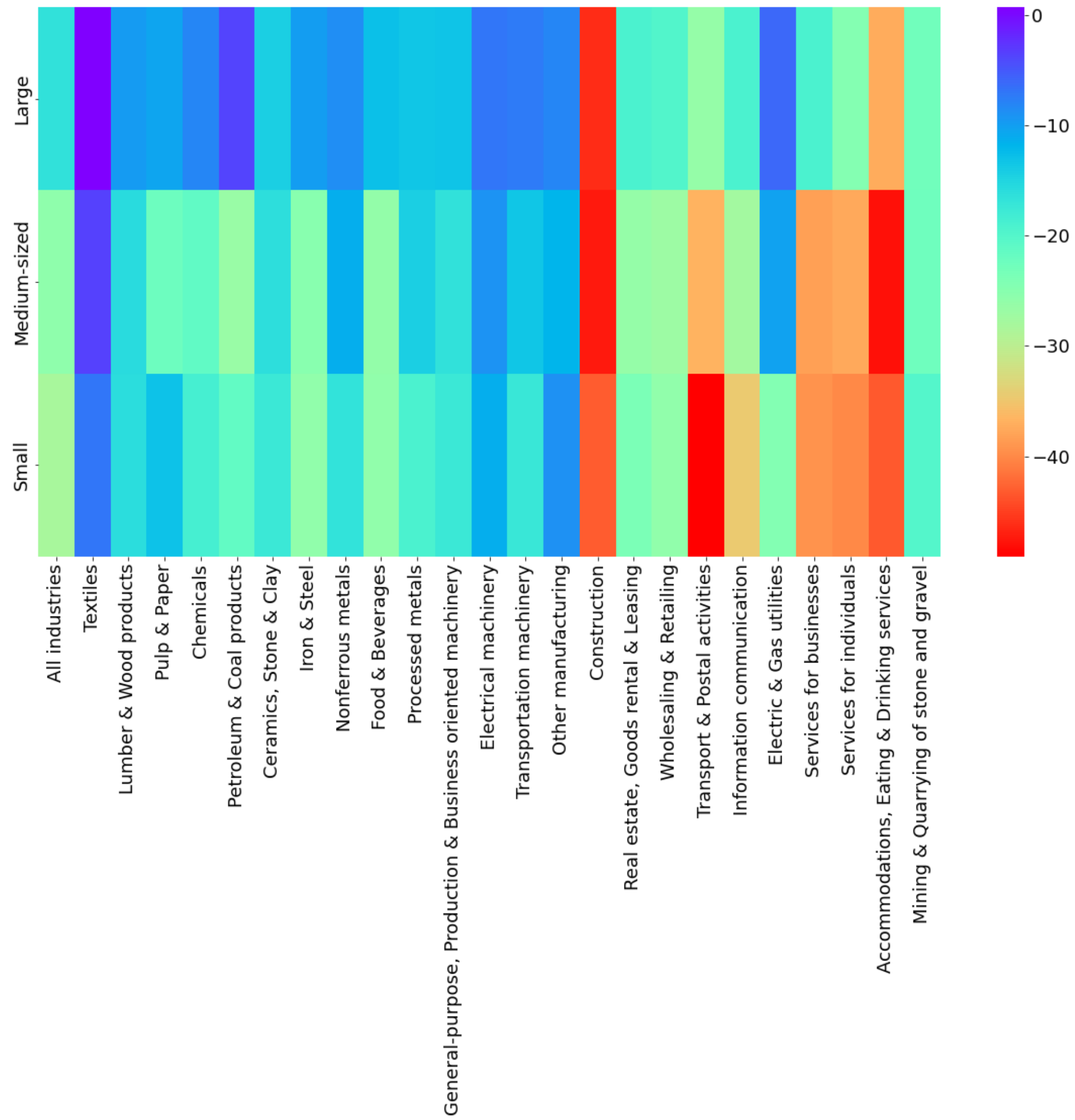
Note: Shaded areas indicate 95% CI.
Source: Ministry of Economy, Trade and Industry; Cabinet Office; Kubota and Shintani (2022); Bank of Japan.

5-2. Labor Shortage

Next, we analyze the impact of labor shortages on the interest rate sensitivity of capital investment using the same method as the previous section. We use the Employment Conditions DI from the Bank of Japan's *Tankan* (Short-term Economic Survey of Enterprises in Japan) to determine whether each firm is experiencing a relatively strong labor shortage. Specifically, firms included in the panel dataset created from the "Basic Survey of Japanese Business Structure and Activities" were classified by size (large, medium-sized, small enterprises) × industry (all 24 industries) mesh. Firms whose Employment Conditions DI (15-year average) in their respective size-industry cell was lower than the all-size, all-industry Employment Conditions DI (15-year average), indicating an excess of labor shortage, were identified as "labor shortage firms."

Figure 12 shows the Employment Conditions DI as a heatmap categorized by company size and industry. The figure reveals that company attributes experiencing strong labor shortages include medium-sized and small enterprises in the service, construction, and transportation and postal services industries.

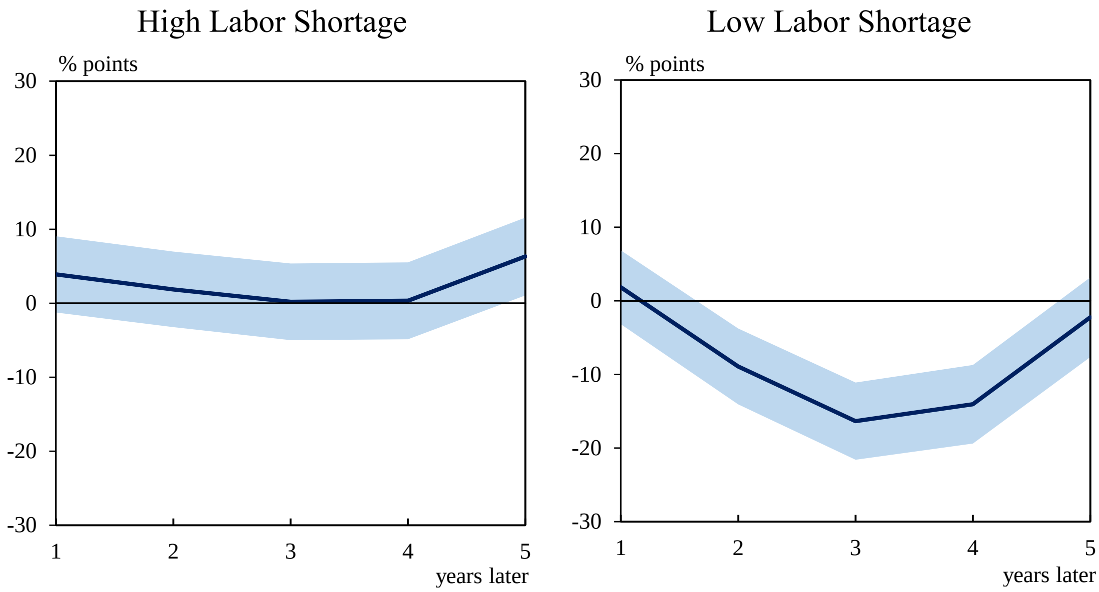
Figure 12: Heatmap of Employment Conditions DI



Note: Redder indicates a stronger sense of labor shortage, bluer indicates a weaker sense of labor shortage.
Source: Bank of Japan.

Figure 13 shows the impulse responses based on Panel LP-IV estimation, classifying firms by the level of labor shortage as described above. Comparing the estimation results, capital investment reacted significantly to interest rates in firms with weak labor shortages, whereas capital investment did not react significantly to interest rates in firms with strong labor shortages. A possible interpretation therefore is, if production volume is constrained by labor input, interest rates do not function as a determinant of capital investment (i.e., capital investment does not change according to the marginal profit of capital). That is, in discussions based on a production function with a certain degree of substitution elasticity between capital and labor, where labor shortages can boost capital investment through an increase in substitution investments as pointed out in prior research, it is possible that firms could undertake capital investment even if interest rates rise. As the labor force population is expected to decline in the future, labor shortages are likely to intensify further, suggesting the possibility that capital investment may become even less sensitive to interest rates.

Figure 13: Impulse Response to Medium-Term Interest Rate Shock
(by Degree of Labor Shortage)



Note: Shaded areas indicate 95% CI.
Source: Ministry of Economy, Trade and Industry; Kubota and Shintani (2022); Bank of Japan.

6. Impact of Increased Overseas Capital Investment on Interest Rate Sensitivity

Another major structural change during recent period affecting Japanese firms' capital investment is the increase in overseas capital investment. This section uses data on overseas local subsidiary capital investment (tangible assets excluding land; hereinafter referred to as overseas capital investment) from the "Basic Survey on Overseas Business Activities," for which survey data was provided by the Ministry of Economy, Trade and Industry. This section discusses the impact of an increase in the overseas investment ratio (overseas local subsidiary capital investment / tangible asset stock) on the interest rate sensitivity of capital investment in Japan.

6-1. Additional Data Used: Basic Survey on Overseas Business Activities

The "Basic Survey on Overseas Business Activities," like the "Basic Survey of Japanese Business Structure and Activities," is a survey conducted by the Ministry of Economy, Trade and Industry. It has been conducted annually since 1971 to understand the overseas business activities of Japanese firms and their impact on local economies and Japan. The survey targets Japanese firms that have overseas local subsidiaries. The survey items cover a wide range of items at each local subsidiary, including employment status, sales/purchases, capital investment, and R&D expenses. Furthermore, each survey form can be linked with the "Basic Survey of Japanese Business Structure and Activities" survey forms through a common identifier called the Permanent Enterprise Number, which is used across statistics managed by the Ministry of Economy, Trade and Industry. In this section, we create an expanded dataset by adding the "Basic Survey on Overseas Business Activities" survey information to the "Basic Survey of Japanese Business Structure and Activities" survey information used in the panel analysis in Section 4. We then estimate the impact of an increasing overseas investment ratio on the interest rate sensitivity of capital investment. Note that the survey data used is limited to those with valid responses (including zero) for overseas capital investment.

6-2. Trends and Distribution of Variables Used in Estimation

This section provides an overview of the time-series trends and distributions of overseas investment-related variables used in the estimation, as shown in Figure 14. Observing the trend of overseas capital investment, while there was a temporary decline during economic downturns such as the financial crisis, a rapid increase has been observed since the 2000s, maintaining high levels, albeit with fluctuations due to factors like the COVID-19 crisis. It should be noted that the overseas capital investment used here does not necessarily correspond exactly with FDI in balance of payments statistics. Specifically, the "Basic Survey on Overseas Business Activities" is a sample survey, and this paper excludes firms with no response from the estimation. Additionally, FDI in forms not covered by Figure 14 (e.g., corporate acquisitions) are not captured.[28] Nevertheless, the observed trend in overseas capital investment used in this paper is broadly similar to that of FDI in balance of payments statistics, despite some differences in level and pace of increase, indicating that it sufficiently captures firm-specific behavior behind FDI movements.

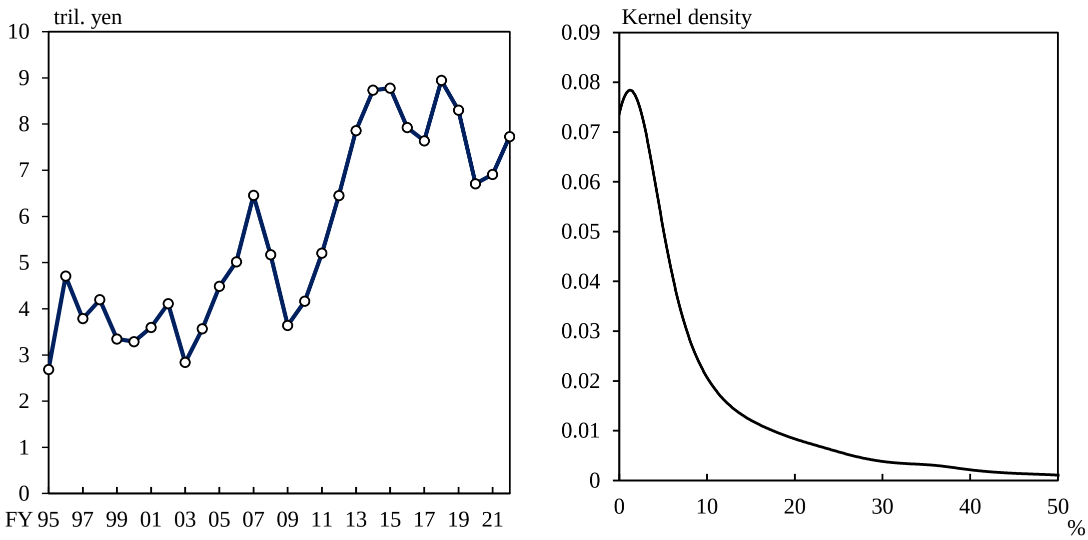
Next, performing kernel density estimation on the 2017 data to check the dispersion of each firm's overseas investment ratio, the majority of firms are concentrated around 0%, indicating a considerable number of firms do not undertake overseas capital investment. Even among firms that do undertake overseas capital investment, the majority have an

[28] According to the IMF Balance of Payments Manual Sixth Edition, direct investment in balance of payments statistics refers to the execution/recovery of investments for corporate acquisitions or establishment of subsidiaries, and capital investment analyzed in this paper is considered a subset of that.

overseas investment ratio within the 0-10% range.

Figure 14: Descriptive Statistics for Overseas Investment-Related Variables

Overseas Capital Investments　　　　Overseas Investments Ratio



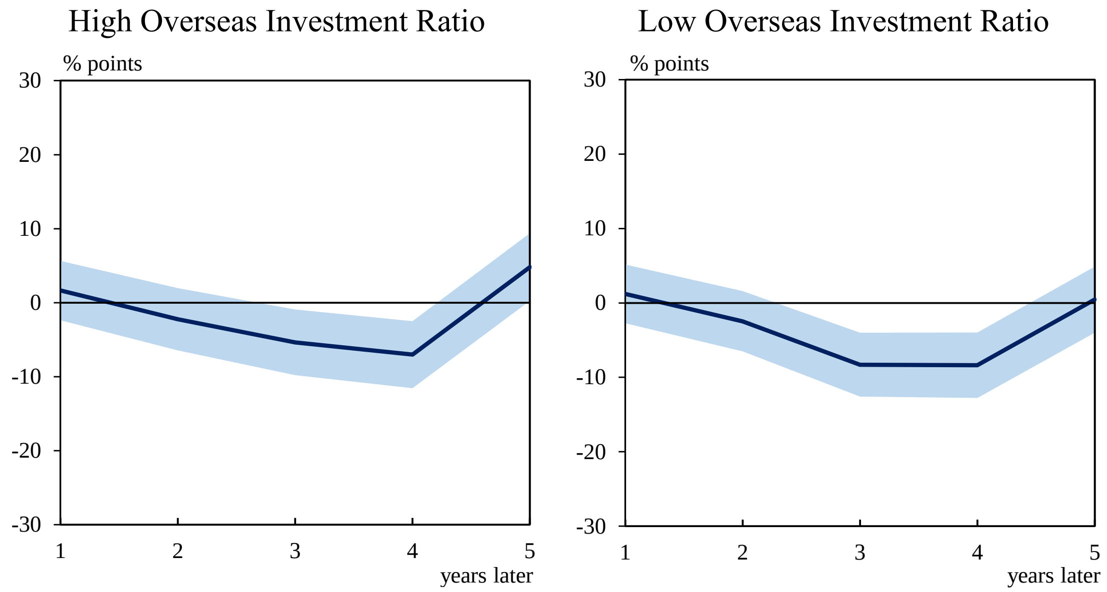
Source: Ministry of Economy, Trade and Industry; Ministry of Finance.

6-3. Impulse Response

Figure 15 compares the impulse responses to a 1 percentage point increase in the medium-term interest rate, grouped by the level of each firm's overseas investment ratio, using Panel LP-IV, as in the previous section. Comparing the point estimates, firms actively engaged in overseas capital investment show relatively lower interest rate sensitivity of capital investment compared to less active firms. However, domestic capital investment decreased in response to an interest rate hike in both groups, and no significant difference in interest rate sensitivity was observed between the two groups.[29] Kang and Piao (2015) point out that domestic capital investment by Japanese firms with overseas operations does not react to Tobin's Q—implying a small impact on capital investment through the interest rate change—Tobin's Q change channel. In contrast, the results of this analysis suggest that interest rate changes can affect domestic capital investment.

[29] In this estimation, due to data constraints, the full-period average of each firm's overseas investment ratio is used, which allows for comparing the average stance of each firm toward overseas capital investment. However, individual firms' reporting years and time-series changes (e.g., increasing/decreasing trends in overseas investment ratio) are not considered.

Figure 15: Impulse Response to Medium-Term Interest Rate Shock (by Overseas Investment Ratio)



Note: Shaded areas indicate 95% CI.
Source: Ministry of Economy, Trade and Industry; Kubota and Shintani (2022); Bank of Japan.

6-4. Robustness Check Using Propensity Score Matching

This section conducts a robustness check of the analysis results from the previous section. In the previous section, firms were simply divided into two groups based on high or low overseas investment ratios, and Panel LP-IV was performed. However, if specific firm attributes influence the aggressiveness of overseas capital investment, this method may include factors other than overseas capital investment (confounding factors) in the estimation results. For example, consider a case where large firms or firms belonging to specific industries tend to be aggressive in overseas capital investment, leading to a bias toward these firms in the high overseas investment ratio group. In such a situation, the control group, which has a low overseas investment ratio, might also experience biases in industry and size distribution, making it impossible to correctly identify whether the difference in interest rate sensitivity estimated by LP-IV is due to overseas capital investment or firm size/industry characteristics.

Therefore, for a robustness check, this section introduces the results of grouping firms while controlling for the influence of variables other than overseas capital investment, using a method called propensity score matching.[30] Propensity score matching is a method that statistically aggregates various covariates that could be confounding factors,

[30] Propensity score matching has also been used in prior research dealing with FDI; for example, Cozza et al. (2015) and Tanaka (2017) analyze the impact of FDI on firm performance and employment.

such as firm size or industry in the example above, into a single composite variable called a propensity score and then remove the influence of confounding factors by constructing a control group based on this propensity score.

The specific grouping procedure is as follows: First, a logit model is used to estimate the probability (propensity score) that each firm is aggressive in overseas capital investment (i.e., its overseas investment ratio exceeds the median), as predicted from its attribute information.[31] The explanatory variables include total assets (logarithm), return on assets (ROA), liquidity ratio, debt ratio, and industry dummy variables.[32]

Figure 16 shows the estimation results of the logit model. The coefficient for total assets is positive and significant, contributing to an increased probability of being aggressive in overseas capital investment. One interpretation of this is that large firms with ample funds and human resources tend to choose overseas expansion as a management strategy (i.e., their overseas investment ratio tends to be high).[33] Furthermore, examining the industry dummy variables, it was confirmed that industries active in overseas production, such as transportation machinery, contribute positively, while petroleum/coal products, accommodation/eating and drinking services, and information communication contribute negatively, indicating a significant influence of industry characteristics.[34]

---

[31] The specific logit model is as follows:

$$\log\left(\frac{p_i}{1-p_i}\right) = \beta_1 + \beta_2(Total\ Assets) + \beta_3\log\,(ROA) + \beta_4(Liquidity\ Ratio) + \beta_5(Debt\ Ratio) + \sum_j \beta_j \times (Industry\ Dummy)$$

Here, p_i is the probability that firm i's overseas investment ratio exceeds the median of all firms.

[32] Industries were classified according to the *Tankan*.

[33] De Maeseneire and Claeys (2012) point out that SMEs often lack sufficient internal funds and face higher hurdles in financing overseas expansion. A survey targeting Japanese SMEs also listed lack of funds and lack of human resources as common reasons for not expanding overseas (Fujii (2013)).

[34] However, the contributions from total assets and liquidity ratio might be influenced by industry characteristics that could not be adjusted by these industry dummies.

Figure 16: Logit Model Estimation Results

	P(Overseas investment ratio>median)
Constant	-0.568
Total assets (mil. yen, log scale)	0.165 ***
ROA (%)	-0.005
Liquidity ratio (%)	-0.009 **
Debt ratio (%)	-0.003
Industry dummy	Yes
Number of companies	2,189
Pseudo R-squared	0.10

Note: ** indicates statistical significance at the 5% level, and *** at the 1% level, respectively.
Source: Ministry of Economy, Trade and Industry.

Next, we construct a dataset that accounts for confounding bias using the propensity scores estimated from the logit model. Here, for each firm in the "actual high overseas investment ratio group" (whose overseas investment ratio exceeds the median), we create pairs by matching them one-to-one, allowing for duplication, with firms from outside that group that have the closest propensity score. By doing so, we construct a dataset consisting of an "upper group" that actually has a high overseas investment ratio and a corresponding "lower group" that is artificially created.[35] Firms in this lower group have firm attributes similar to those in the upper group, except for their overseas investment ratio, and are expected to mitigate the impact of factors other than overseas capital investment on interest rate sensitivity.

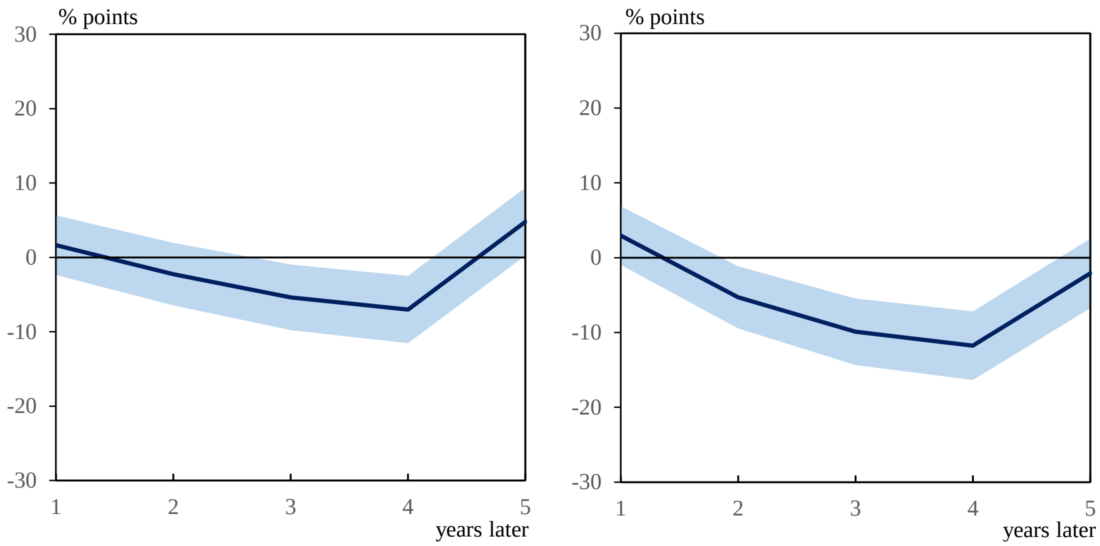
Figure 17 compares the impulse responses to a 1 percentage point increase in the medium-term interest rate, obtained by applying Panel LP-IV to the upper group and the matched lower group, as with the previous section. The upper group's impulse response is identical to the result shown in the previous section. Observing the impulse response of the lower group, created using propensity score matching, the result is broadly similar to the impulse response shown in Figure 15 (right panel), even after adjusting for covariates affecting interest rate sensitivity. This suggests that the result presented in the previous section is reasonably robust.[36]

[35] The treatment effect estimated in this section's dataset is called ATT (Average Treatment effect on Treated). As another treatment effect, ATE (Average Treatment Effect) is estimated with a dataset that matches both control and treatment groups; however, this paper focuses on the treatment effect (impact on interest rate sensitivity) for firms with high overseas investment ratios, thus estimating ATT, which is also used in prior research.
[36] The bias pointed out in this section could similarly exist in the LP-IV analyses in the preceding sections.

Figure 17: Robustness Check

Impulse Response to Medium-Term Interest Rate Shock (by Overseas Investment Ratio)

High Overseas Investment Ratio Low Overseas Investment Ratio



Note: Shaded areas indicate 95% CI.
Source: Ministry of Economy, Trade and Industry; Kubota and Shintani (2022); Bank of Japan.

7. Conclusion

This paper summarized recent trends in the interest rate sensitivity of capital investment using macro statistics and firm-level financial survey data. It also organized the impact of structural changes surrounding Japanese firms, such as the increase in intangible asset investment and overseas capital investment, on interest rate sensitivity. Analysis using the "Basic Survey of Japanese Business Structure and Activities" and the "Basic Survey on Overseas Business Activities" confirmed that intangible asset investment has low interest rate sensitivity. Consequently, firms with a higher proportion of intangible assets in their capital investment clearly showed lower interest rate sensitivity compared to firms with a lower proportion. Furthermore, declining growth expectations and rising labor shortages were also suggested to contribute to depressing interest rate sensitivity. On the other hand, the overseas investment ratio was found to have no significant impact on the interest rate sensitivity of domestic tangible asset investment.

There are four challenges for future research. First, the data handled in this paper consists of corporate financial data up to 2023, and particularly the most recent 20 years have been a period where policy interest rates hovered near zero. While this paper presents analysis

For example, for the intangible asset ratio, industry and firm size could be confounding factors, so similar robustness checks were conducted. The estimation results were generally unchanged from the baseline in Figure 7 (right), confirming the robustness of this analysis.

results based on past average trends, it will be necessary to update the analysis as data accumulates, from the perspective of understanding corporate behavior since the Bank of Japan's interest rate hike in 2024.

Second, in this analysis, assumptions such as the depreciation rate for calculating firm-specific intangible asset stock were set following prior research in the U.S. However, it is not guaranteed that these assumptions are the same in Japan as in the U.S. Moreover, considering the qualitative changes in intangible asset investment due to the recent spread of AI in the U.S., the assumptions themselves might have lost validity. Since such parameters can directly influence the analysis results, refinement is a future task.

Another point is regarding the challenges of the analysis of overseas investment ratios. In this estimation, the average overseas investment ratio over the entire period for each firm is used, which allows for the comparison of firms' average stance toward overseas capital investment. However, heterogeneity in individual firms' reporting years and time-series changes are not considered. It may be possible to refine the estimation by using methods that also account for such factors in addition to this analysis. Furthermore, the "Basic Survey on Overseas Business Activities" used in this estimation allows for calculating firm-specific capital investment amounts by country. Therefore, it would be an interesting topic to examine how overseas capital investment reacts to overseas interest rates, and how interest rate trends in various countries affect firms' allocation of overseas capital investment. Additionally, although data limitations exist, analysis incorporating forms of FDI other than overseas capital investment is also important.

Finally, one caveat for an analysis using the "Basic Survey of Japanese Business Structure and Activities" is that firms surveyed are those with 50 or more employees and capital or investment of 30 million yen or more, thus excluding SMEs. While the capital investment amount of SMEs is smaller compared to large firms, SMEs are more reliant on borrowing than large firms, which often hold sufficient cash and deposits, suggesting a potential for higher interest rate sensitivity. Moreover, the interest rate sensitivity of SMEs may be significantly influenced by not only interest rate levels but also financial conditions such as availability. Constructing a dataset that includes smaller firms and examining whether there are differences in interest rate sensitivity by firm size is also a future research topic.

Appendix. Method for Creating Intangible Asset Stock Data

This appendix details the method for creating intangible asset stock data. As stated in the main text, firm-specific intangible asset stock data is not surveyed in the "Basic Survey of Japanese Business Structure and Activities," so it is necessary to create the stock artificially. Here, following prior research such as Peters and Taylor (2017) and Caggese and Pérez-Orive (2022), we estimate firm-specific intangible asset stock amounts using a method called the Perpetual Inventory Method.

Specifically, in addition to the intangible assets which are actually obtainable from survey data (mainly goodwill, etc.), we account for 30 percent of research and development expenses and selling, general, and administrative expenses (representing human capital investment, branding investment, etc.) as intangible assets, even though they are not recorded as assets on the balance sheet. These assets are then added up, assuming they depreciate. For research and development expenses, a depreciation rate of 15 percent is assumed, and for selling, general, and administrative expenses, a depreciation rate of 20 percent is assumed. The cumulative selling, general, and administrative expenses and depreciation rates are set to the values used in Peters and Taylor (2017).

$$K_{i,t}^{IT} = K_{i,t}^{GW} + K_{i,t}^{RD} + K_{i,t}^{SGA}$$

$K_{i,t}^{IT}$: Intangible asset stock

$K_{i,t}^{GW}$: Intangible assets (mainly goodwill, etc.; surveyed in Basic Survey of Japanese Business Structure and Activities)

$K_{i,t}^{RD}$: Research and development expense stock $K_{i,t}^{RD} = (1 - \delta^{RD})K_{i,t-1}^{RD} + I_{i,t}^{RD}$

$K_{i,t}^{SGA}$: Selling, general, and administrative expense stock $K_{i,t}^{SGA} = (1 - \delta^{SGA})K_{i,t-1}^{SGA} + 0.3 \times I_{i,t}^{SGA}$

δ^{RD}: Depreciation rate for research and development expenses (15 percent)

$I_{i,t}^{RD}$: Research and development investment amount.

δ^{SGA}: Depreciation rate for selling, general, and administrative expenses (20 percent).

$I_{i,t}^{SGA}$: Selling, general, and administrative expenses.

For the initial data points of the sample period used in the estimation, pre-existing accumulated intangible assets cannot be considered, so these data points are not used in the analysis. Specifically, the first five years of data are discarded as a "burn-in" period.

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