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Linkages of Firm Spending Behavior through Supply Chains

Ko Adachi*
kou.adachi@boj.or.jp

Kosuke Aoki**
kaoki@e.u-tokyo.ac.jp

Yoshiyuki Kurachi***
yoshiyuki.kurachi@boj.or.jp

Taiki Ono***
taiki.ono@boj.or.jp

Akitoshi Toyoda****
akitoshi.toyoda@boj.or.jp

Bank of Japan
2-1-1 Nihonbashi-Hongokucho, Chuo-ku, Tokyo 103-0021, Japan

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* Research and Statistics Department, Bank of Japan (currently Monetary Affairs Department)
** Graduate School of Economics, University of Tokyo
*** Research and Statistics Department, Bank of Japan
**** Research and Statistics Department, Bank of Japan (currently Financial System and Bank Examination Department)

Linkages of Firm Spending Behavior through Supply Chains[*]

Ko Adachi[†] Kosuke Aoki[‡] Yoshiyuki Kurachi[§] Taiki Ono[**] Akitoshi Toyoda[††]

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Abstract

This paper empirically analyzes the linkages of firm spending behavior along supply chains, with a focus on capital investment and wage-setting, using production network data from Japan's manufacturing sector. The analysis yields the following findings. First, there is evidence of bonus linkages within supply chains, originating from temporary foreign demand shocks. Second, more broadly, the capital investment of firms can be influenced by downstream investment activity in supply chains, whether domestically or internationally. In addition, the determination of regular wages within a firm appears to be influenced by the wage rates set by focal firms within the same supply chains. These results underscore the importance of analyzing firm behavior while taking into account the multilayered supply chain structure centered around large manufacturing firms in order to understand Japan's economic dynamics.

JEL Classification: D22, E22, J31, L14
Keywords: Supply Chain, Firm-to-Firm Transaction Data, Firm Behavior, Linkages

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[†] Research and Statistics Department, Bank of Japan (currently Monetary Affairs Department) (kou.adachi@boj.or.jp)
[‡] Graduate School of Economics, University of Tokyo (kaoki@e.u-tokyo.ac.jp)
[§] Research and Statistics Department, Bank of Japan (yoshiyuki.kurachi@boj.or.jp)
[**] Research and Statistics Department, Bank of Japan (taiki.ono@boj.or.jp)
[††] Research and Statistics Department, Bank of Japan (currently Financial System and Bank Examination Department) (akitoshi.toyoda@boj.or.jp)

1. Introduction

The *keiretsu* system, a vertical corporate group centered around large manufacturing firms that once characterized Japan's economy, functioned as a unified entity based on strong trading relationships (Aoki, 1990). Within this structure, a wide range of firm behaviors, including investment, employment, the setting of wages and prices, were closely coordinated. Although this traditional *keiretsu* structure has undergone significant changes with the emergence of global supply chains, synchronized behavior among firms in various fields continues to be observed in Japan's business cycles today.

The mechanisms underlying such linkages in firm behaviors have traditionally been explained by macroeconomic shocks common to all firms (Lucas, 1977). However, in recent years, the importance of idiosyncratic shocks affecting individual firms has been increasingly highlighted. For instance, the literature on the network origins of aggregate fluctuations, pioneered by Acemoglu et al. (2012), demonstrates that shocks propagating through supply chains can lead to synchronized firm behaviors.

The framework of supply chain governance (Gereffi et al., 2005), which developed after the year 2000, suggests a synchronization of firm behavior that goes beyond the mere propagation of shocks. In this framework, lead firms, positioned at the apex of the supply chains, play a role in determining both the "value creation" and "value distribution" among suppliers, thereby driving synchronization of firm behaviors within the supply chains.

As highlighted by Adachi et al. (2026), analyzing the linkage of firm behaviors mediated through supply chains is crucial for understanding business cycle fluctuations, especially in Japan's manufacturing sector, which is characterized by multilayered supply chain structures. This paper employs the production network data among Japanese manufacturing firms, constructed by Adachi et al. (2026), to conduct the following three analyses regarding the linkage of firm spending behaviors through supply chains.

The first analysis examines the linkage of spending behavior in response to demand shocks occurring downstream in the supply chains. Following Hummels et al. (2014) and Dhyne et al. (2025), we estimate foreign demand shocks for individual firms using Japanese data and analyze the response of their spending behaviors to these shocks. Specifically, we examine whether changes in foreign demand influence capital investment and wages not only for direct export firms that transact directly with overseas companies, but also for indirect export firms that supply materials and components to direct export firms. In the analysis, we did not find clear evidence that temporary fluctuations in foreign demand lead to linkages in capital investment or regular salary (i.e., base salary plus overtime pay) within supply chains. On the other hand, we report that temporary fluctuations in foreign demand induce strong linkages in bonuses.

In the second part, building on Nirei (2024), which examined the linkage of capital investment among trading partners in Japan, we conduct a more detailed analysis of the linkage of capital investment. We provide new analyses, including the heterogeneity of linkages across industries and the investment linkages involving overseas subsidiaries, thereby complementing the findings of the previous study. The analysis reveals that the capital investment of firms can be influenced by downstream investment activity in supply chains, whether domestically or internationally. Furthermore, it is found that the strength of the linkage in capital investment exhibits considerable heterogeneity across industries.

The third analysis focuses on the linkage of regular wages within supply chains. Specifically, it examines how regular wages within a firm are linked with its trading partners or with the focal firms of the supply chains. The analysis suggests that in supply chains led by transport machinery manufacturers, the wage rates set by focal firms influence the wage determination of their suppliers. Moreover, it highlights that a firm's position within supply chains can also affect the strength of such linkages in regular wages.

These analyses offer empirical insights into the mechanisms of macroeconomic fluctuations mediated through production networks, which can be regarded as a key contribution of this paper.

(Literature Review)

This paper builds on three strands of research: the linkage of spending behavior in response to demand shocks, the linkage of capital investment among firms, and the linkage of wage-setting behavior.

First, in previous studies analyzing the propagation of demand shocks, particularly foreign demand shocks, multiple attempts have been made to identify shocks by employing firm-level transaction data to account for the indirect export exposure of individual firms (Hummels et al., 2014; Dhyne et al., 2021; Dhyne et al., 2025). This approach enables the quantification of the impact of foreign demand shocks not only on direct export firms but also on domestic firms engaged in transactions with those exporters. For instance, Dhyne et al. (2021) analyze the spillover effects of foreign demand shocks on sales using data on inter-firm transactions and financial data of firms, which were constructed from value-added tax declarations in Belgium. Their study reveals that while the number of firms directly exporting is small, many firms have indirect exposure to foreign markets. Furthermore, their findings show that the distinction between direct and indirect exporting is not a significant factor in determining the magnitude of the impact of foreign demand shocks. Instead, a firm's total export exposure plays a critical role.

Additionally, studies focusing on the role of indirect export firms in Japan include Fujii (2017) and Ito and Saito (2021). Notably, Fujii (2017) uses Japanese inter-firm

transaction data to identify firms directly involved in exporting and those performing first-tier or second-tier indirect exporting, analyzing the impact of changes in foreign demand on the sales growth rates of domestic firms. The study conducts an event study focusing on two points in time when significant exchange rate fluctuations occurred. The results show that both direct and indirect export firms responded significantly to changes in foreign demand, while the effects diminished as one moves upstream in the supply chains. On the other hand, our paper is the first study to apply the methodology of Dhyne et al. (2025) to analyze the linkage of spending behavior in Japan caused by foreign demand shocks.

Regarding the linkages of capital investment, many studies have pointed out that investment spikes (lumpy investment), which is large-scale and concentrated capital investments, tend to occur simultaneously among firms, influencing fluctuations in capital investment at the macroeconomic level (Cooper and Haltiwanger, 1996; Caballero, 1999; Gourio and Kashyap, 2007). Previous research has proposed mechanisms to explain this phenomenon, such as firms facing common shocks (Bertola and Caballero, 1990; Cooper et al., 1999; Gourio and Kashyap, 2007) and the endogenous interdependence of firms' capital investment behaviors through input-output linkages and other structures (Miyagawa, 1996; Nirei, 2008; Guiso et al., 2017).

In particular, concerning the latter mechanism, recent studies have attempted to analyze the linkage of investment spikes among firms by using firm-to-firm transaction data that has become available in recent years. Nirei (2024) empirically examines the propagation of investment spikes within supply chains in Japan using inter-firm transaction data. This study demonstrates that when an investment spike occurs, the probability of investment spikes also increases among firms located upstream and downstream in the supply chain, revealing that the capital investment behaviors of firms behaviors are interconnected through supply chains. This paper is closely related to Nirei (2024) in that it focuses on firm investment behavior through the supply chain. It contributes new findings by analyzing previously unexplored aspects such as the heterogeneity of linkages across industries and the linkages of investments in overseas subsidiaries.

Finally, concerning wage linkage, discussions through the 1980s on "wage spillover" highlighted a mechanism where specific industries or firms functioned as pattern-setters, thereby shaping the wage-setting behavior of a broad range of enterprises (Mehra, 1976; Shinkai, 1980; Ueda & Okazaki, 1989; Sako, 1997)[1]. While these debates subsequently subsided reflecting the decline in labor union bargaining power, conformist corporate

[1] Existing literature highlights competitive relationships among firms in local labor markets as another mechanism driving wage linkage across companies (Staiger et al., 2010; Bassier, 2021; Bassier, 2022; Droste, 2024; Derenoncourt and Weil, 2025; Goto and Yamagishi, 2025). These studies frequently discuss this mechanism particularly in connection with monopsony structures.

behavior aligned with the wage-setting of specific firms remains a notable feature in Japan even today (e.g., Ikeda et al., 2024). The analysis in this paper focuses on the linkage of regular wages within supply chains and represents the first quantitative examination of whether there is synchronization of regular wages between direct trading partners and with focal firms at the apex of supply chains.

The structure of this paper is as follows. In Section 2, the data used for the analysis is introduced. Section 3 examines whether there are linkages in firm spending behaviors triggered by foreign demand shocks. Sections 4 and 5 respectively shed light on the linkages among firms within supply chains and their characteristics in terms of capital investments and regular wages. Finally, Section 6 provides concluding remarks.

2. Data

2.1. Production Network Data

To analyze the linkages of firm spending behavior through supply chains, it is essential to have production network data that represents the input-output structure between firms. This paper employs production network data for Japanese manufacturing firms constructed by Adachi et al. (2026). The data covers domestic transactions among manufacturing firms with capital of at least 50 million yen as of 2025[2].

As illustrated in Figure 1, Adachi et al. (2026) estimate the flow of materials and components between firms by combining multiple datasets: the Transaction Share Data from Teikoku Databank, which records inter-firm transaction information; the microdata on firms' manufactured products from the *Annual Business Survey* (hereafter ABS) by the Ministry of Internal Affairs and Communications (MIC) and the Ministry of Economy, Trade and Industry (METI), and the input-output relationships documented in the *Input-Output Tables* compiled by the MIC. Since the subsequent analysis primarily focuses on the firm level, we utilize firm-level transaction data derived from aggregating the firm-product level network constructed by Adachi et al. (2026). This original network comprises 1,105,563 transactions across 13,013 firms and 2,056 products. After aggregation, the resulting firm-level network consists of 81,053 transactions among the same 13,013 firms. This network is represented as an adjacency matrix $\widetilde{W} = \left[\widetilde{w}_{i,j}\right]_{i,j\in J}$, where J denotes the set of all firms, and each element $\widetilde{w}_{i,j}$ represents the sales share from firm i to firm j[3].

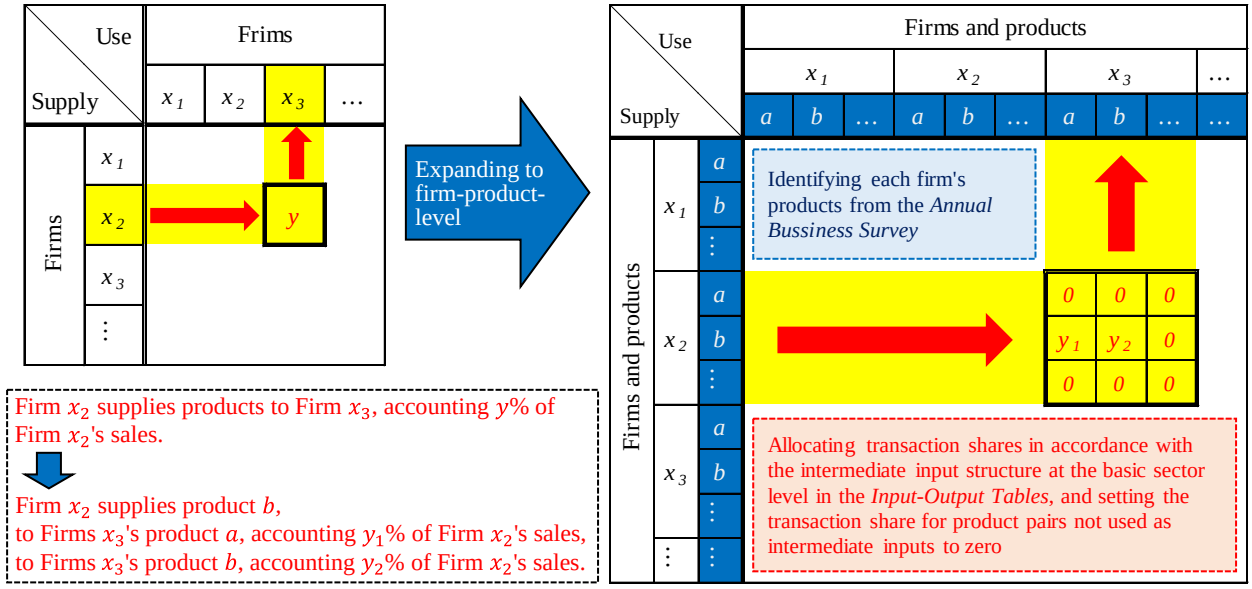
Through the above processes, transactional relationships that are inconsistent with the

[2] This transaction data covers approximately 80 percent of Japan's manufacturing firms with capital of at least 50 million yen (Adachi et al., 2026). Additionally, these firms account for over 70 percent of the total manufacturing sector in terms of financial attributes such as sales, labor costs, and capital expenditures.
[3] The proportion of sales from firm i to firm j (excluding sales other than intermediate inputs) relative to the total sales of firm i.

input structure in the *Input-Output Tables*—such as the purchase of capital goods for investment purposes—are excluded from the original inter-firm transaction data. This enables the identification of intermediate input flows within supply chains. Additionally, Adachi et al. (2026) identify firms positioned at the very downstream end of the supply chain, referred to as "focal firms," based on the identified production network data. In this paper, we conduct some analyses using the identified focal firms (a total of 197 firms).

As noted above, the production network data used in this paper is a snapshot from 2025. Therefore, note that the analyses in the following sections assume that inter-firm transactional relationships are sticky and do not change significantly in the short term[4].

(Figure 1) Firm-Product-Level Production Network



Source: Adachi et al. (2026).

2.2. Data on Investment and Wages

To analyze inter-firm spending behavior within supply chains, we integrate the production network data with microdata from various economic statistics using the corporate numbers assigned to firms by the National Tax Agency.

In the analysis of foreign demand shocks in Section 3, we use the *Quarterly Financial Statements Statistics of Corporations by Industry* (hereafter QFSSCI) published by the Ministry of Finance (MOF). This is a fundamental statistical survey conducted quarterly, aiming to capture the business activities of profit-oriented corporations in Japan with a capital or fund amount of 10 million yen or more. The survey covers a wide range of items,

[4] For example, if the data includes pairs of firms that currently have a transaction relationship but did not in the past, treating those firms as business partners in previous time periods may result in an underestimation of the supply chain linkage. To mitigate this effect, the analysis uses data starting from 2010 or later.

including corporate attributes and financial information, such as profit and loss statements and balance sheet items. Notably, one of the key advantages of this survey is that labor costs are categorized separately into bonuses and other wages. For the analysis, the data from this survey is aggregated on an annual basis.

In the analysis of investment linkages in Section 4, we use the *Basic Survey of Japanese Business Structure and Activities* (hereafter BSJBSA) and the *Basic Survey on Overseas Business Activities* (hereafter BSOBA)[5], both published by the METI. The BSJBSA is a fundamental statistical survey conducted annually to understand the business activities of Japanese companies. It targets firms with 50 or more employees and capital of 30 million yen or more. The survey includes a wide range of items such as corporate attributes and financial information (e.g., profit and loss statements and balance sheet items). Notably, the survey covers items related to capital investment, such as the acquisition amount of tangible fixed assets and the balance of tangible fixed assets. The BSOBA is a general statistical survey conducted annually to understand the overseas business activities of Japanese companies. It targets companies that have local subsidiaries abroad. The survey collects information about parent companies and local subsidiaries (e.g., attributes and financial data), including the amount of capital investment made by local subsidiaries.

In the analysis of wage linkages in Section 5, we use the *Basic Survey on Wage Structure* (hereafter BSWS) and the *Survey on Wage Increase* (hereafter SWI), both published by the Ministry of Health, Labour and Welfare (MHLW). The BSWS is a fundamental statistical survey conducted annually to understand the wage structure in Japan. It targets private establishments with five or more regular employees and samples establishments based on prefecture, industry, and establishment size. The survey covers a wide range of data, including a detailed breakdown of wages such as scheduled earnings and bonuses. It is also possible to compute regular wages from the survey. The SWI is a general statistical survey conducted annually to understand the conditions surrounding wage and bonus revisions in Japanese companies. It targets private firms with 100 or more employees, sampled by industry and company size. The survey includes quantitative items such as wage revision amounts (e.g., across-the-board wage increase and regular wage increase) as well as qualitative items, such as factors emphasized during wage revisions. It also collects data on bonus revisions, including amounts revised. In this paper, by combining data on regular wages (revision rates) from both surveys, we analyze the linkages of regular wages along supply chains.

As previously mentioned, the production network data of Japanese manufacturing firms used in this paper represents data for the single year of 2025. Therefore, to mitigate

[5] Starting in 2026, the BSJBSA and the BSOBA will be integrated into a single survey.

the influence of changes in transaction structures, the starting point of the data used in the analysis is set to 2010 or later.

3. Linkages in Spending Behavior Driven by Foreign Demand Shocks

In this section, following the methodology of prior overseas studies, we construct overseas demand shocks faced by individual firms using Japanese data. Subsequently, we examine whether these shocks cause linkages in wages and capital investment along supply chains.

3.1. Construction of Foreign Demand Shocks

(Definition of Foreign Demand Shocks)

Hummels et al. (2014) proposed a methodology for measuring the foreign demand shocks faced directly by exporting firms ("direct export shocks") as well as the foreign demand shocks indirectly faced by individual firms through domestic transaction networks ("indirect export shocks"). This methodology has been employed in several subsequent studies, such as Dhyne et al. (2021) and Dhyne et al. (2025). Below, we explain the definitions of direct export shocks and indirect export shocks following these studies.

First, the direct export shock faced by firm i ($\varepsilon_{i,t}^{direct}$) is defined by the following equation:

$$\varepsilon_{i,t}^{direct} = \sum_{a \in A} \sum_{d \in D} r_{i,a,d} \times \Delta \log M_{a,d,t},$$

where $r_{i,a,d}$ represents the ratio of firm i's export value of product a to region d relative to its total sales, and $\Delta \log M_{a,d,t}$ denotes the import growth rate of product a in region d from countries other than Japan (A is the set of all products, and D is the set of all regions). Consequently, the direct export shock ($\varepsilon_{i,t}^{direct}$) is calculated as the weighted sum of the import growth rates ($\Delta \log M_{a,d,t}$) for each product and region outside Japan, where the weights are given by the export exposure of firm i to those regions and products ($r_{i,a,d}$). Here, we assume that the import growth rate from non-Japanese sources in a given region and for a given product represents the demand fluctuations in that region and product.

Next, the indirect export shock ($\varepsilon_{i,t}^{indirect}$) faced by firm i is defined by the following equation:

$$\varepsilon_{i,t}^{indirect} = \sum_{j \in J} (G_{i,j} - I_{i,j}) \times \varepsilon_{j,t}^{direct},$$

where $G_{i,j}$ represents the (i,j) element of the Ghosh inverse matrix (G) of the production network $\widetilde{W}$, while $I_{i,j}$ represents the (i,j) element of the identity matrix I of the same dimension as G. The difference $(G_{i,j} - I_{i,j})$ captures the total of direct and indirect sales share of firm i to firm j (where J denotes the set of all sample firms). Therefore, the indirect export shock ($\varepsilon_{i,t}^{indirect}$) is obtained by taking a weighted sum of the direct export shocks ($\varepsilon_{j,t}^{direct}$) faced by other firms, using the direct and indirect sales shares ($G_{i,j} - I_{i,j}$) to those firms as weights.

(Data)

The export share by product and region ($r_{i,a,d}$) is calculated by combining the product-level shipment values from the ABS with the region-level export values from the BSJBSA (using the most recent figures available for each firm). Specifically, we assume that, for each firm, the product-level export share for each region is identical and equal to the product-level shipment share. Based on this assumption, we compute the export share by product and region ($r_{i,a,d}$) by multiplying the product-level shipment share by the region-level export share.

In addition, data on the region- and product-specific import values in U.S. dollars ($\log M_{a,d,t}$) is obtained from the UN Comtrade. The granularity for product a is set at the 6-digit level of the product classification used in the ABS, while the granularity for region d corresponds to the classification of six export destination regions in the BSJBSA, which are: Asia (excluding China), China, the Middle East, Europe, North America, and Others[6].

3.2. Spending Responses of Direct Exporters to Direct Export Shocks

Below, we analyze firm spending responses to foreign demand shocks using microdata from the QFSSCI and following the methodology of Dhyne et al. (2025). Here, we first examine the spending responses of direct exporters to direct export shocks.

Specifically, we estimate the cumulative impulse response of variables of direct exporters to direct export shocks base on the following local projection:

$$z_{i,t+\tau} = \beta_{\tau}^{direct}\varepsilon_{i,t}^{direct} + \gamma_{\tau}X_{i,t-1} + \alpha_i + \delta_{k,t} + u_{i,t+\tau}, \quad (1)$$

where $z_{i,t+\tau}$ represents the rate of change or magnitude of change in the target variables from year $t-1$ to year $t+\tau$ ($\tau \in \{0,1,2,3\}$). For target variables related to labor costs, we examine the rate of change in regular salary (i.e., base salary plus overtime pay) and bonuses on per employee basis. In the case of capital investment, the change in the

[6] Some prior overseas studies, such as Dhyne et al. (2025), calculate shocks using data at a higher granularity than in this paper, such as at the 8-digit HS code level and the country level.

investment-to-capital-stock ratio (I/K ratio) is analyzed. $X_{i,t-1}$ represents the lagged values of the target variables and the direct export shocks[7]. Additionally, α_i denotes firm fixed effects, and $\delta_{k,t}$ represents time fixed effects associated with the industry k (at the 2-digit classification level) to which firm i belongs.

Figure 2 presents the estimation results of Equation (1). First, the top-left panel, which shows sales revenue, indicates that in response to positive direct export shocks, sales revenue significantly increases in the year of the shock and the following year before returning to its original level. This suggests that the measured foreign demand shocks capture temporary demand fluctuations[8]. Along with this increase in sales revenue, per employee bonuses (top-right panel) also significantly increase in the following year. On the other hand, the responses of per employee regular salary and the I/K ratio, shown in the bottom panels, are statistically insignificant. These findings of no clear response in regular earnings or capital investment could be attributed to the fact that the direct export shocks identified in this paper represent temporary, firm-specific demand shocks[9].

3.3. Response of Bonuses to Indirect Export Shocks

In the previous subsection, significant responses in per employee bonuses to direct export shocks were confirmed. This section examines whether significant responses can also be observed in indirect export firms through domestic transaction networks. Additionally, we compare the strength of these responses between direct export firms and indirect export firms.

The response of bonuses to indirect export shocks is estimated based on the following local projections, as in the previous subsection:

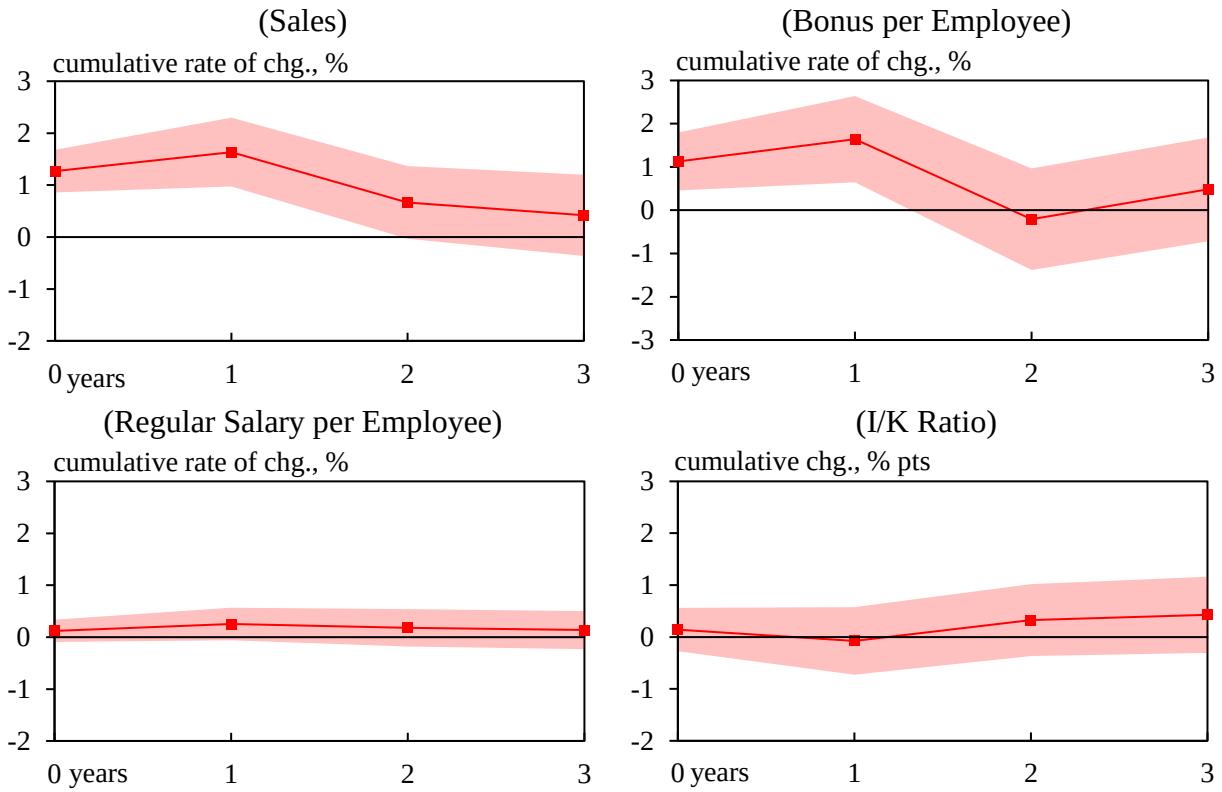
$$bonus_{i,t+\tau} = \beta_{\tau}^{indirect}\varepsilon_{i,t}^{indirect} + \gamma_{\tau}X_{i,t-1} + \alpha_i + \delta_{k,t} + u_{i,t+\tau},$$

where $bonus_{i,t+\tau}$ represents the rate of change in per employee bonuses from year $t-1$ to year $t+\tau$ ($\tau \in \{0,1,2,3\}$).

The estimation results presented in Figure 3 reveal that, similar to the response observed for direct export shocks, per employee bonuses significantly increase both in the year of the indirect export shock and the following year. This finding suggests that temporary fluctuations in foreign demand serve as a trigger for the bonus linkages along supply chains.

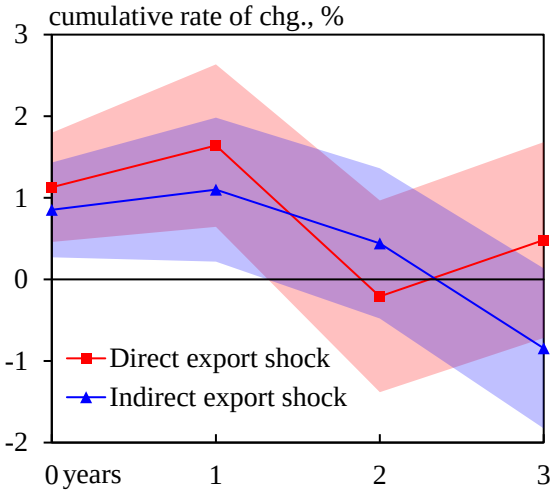
[7] The lagged target variables are based on the rate (or magnitude) of change from year $t-2$ to year $t-1$.
[8] Since the variables on both sides of the estimation equation are nominal, the response of sales revenue may partially capture the effects of nominal price changes in the products manufactured by each firm.
[9] The responses may differ for more persistent shocks or macro-level demand shocks.

(Figure 2) Cumulative Impulse Responses to Direct Demand Shocks



Note: The figure illustrates the cumulative impulse response of each variable to a direct export shock (+1 standard deviation). All variables are windsorized at the upper and lower 2.5% percentiles. The error bands represent the 95% confidence intervals. Standard errors are clustered at the firm level. The sample period is from fiscal 2010 to 2024.
Sources: Ministry of Economy, Trade and Industry; Ministry of Finance; Teikoku Databank; UN Comtrade.

(Figure 3) Bonus Responses to Direct and Indirect Export Shocks



Note: The figure illustrates the cumulative impulse responses of bonus to a direct and indirect export shock (+1 standard deviation). All variables are windsorized at the upper and lower 2.5% percentiles. The error bands represent the 95% confidence intervals. Standard errors are clustered at the firm level. The sample period is from fiscal 2010 to 2024.
Sources: Ministry of Economy, Trade and Industry; Ministry of Finance; Teikoku Databank; UN Comtrade.

Finally, we compare the strength of the responses of bonuses to direct and indirect export shocks. Specifically, following Dhyne et al. (2025), we estimate the elasticity of per employee bonuses to sales revenue ($\beta^{direct,IV}$ and $\beta^{indirect,IV}$) using a two-stage least squares (2SLS) approach, with foreign demand shocks (direct and indirect export shocks) as instrumental variables. The estimation equation, using direct export shocks as the instrumental variable, is expressed as follows:

$$\begin{aligned} &\text{1st stage: } sales_{i,t} = b\varepsilon_{i,t}^{direct} + \gamma X_{i,t-1} + v_{i,t}, \\ &\text{2nd stage: } bonus_{i,t} = \beta^{direct,IV}\widehat{sales}_{i,t} + \gamma X_{i,t-1} + u_{i,t}, \end{aligned} \tag{2}$$

where $sales_{i,t}$ represents the year-on-year change in sales revenue for firm i in year t, and $\widehat{sales}_{i,t}$ represents the predicted value of $sales_{i,t}$ from the first stage. $X_{i,t-1}$ includes the one-period lagged values of $\varepsilon_{i,t}^{direct}$, $sales_{i,t}$, and $bonus_{i,t}$. Additionally, firm fixed effects and industry-year fixed effects are controlled for in the estimation. When using indirect export shocks as the instrumental variable, $\varepsilon_{i,t}^{direct}$ and $\beta^{direct,IV}$ in the equation above should be replaced with $\varepsilon_{i,t}^{indirect}$ and $\beta^{indirect,IV}$, respectively.

The estimation results of Equation (2) in Table 1 show that the elasticity of per employee bonuses to sales revenue is roughly the same regardless of whether direct export shocks or indirect export shocks are used as instrumental variables. This result suggests that when foreign demand shocks occur, bonuses change in proportion to fluctuations in sales revenue, regardless of whether the firm directly exports or engages in indirect exports. In other words, from the perspective of linkages along the supply chain, temporary fluctuations in foreign demand can result in strong linkages in bonuses.

(Table 1) IV Estimation of Sales Elasticity of Bonus

Dependent variable:	Bonus per employee (yoy % chg.)	
Instrumental variable:	Direct export shock	Indirect export shock
Sales (yoy % chg.)	0.9969***	0.9336***
	(0.2655)	(0.3160)
Firm FE	Yes	Yes
Industry×Year FE	Yes	Yes
Observations	25,867	25,867
First-stage *F*-Statistic	79.734	54.369

Note: Estimation results of the 2nd stage of Equation (2). All variables are windsorized at the upper and lower 2.5% percentiles. Figures in parentheses are clustered standard errors at the firm level. *** indicates a 1% significance level. The sample period is from fiscal 2010 to 2024.
Sources: Ministry of Economy, Trade and Industry; Ministry of Finance; Teikoku Databank; UN Comtrade.

4. Linkages in Capital Investment

In this section, building on Nirei (2024), we analyze capital investment, for which no significant linkages caused by temporary demand shocks were observed in the previous section. In addition to examining the investment linkages between customers and suppliers, we investigate whether the spending behavior of focal firms—positioned at the downstream end of supply chains, as identified by Adachi et al. (2026)—affects the spending behavior of supplier firms within those supply chains. Moreover, we also address industry-specific heterogeneities and the linkages in overseas capital investment.

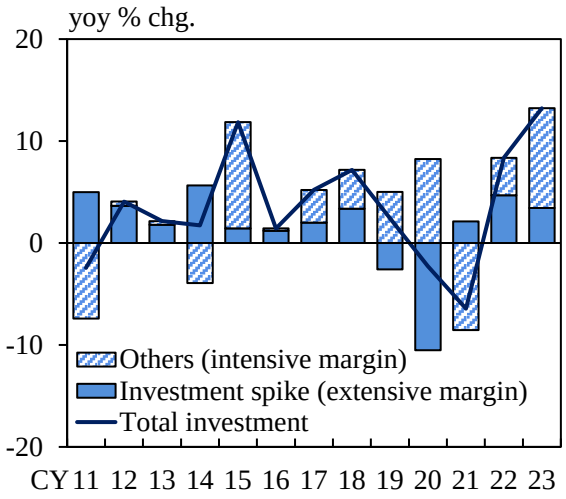
4.1. Linkages in Domestic Capital Investment

Regarding the inter-firm linkage of capital investment, evidence highlights the co-movement of "investment spikes" (lumpy investment), a phenomenon where large-scale investments exceeding 20% of the capital stock occur simultaneously. Traditionally, against the backdrop of fixed investment costs, this co-movement has been attributed to the fact that the probability of investment spikes varies pro-cyclically (Gourio and Kashyap, 2007). In recent years, alongside this mechanism, it has also been pointed out that transaction relationships among firms generate linkages in investment spikes (Nirei, 2024).

However, recent trends in capital investment within Japan's manufacturing sector reveal significant fluctuations that cannot be fully explained by the extensive margin—i.e., changes in the proportion of firms experiencing investment spikes—which was a primary focus of previous studies (Figure 4). In light of this, this paper investigates the linkages in the investment-to-capital-stock ratio (I/K ratio) itself. In other words, we explore broader linkages in capital investment including the intensive margin (i.e., changes in the size of average capital investment)[10].

[10] The appendix presents the results focusing on the linkages in investment spikes.

(Figure 4) Contribution Decomposition of Investment in the Manufacturing Sector



Note: The figure presents a decomposition of the contribution to the year-on-year rate of change in the average capital investment (new acquisitions of tangible fixed assets) of the manufacturing firms, based on the published figures from the BSJBSA. The "Investment spike (extensive margin)" contribution is calculated using microdata from the BSJBSA and represents the contribution attributable to changes in the proportion of firms experiencing investment spikes (investment exceeding 20% of the previous year's tangible fixed assets). The "Others (intensive margin)" contribution is calculated as the residual of the decomposition.
Source: Ministry of Economy, Trade and Industry.

(Estimation Equation)

To examine the linkages in capital investment through supply chains, the following equation is estimated, building on the framework proposed by Nirei (2024):

$$\begin{aligned}\Delta IK_{i,t} = {} & \beta_0^c \Delta IK_{i,t}^c + \beta_1^c \Delta IK_{i,t-1}^c + \beta_0^s \Delta IK_{i,t}^s + \beta_1^s \Delta IK_{i,t-1}^s \\ & + \beta_0^{top} \Delta IK_{i,t}^{top} + \beta_1^{top} \Delta IK_{i,t-1}^{top} + \gamma X_{i,t-1} + \alpha_i + \delta_{k,t} \\ & + \eta_{l,t} + u_{i,t},\end{aligned} \qquad (3)$$

where dependent variable ($\Delta IK_{i,t}$) represents the year-on-year change in the I/K ratio of firm i. The explanatory variables include the year-on-year change in the I/K ratio of customers downstream in firm i's supply chain ($\Delta IK_{i,t}^c$), the year-on-year change in the I/K ratio of suppliers upstream in firm i's supply chain ($\Delta IK_{i,t}^s$), the year-on-year change in the I/K ratio of focal firms in the supply chain ($\Delta IK_{i,t}^{top}$), as well as the one-period lag of each variable (variable definitions are explained later).

According to the theoretical analysis of Nirei (2024), the mechanisms through which each term on the right-hand side affects firm i's capital investment can be summarized as follows. The first and second terms on the right-hand side capture the channel where capital investment by customers of firm i increases the demand for intermediate goods supplied by firm i, thereby stimulating firm i's capital investment. As for the effects of capital investment by supplier firms, represented in the third and fourth terms, these investments

by supplier firms reduce their production costs, which can in turn lower the prices of intermediate goods faced by firm i. If firm i passes on these cost reductions to its own product prices, the increased demand for firm i's products may induce capital investment by firm i.

Furthermore, the capital investment of focal firms in the supply chain, as represented by the fifth and sixth terms, could potentially align with that of their suppliers if, for example, decision-making authority over capital investment is effectively centralized within the focal firms, such as in the context of corporate group structures. Moreover, the investment behavior of focal firms may shape the suppliers' expectations about future demand, thereby influencing their own capital investment decisions.

In the above estimation equation, it is important to note the potential endogeneity issue when estimating the coefficients (β_0^c and β_0^s) that represent contemporaneous linkages between direct trading partners. For example, even if there is no contemporaneous investment inducing effect from customer firms to supplier firms, the coefficient β_0^c could still be positive if there is a positive inducing effect in the opposite direction. Therefore, when making inferences about the direction of causality, it is necessary to examine the significance of the coefficients, including those of the lagged terms, which are considered less prone to endogeneity issues.

The explanatory variables are constructed as follows, taking into account the strength of inter-firm transaction relationships. First, the year-on-year change in the I/K ratio of customer firms ($\Delta IK_{i,t}^c$) is calculated as the weighted sum of the year-on-year changes in the I/K ratios of customer firms, with the sales share used as the weight.

$$\Delta IK_{i,t}^c = \sum_j \widetilde{w}_{i,j}\, \Delta IK_{j,t},$$

where $\widetilde{w}_{i,j}$ represents the sales share explained in Section 2.1, specifically the proportion of firm i's sales accounted for by its sales to firm j.

Similarly, the year-on-year change in the I/K ratio of suppliers ($\Delta IK_{i,t}^s$) is calculated as the weighted sum of the year-on-year changes in the I/K ratios of suppliers, using the purchase share as the weight.

$$\Delta IK_{i,t}^s = \sum_j \omega_{i,j}\, \Delta IK_{j,t},$$

where $\omega_{i,j}$ represents the purchase share, specifically the proportion of firm i's total purchases accounted for by its purchases from firm j.

In addition, to examine whether there is any influence from focal firms beyond direct trading partners, this study includes the year-on-year change in the I/K ratio of focal firms ($\Delta IK_{i,t}^{top}$) and its one-period lag as explanatory variables. For firms belonging to supply chains of multiple focal firms, the year-on-year changes in the I/K ratios of the focal firms are calculated as a simple average.

Finally, $X_{i,t-1}$ represents control variables (the ratio of current assets and profitability in the previous year), and α_i denotes firm fixed effects. Furthermore, to isolate the synchronization effects in capital investment caused by industry-specific investment trends or investment support measures such as subsidies targeted at firms of specific sizes, industry-year fixed effects ($\delta_{k,t}$) and scale-year fixed effects ($\eta_{l,t}$) are incorporated[11].

(Data)

In estimating Equation (3), each variable is constructed using microdata from the BSJBSA. The I/K ratio is calculated by dividing the acquisition value of tangible fixed assets during the current period by the tangible fixed assets at the end of the previous period. Similarly, the liquidity asset ratio (profit rate) is calculated, following Nirei (2024), by dividing the amount of liquid assets (or operating profit) by the combined total of tangible and intangible fixed assets.

The purchase share of firm i from firm j ($\omega_{i,j}$) is calculated as $\widehat{\omega}_{i,j}$ using the following formula, based on the information of the sales share ($\widetilde{w}_{j,i}$) and the sales (y_j).

$$\widehat{\omega}_{i,j} = \frac{\widetilde{w}_{j,i} y_j}{\sum_j \widetilde{w}_{j,i} y_j}.$$

(Estimation Results)

The estimation results of Equation (3) are presented in Table 2. First, both β_0^c and β_1^c are positive and statistically significant. This suggests that capital investment occurring downstream in the supply chain (on the final product side) stimulates capital investment upstream (on the raw materials and components side). On the other hand, β_0^s and β_1^s are not statistically significant, suggesting that, based on the data and formulation used in this paper, there is no evidence that suppliers' capital investment induces downstream capital

[11] k represents the industry (4-digit classification) of firm i, and l indicates the capital size of firm i (classified into three categories: over 1 billion yen, between 100 million yen and 1 billion yen, and 100 million yen or less).

investment. Additionally, the coefficients for the focal firms (β_0^{top} and β_1^{top}) are also not significant, implying that the mechanisms mentioned in the previous section could not be empirically confirmed. These findings indicate that, as a determinant of capital investment by manufacturing firms in Japan, the investment activities of direct customer firms play an important role.

(Table 2) Estimation Results of the I/K Ratio Linkage

	I/K Ratio (yoy chg.)
Customers' I/K ratio (yoy chg.)	0.0526**
	(0.0226)
Customers' I/K ratio (yoy chg., 1-year lag)	0.0458**
	(0.0223)
Suppliers' I/K ratio (yoy chg.)	0.0083
	(0.0096)
Suppliers' I/K ratio (yoy chg., 1-year lag)	0.0037
	(0.0098)
Focal firms' I/K ratio (yoy chg.)	0.0056
	(0.0201)
Focal firms' I/K ratio (yoy chg., 1-year lag)	0.0007
	(0.0183)
Profit rate (1-year lag)	0.0023**
	(0.0009)
Liquid asset ratio (1-year lag)	0.0002***
	(4.38e-5)
Firm FE	Yes
Industry×Year FE	Yes
Scale×Year FE	Yes
Observations	57,979

Note: The variables regarding I/K ratio (yoy chg.) are windsorized at the upper and lower 2.5% percentiles. Figures in parentheses are clustered standard errors at the firm level. ** and *** indicate 5% and 1% significance levels, respectively. The sample period is from fiscal 2010 to 2023.
Sources: Ministry of Economy, Trade and Industry; Teikoku Databank.

(Estimation by Industry)

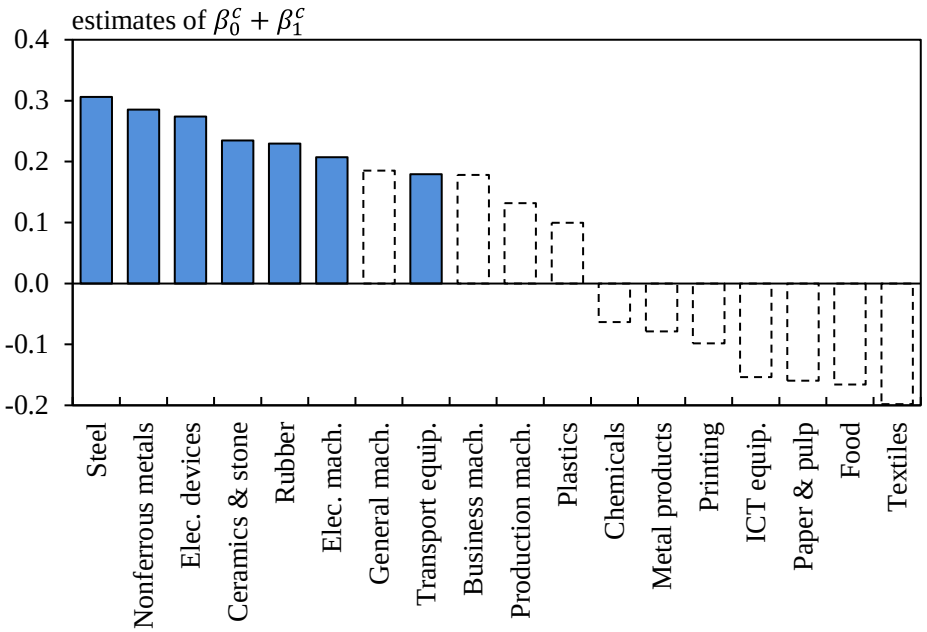
Here, we investigate the heterogeneity across industries in the investment linkages with customers that exhibit a statistically significant relationship. Specifically, we estimate the following equation for each industry-specific subsample.

$$\Delta IK_{i,t} = \beta_0^c \Delta IK_{i,t}^c + \beta_1^c \Delta IK_{i,t-1}^c + \gamma X_{i,t-1} + \alpha_i + \delta_{k,t} + \eta_{l,t} + u_{i,t}$$

Figure 5 compares the sum of the estimated values of β_0^c and β_1^c across different industries. The results indicate strong and significant investment linkages in industries such as steel, non-ferrous metals, ceramics/stones, and electronic components/devices. A

possible explanation for this is that these industries often involve the production of a wide variety of components, which may facilitate the synchronization of capital investments in response to changes in molds or specifications. Additionally, a similar mechanism is likely at play in industries such as electrical machinery and transport equipment—especially among component manufacturers, suggesting that capital investments within supply chains are more closely interlinked in these industries as well.

(Figure 5) Estimation Results of Investment Linkage by Industry

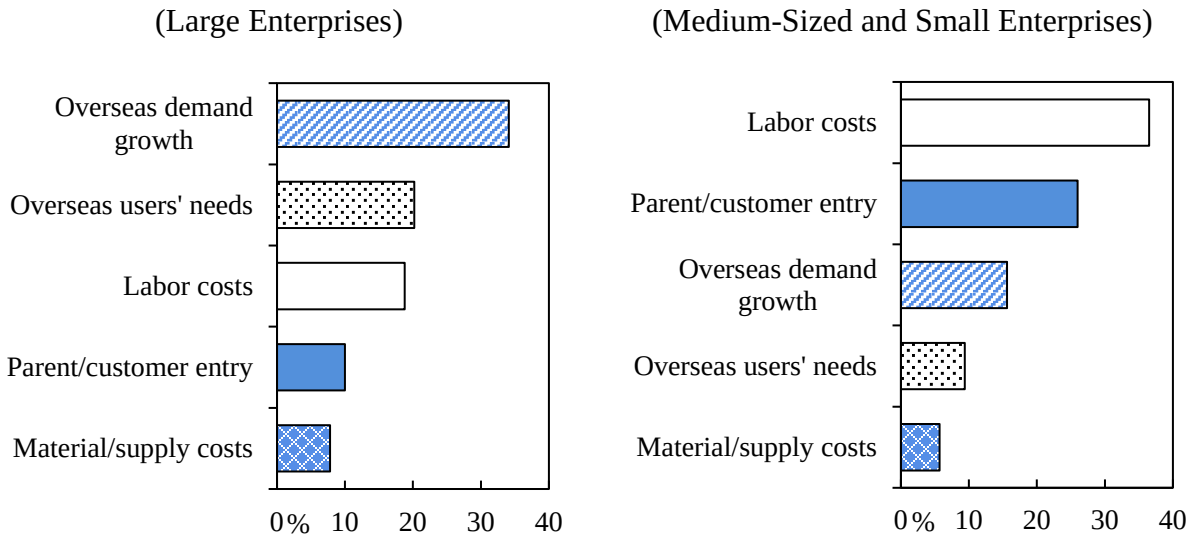


Note: Estimates of $\beta_0^c + \beta_1^c$ from sub-sample estimations by 2-digit industry classification of firm i. Industries with fewer than 1,000 observations are excluded. The blue bars represent industries where the null hypothesis $\beta_0^c + \beta_1^c = 0$ is rejected at the 10% significance level based on the χ^2 test.Variables of I/K ratio (yoy chg.) are windsorized at the upper and lower 2.5% percentiles. The sample period is from fiscal 2010 to 2023.
Sources: Ministry of Economy, Trade and Industry; Teikoku Databank.

4.2. Linkages in Foreign Investment

Japan's supply chains have increasingly expanded overseas, fueled by globalization since the 2000s and the shift of the domestic manufacturing sector towards overseas production. According to the Cabinet Office's *Annual Survey on Corporate Behavior*, one of the primary reasons for establishing overseas production bases, particularly among relatively smaller firms, is "following the expansion of parent companies or business partners into overseas markets." This is referred to as "Parent/customer entry" in Figure 6. This indicates that domestic business relationships may also play a significant role in shaping investment activities abroad.

(Figure 6) Top 5 Reasons for Establishing Overseas Production Bases



Note: The figures present the top 5 reasons for large enterprises and medium-sized and small enterprizes. Large enterprises are defined as companies listed on the Tokyo Stock Exchange (Prime and Standard Markets) or the Nagoya Stock Exchange (Premier and Main Markets) as of fiscal 2025. Medium-sized and small enterprises are defined as companies with capital between 100 million yen and 1 billion yen as of fiscal 2020.
Source: Cabinet Office, "Annual Survey on Corporate Behavior."

Here, building on the analysis of domestic investment linkages, we investigate whether similar linkages exist in the capital investments of overseas subsidiaries by estimating the following equation:

$$F_{i,t} = \beta_0^c F_{i,t}^c + \beta_1^c F_{i,t-1}^c + \alpha_i + \delta_{k,t} + u_{i,t}, \quad (4)$$

where $F_{i,t}$ represents the amount of capital investment by overseas subsidiaries of firm i, as obtained from the BSOBA. On the right-hand side, $F_{i,t}^c$ represents the amount of capital investment by the overseas subsidiaries of firm i's customer firms. When multiple customer firms with overseas subsidiaries exist, the median value among these firms is used. Notably, since the survey does not include information on capital stock, the variables used in the estimation are expressed as the deviation of capital investment amounts from their average over the period, instead of using the I/K ratio. α_i denotes the fixed effects for firm i, and $\delta_{k,t}$ represents industry-specific trends (industry-year fixed effects) for industry k to which firm i belongs (in 4-digit classification).

The estimation results for Equation (4) are shown in Table 3. The coefficient β_0^c for $F_{i,t}^c$ is positive and statistically significant. This suggests that the capital investments made by the overseas subsidiaries of Japanese manufacturing firms tend to move in tandem with the foreign investments of their domestic customer firms, which is consistent with the qualitative information presented in Figure 6.

(Table 3) Estimation Results of the Overseas Investment Linkage

	Investment by foreign subsidiaries
Investment by customers' foreign subsidiaries	0.1197**
	(0.0586)
Investment by customers' foreign subsidiaries (1-year lag)	0.0446
	(0.0593)
Firm FE	Yes
Industry×Year FE	Yes
Observations	12,144

Note: The investment of each firm is expressed as the deviation rate from its sample average. All variables are windsorized at the upper and lower 2.5% percentiles. Figures in parentheses are clustered standard errors at the firm level. ** indicates a 5% significance level. The sample period is from fiscal 2010 to 2023.
Sources: Ministry of Economy, Trade and Industry; Teikoku Databank.

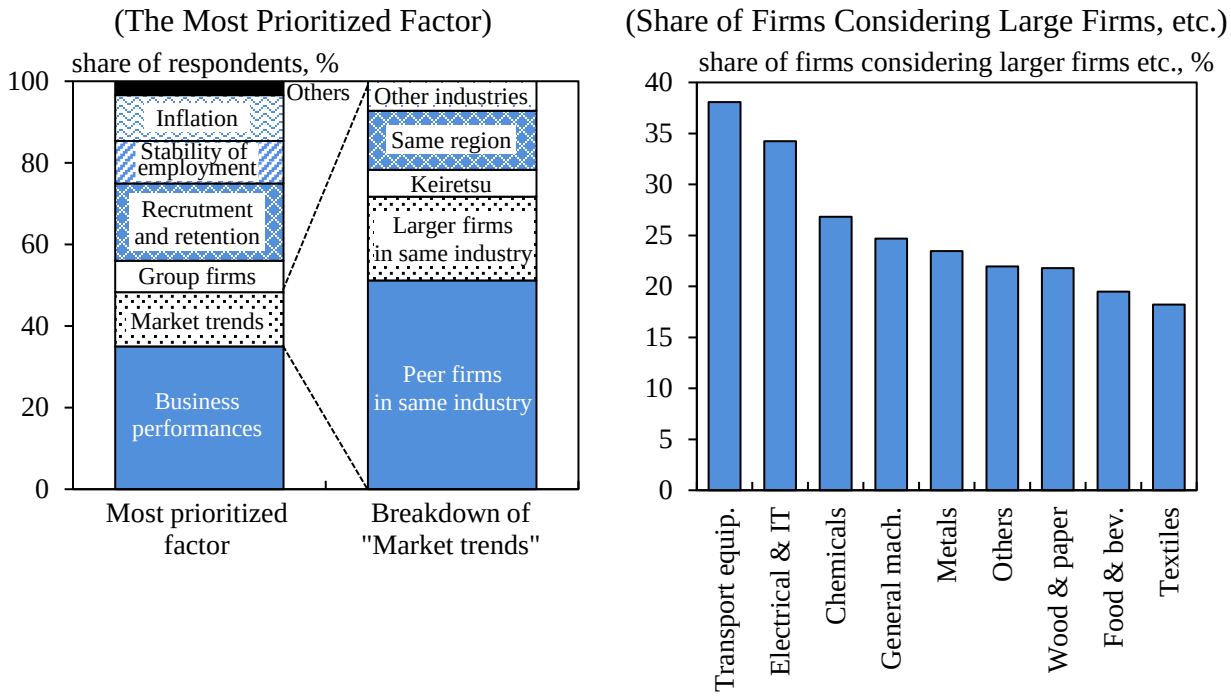
5. Linkages in Wage-Setting Behavior

Finally, this section examines the linkages in regular wages, adopting a framework similar to the one used earlier in this paper.

5.1. Linkages in Regular Wages

According to the SWI by the MHLW, many firms in Japan's manufacturing sector revise their regular wages by paying close attention to the trends of peer firms within the same industry (Figure 7). This highlights the strong awareness of uniformity often noted in wage determination within Japan's manufacturing sector. At the same time, a considerable number of firms—though varying by industry—also take into account the trends of larger firms within the same industry, affiliated firms, or group firms when determining wages. This suggests that wage-setting behavior for regular wages could be linked through supply chains, and the strength of this linkage may differ across industries. In the following section, we conduct a quantitative analysis of the linkages in regular wage-setting behavior along supply chains.

(Figure 7) Key Factors for Wage Revisions in Manufacturing Firms



Note: Figures are computed based on microdata from the SWI. The left panel shows the proportion of respondents from manufacturing firms who identified the factor most prioritized in the revision of regular wages (as of the 2024 survey). The right panel presents the proportion of respondents from manufacturing firms who cited at least one of the following factors as either "most prioritized" or "additionally prioritized" during the revision of regular wages: "larger firms in the same industry," "affiliated firms (keiretsu)," or "group firms," in the surveys conducted between 2010 and 2024. The industry classifications in the right panel are defined as follows: General machinery: General-purpose, production-use, and business-use machinery; Chemicals: Chemicals, plastics, petroleum and coal, rubber; Electrical & IT: Electrical machinery, information and communication machinery, electronic components and devices; Textiles: Textiles, leather; Wood & Paper: Wood and wood products, pulp and paper, printing; Metals: Steel, non-ferrous metals.
Source: Ministry of Health, Labour and Welfare.

(Estimation Equation)

The estimation equation for examining the linkages in regular wages is as follows:

$$\pi^{w}_{i(h),t} = \beta^{top}\pi^{w,top}_{i,t} + \beta^{c}\pi^{w,c}_{i,t} + \beta^{s}\pi^{w,s}_{i,t} + \alpha_{i(h)} + \delta_{k,t} + u_{i(h),t}, \qquad (5)$$

where $\pi^{w}_{i(h),t}$ represents the regular wage (year-on-year rate of change) of establishment h of firm i, derived from the BSWS. Additionally, $\pi^{w,top}_{i,t}$ indicates the average year-on-year rate of change in the regular wages of the focal firms in the supply chains to which firm i belongs. $\pi^{w,c}_{i,t}$ is the average year-on-year rate of change in the regular wages of firm i's customer firms, while $\pi^{w,s}_{i,t}$ is the average year-on-year rate of change in the regular wages of firm i's supplier firms. Since transactional relationships at the establishment level are not available, these explanatory variables are assumed to be the same across establishments within the same firm. $\alpha_{i(h)}$ represents establishment fixed effects, and $\delta_{k,t}$ denotes the industry-specific trend (industry-year fixed effects) for

industry k, to which firm i belongs (in 4-digit classification). It should be noted that the panel data on regular wages used in this section include fewer continuous samples than the BSJBSA used in the previous section, due to the annual rotation of surveyed establishments. Consequently, if lag terms for the explanatory variables are included, the number of observations decreases significantly. For this reason, lag terms for explanatory variables are not included in the estimation equation. In this case, as discussed in Section 4, caution is needed when inferring the causal direction of relationships between direct trading partners.

(Data)

The dependent variable in Equation (5), the year-on-year rate of change in regular wages at the establishment level, is constructed based on microdata from the BSWS. Since the sample for this survey is based on a two-stage stratified sampling of establishments and workers, the establishment-level regular wages and their year-on-year rates of change were calculated by taking a weighted average of individual workers' regular wages, using the worker inflation factor (sampling weight) as the weight.

The explanatory variables on the right-hand side, the year-on-year rates of change in regular wages at the firm level, were constructed by combining the microdata from the BSWS and the SWI. Since the BSWS tends to have a low second-stage worker sampling rate, particularly for large establishments with a high number of employees[12], the wage estimates for these establishments may contain sizable sampling errors. In this regard, while the SWI covers fewer firms, it targets all employees within each firm, resulting in improved data accuracy. Therefore, to enhance the precision of the data, wage revision rates from the latter survey are also used. Specifically, where wage revision rate[13] responses are available from the SWI, those values are used. If not, values from the BSWS are employed instead[14].

(Estimation Results)

The first column of Table 4 presents the estimation results for Equation (5). While the coefficients for customer and supplier firms (i.e., direct business partners) are not statistically significant, the coefficient for focal firms within the supply chains is significantly positive. This implies that, in the context of wage determination, linkages with focal firms play a more important role.

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[12] For example, in the 2025 BSWS, the sampling rate for regular employees in manufacturing establishments with 1,000 to 4,999 regular employees is set between 1/15 and 1/35, depending on the industry.
[13] To be precise, the value used is the wage revision rate minus the regular wage increase rate.
[14] When using the BSWS, the weighted average is calculated using the number of regular employees as the weight to convert the establishment-level wage change rate to the firm level.

(Table 4) Estimation Results of the Regular Wage Linkage

	Regular wage (yoy % chg.)			
Focal firms' regular wage (yoy % chg.)	0.190*	0.246*	0.278**	-0.013
	(0.099)	(0.132)	(0.125)	(0.107)
Customers' regular wage (yoy % chg.)	-0.082	-0.084		
	(0.053)	(0.053)		
Suppliers' regular wage (yoy % chg.)	-0.061	-0.061		
	(0.047)	(0.046)		
Other focal firms' regular wage (yoy % chg.)		0.522		
		(0.779)		
Establishment FE	Yes	Yes	Yes	Yes
Industry×Year FE	Yes	Yes	Yes	Yes
Observations	9,173	9,173	6,994	4,522
Sample	All establishments	All establishments	Primarily in transport equip. SC	Primarily in other SC

Note: The subsample of "Primarily in transport equip. SC" consists of establishments where the sales share to focal firms in the transport equipment industry exceeds the sales share to focal firms in other industries, based on the total of direct and indirect transactions. The subsample of "Primarily in other SC" consists of other establishments. Due to missing values in the year-on-year change in regular wages for both customers and suppliers, the total number of observations in the full sample is smaller than the sum of observations in the subsamples. All variables are windsorized at the upper and lower 2.5% percentiles. Figures in parentheses are clustered standard errors at the firm level. * and ** indicate 10% and 5% significance level, respectively. The sample period is from 2014 to 2024, during which panel data could be constructed using the BSWS.
Source: Ministry of Economy, Trade and Industry; Ministry of Health, Labour and Welfare; Teikoku Databank.

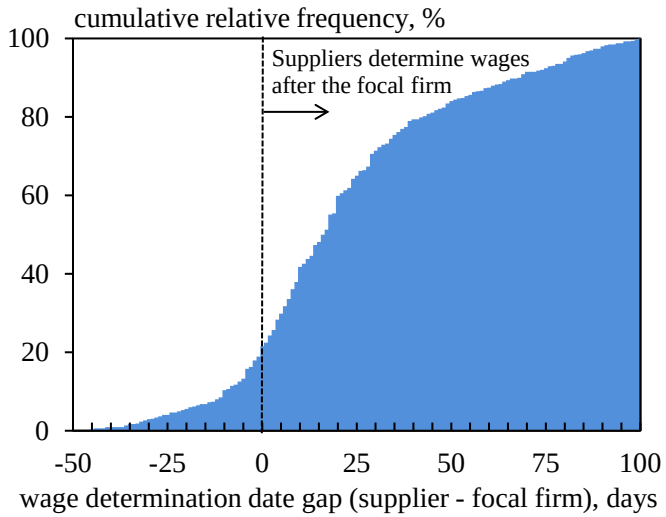
In the second column of Table 4, we include the additional control variable: regular wages of focal firms outside the firm's supply chain. In Japan's spring wage negotiations, it is well known that wage revision at a specific firm can influence other firms' wage revision (Ikeda et al., 2024). Therefore, the estimated coefficients for the focal firms in the first column may include the influence of wage-setting decisions by firms outside of the supply chain. To mitigate such effects, we add the regular wage growth rates of focal firms outside of the firm's supply chain as an additional control variable, in addition to the industry-year fixed effects. The estimates in the second column show that the coefficient for focal firms within the supply chain remains significantly positive. This confirms that the estimation results are robust even after adding the aforementioned control variable.

Figure 8 illustrates the distribution of differences between the wage determination dates of individual firms and those of their respective focal firms. It shows that the majority of firms determine their wages following their focal firms' decision. These results suggest that Japanese manufacturing firms are referencing the wage revisions set by their focal firms when making wage decisions.

In addition, to examine the heterogeneity of wage linkages with focal firms across industries, the third and fourth columns of Table 4 present the results of subsample estimations, where the sample is divided into two groups. Specifically, the third column focuses on firms mainly embedded in the supply chains led by transport equipment focal

firms ("Primarily in transport equip. SC"), while the fourth column focuses on firms outside this category ("Primarily in other SC")[15]. The results show that the coefficient is positive and statistically significant in the former subsample presented in the third column. This suggests that wage linkages between focal firms and their suppliers are particularly strong within the supply chains of transport equipment, such as the automotive sector.

(Figure 8) Wage Determination Dates for Focal Firms and Suppliers



Note: The cumulative relative frequency illustrates the differences in days between the wage revision determination dates of suppliers and their focal firms. These calculations are based on the microdata from the SWI. For firms that belong to the supply chains of multiple focal firms, the difference is calculated with reference to the focal firm for which the element of the Ghosh inverse matrix (representing the total sales share through direct and indirect transactions) is the largest. If firms provided their wage determination dates using ten-day units (dekads), the dates were converted as follows: the upper dekad = the 10th, the middle dekad = the 20th, and the lower dekad = the 30th. Only firms that reported wage determination dates within the months of March to June were included in the analysis.
Sources: Ministry of Economy, Trade and Industry; Ministry of Health, Labour and Welfare; Teikoku Databank.

5.2. Heterogeneity by Position within the Supply Chain

Next, we examine whether the strength of the linkages in regular wages with focal firms varies depending on a firm's position within the supply chains. The estimation equation is as follows:

$$\pi^{w}_{i(h),t} = \beta^{top}\pi^{w,top}_{i,t} + \gamma\pi^{w,top}_{i,t} \times \widetilde{APL}_i + \alpha_{i(h)} + \delta_{k,t} + u_{i(h),t}, \qquad (6)$$

where $\widetilde{APL}_i$ represents the average of the Average Propagation Lengths (APL) that measure the average distance between firm i and the focal firms of the supply chains to which it belongs. Here, APL is an index indicating the average number of transactions

[15] When calculating the explanatory variable regarding focal firms, in the subsample classified as "Primarily in transport equip. SC," the focal firms are exclusively transport equipment manufacturers, whereas in the subsample classified as "Primarily in other SC," the focal firms are exclusively non-transport equipment manufacturers.

linking firm i to its focal firm. To standardize, $\widetilde{APL}_i$ is adjusted by subtracting 1. For instance, if $\widetilde{APL}_i = 1$ for firm i, this implies that the firm, as a Tier 2 supplier, is on average connected to the focal firms through two transactions. Therefore, if the coefficient γ for the interaction term is significantly negative, it would indicate that the further a firm is positioned from the focal firm within the supply chain, the weaker the linkages in regular wages become.

The first column of Table 5 shows the estimation results for Equation (6), which indicates that the coefficient for the interaction term is negative and statistically significant. This implies that the regular wages of firms closer to the focal firms, such as Tier 1 suppliers, are strongly linked to the wages of the focal firms. However, for firms at Tier 3 or beyond, the linkages with the focal firm's wages approach zero. Additionally, as noted by Adachi et al. (2026), there is a negative correlation between APL and firm size. Nevertheless, even when controlling for the effect of firm size in the estimations presented in the second and third columns of Table 5, the estimated coefficient for the interaction term with APL remains significantly negative, suggesting the robustness of this result.

(Table 5) Position in the Supply Chain and Strength of Linkages

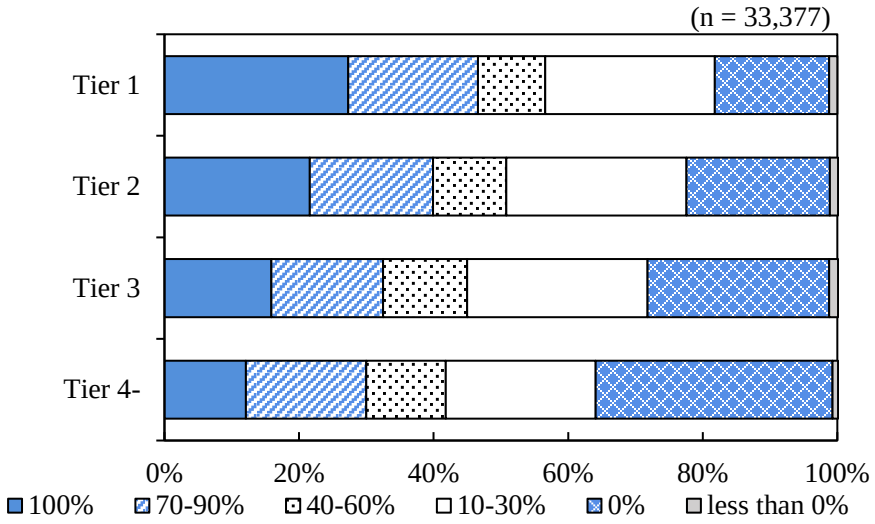
	Regular wage (yoy % chg.)		
Focal firms' regular wage (yoy % chg.)	0.334***	0.342***	0.288**
	(0.125)	(0.127)	(0.122)
Focal firms' regular wage (yoy % chg.)	-0.162**	-0.157**	-0.143*
×$\widetilde{APL}$	(0.075)	(0.074)	(0.078)
Focal firms' regular wage (yoy % chg.)		-1.29	
×Small enterprise dummy		(1.07)	
Focal firms' regular wage (yoy % chg.)		-0.044	
×Medium enterprise dummy		(0.110)	
Focal firms' regular wage (yoy % chg.)			1.81e-6
×Capital (100 mil. yen)			(2.33e-6)
Focal firms' regular wage (yoy % chg.)			4.06e-6
×Sales (100 mil. yen)			(8.75e-6)
Establishment FE	Yes	Yes	Yes
Industry×Year FE	Yes	Yes	Yes
Observations	11,516	11,458	11,458

Note: The dummy variables for small and midium-sized enterprizes take the value of 1 if the firm's capital is 100 million yen or less, or more than 100 million yen and up to 1 billion yen, respectively. All variables are windsorized at the upper and lower 2.5% percentiles. Figures in parentheses are clustered standard errors at the firm level. *, **, and *** indicate 10%, 5%, and 1% significance level, respectively. The sample period is from 2014 to 2024, during which panel data could be constructed using the Basic Survey on Wage Structure.
Sources: Ministry of Economy, Trade and Industry; Ministry of Health, Labour and Welfare; Teikoku Databank.

Various factors may underlie these results. A survey conducted by the Small and Medium Enterprise Agency in September 2024 highlights that as the distance from the final goods manufacturer increases within the transaction network, it becomes increasingly difficult to pass on rising costs onto prices (Figure 9). This weakness in price negotiation

power might have reduced the ability of firms more distant from focal firms to follow the wage hikes of those focal firms.

(Figure 9) Degree of Price Pass-Through by Tier



Note: The survey respondents are "small and medium-sized enterprises" as defined by the Small and Medium-sized Enterprise Basic Act (capital of 300 million yen or less, or 300 or fewer regular employees for the manufacturing industry). The figure represents the responses from these firms on how much of their overall cost increases over the past six months have been passed on to prices, categorized by each transaction stage (i.e., tier). The analysis excludes respondents who answered "price pass-through is unnecessary." A transaction stage (tier) refers to the responses to the question directed at the receiving small and medium-sized enterprises: "At which transaction stage are you located, counting from the firm that provides the final product or service?"

Source: Small and Medium Enterprise Agency, "Follow-Up Survey on Price Negotiation Promotion Month (September 2024)."

6. Conclusion

This paper empirically analyzes the linkages in firm spending behavior along supply chains in Japan's manufacturing sector, with a focus on capital investment and wage-setting, using firm-level production network data.

From the analysis presented in this paper, the following findings have emerged. First, within supply chains, temporary foreign demand shocks trigger the bonus linkages across firms. Additionally, broader linkages have been identified, revealing that the capital investment of firms can be influenced by downstream investment activity in supply chains, whether domestically or internationally. Furthermore, the determination of the regular wages of firms is shown to be affected by the wage setting of focal firms at the downstream end of their respective supply chains. Lastly, it is suggested that these linkages in corporate spending behavior exhibit considerable heterogeneity depending on the industry.

These results underscore the importance of analyzing firm behavior while taking into account the multilayered supply chain structure centered around large manufacturing firms in order to better understand Japan's economic dynamics. Looking forward, it will be important to expand the scope of data to include non-manufacturing sectors, such as service

industries and wholesale/retail businesses, and deepen the analysis of firm behavior linkages across broader fields.

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Appendix: Robustness Check of Investment Linkages

In this appendix, we examine the robustness of the findings on investment linkages presented in Section 4 by (1) replacing the target variable with investment spikes, as used in previous studies, and (2) accounting for capital relationships between firms.

A1. Linkages in Investment Spikes

Nirei (2024) is a pioneering work exploring the linkages of capital investment through supply chains using Japanese data, with a focus on the investment spike linkages. Following this study, we estimate the equation in Section 4, replacing the target variable—originally the year-on-year change in the I/K ratio—with investment spikes as follows:

$$Z_{i,t} = \beta_0^c Z_{i,t}^c + \beta_1^c Z_{i,t-1}^c + \beta_0^s Z_{i,t}^s + \beta_1^s Z_{i,t-1}^s + \beta_0^{top} Z_{i,t}^{top} + \beta_1^{top} Z_{i,t-1}^{top} + \gamma X_{t-1} + \alpha_i + \delta_{k,t} + \eta_{l,t} + u_{i,t},$$

where $Z_{i,t}$ denote a dummy variable indicating the occurrence of an investment spike for firm i in period t. It takes the value of 1 if the I/K ratio of firm i in period t is 20% or higher, and 0 otherwise. The explanatory variables on the right-hand side are constructed in the same manner as in Section 4.

Table A1 presents the estimation results, revealing a significant relationship with customer firms, including lagged terms, for investment spikes. In contrast, no correlation is observed with the focal firms, consistent with previous findings. These results appear robust, regardless of whether the analysis targets the I/K ratio or the investment spike dummy. Notably, however, the coefficient associated with supplier firms is significantly positive for the lagged terms in this specification, making a difference from the findings in the case of the I/K ratio.

(Table A1) Estimation Results of Investment Spike Linkages

	Investment spike dummy
Customers' investment spike ratio	0.0553***
	(0.0128)
Customers' investment spike ratio (1-year lag)	0.0230*
	(0.0122)
Suppliers' investment spike ratio	-0.0037
	(0.0075)
Suppliers' investment spike ratio (1-year lag)	0.0191**
	(0.0076)
Focal firms' investment spike ratio	-0.0028
	(0.0134)
Focal firms' investment spike ratio (1-year lag)	-0.0029
	(0.0128)
Profit rate (1-year lag)	0.0020*
	(0.0012)
Liquid asset ratio (1-year lag)	0.0001**
	(5.23e-5)
Firm FE	Yes
Industry×Year FE	Yes
Scale×Year FE	Yes
Observations	57,979

Note: Figures in parentheses are clustered standard errors at the firm level. *, ** and *** indicate 10%, 5%, and 1% significance levels, respectively. The sample period is from fiscal 2010 to 2023.
Sources: Ministry of Economy, Trade and Industry; Teikoku Databank.

A2. Impact of Capital Relationships

One possible reason for the synchronization of capital investment timing among firms could be that within a group of companies connected by capital relationships, the actual decision-making entity for capital investments is essentially the same. Here, we aim to confirm that the synchronization of capital investment behavior observed among trading partners in this study is not solely driven by such linkages through capital relationships.

Specifically, the following equation is estimated by splitting the year-on-year change in the I/K ratio of customers based on the presence or absence of capital relationships (parent-subsidiary relationships).

$$\Delta IK_{i,t} = \beta_0^{c,G}\Delta IK_{i,t}^{c,G} + \beta_1^{c,G}\Delta IK_{i,t-1}^{c,G} + \beta_0^{c,NG}\Delta IK_{i,t}^{c,NG} + \beta_1^{c,NG}\Delta IK_{i,t-1}^{c,NG} + \gamma X_{i,t-1} + \alpha_i + \delta_{k,t} + \eta_{l,t} + u_{i,t},$$

where $\Delta IK_{i,t}^{c,G}$ represents the year-on-year change in the I/K ratio of customers with capital relationships, and $\Delta IK_{i,t}^{c,NG}$ represents the year-on-year change in the I/K ratio of customer firms without capital relationships. These are defined as follows:

$$\Delta IK_{i,t}^{c,G} = \sum_{j \in C_i^G} \widetilde{w}_{i,j}\, \Delta IK_{j,t} \quad \text{and}$$

$$\Delta IK_{i,t}^{c,NG} = \sum_{j \in C_i^{NG}} \widetilde{w}_{i,j}\, \Delta IK_{j,t} = \Delta IK_{i,t}^{c} - \Delta IK_{i,t}^{c,G}.$$

Here, C_i^G (C_i^{NG}) denotes the set of customers of firm i that have (do not have) capital relationships with firm i. Similar estimations are also conducted for the investment spikes discussed in the previous subsection.

The identification of capital relationships between firms is based on the parent company information provided in the Basic Survey of Japanese Business Structure and Activities. Parent-subsidiary relationships are determined, and a capital relationship is deemed to exist when these relationships are directly or indirectly connected. Consequently, the analysis includes not only direct parent-subsidiary relationships but also relationships between grandparent companies and subsidiary companies, as well as between sibling companies. However, it is important to note that capital relationships that do not fulfill the definition of a parent company are excluded.

The estimation results in Table A2 suggest that the relationship in capital investment with customer firms exists regardless of the presence of capital relationships. This result indicates that the analysis in this study, which posits that trade relationships through supply chains generate linkages in capital investment, remains robust even after controlling for capital relationships.

(Table A2) Estimation Considering Capital Relationships

	I/K Ratio (yoy chg.)	Investment spike dummy
Affiliated customers' I/K ratio (yoy chg.) or investment spike ratio	0.1225**	0.0560***
	(0.0624)	(0.0174)
Affiliated customers' I/K ratio (yoy chg.) or investment spike ratio (1-year lag)	0.1583***	0.0127
	(0.0595)	(0.0160)
Non-affiliated customers' I/K ratio (yoy chg.) or investment spike ratio	0.0627*	0.0611***
	(0.0334)	(0.0191)
Non-affiliated customers' I/K ratio (yoy chg.) or investment spike ratio (1-year lag)	0.0490	0.0450**
	(0.0345)	(0.0197)
Profit rate (1-year lag)	0.0023**	0.0020*
	(0.0009)	(0.0012)
Liquid asset ratio (1-year lag)	0.0002***	0.0001**
	(4.37e-5)	(5.23e-5)
Firm FE	Yes	Yes
Industry×Year FE	Yes	Yes
Scale×Year FE	Yes	Yes
Observations	57,979	57,979

Note: The variables regarding I/K ratio (yoy chg.) are windsorized at the upper and lower 2.5% percentiles. Figures in parentheses are clustered standard errors at the firm level. ** and *** indicate 5% and 1% significance levels, respectively. The sample period is from fiscal 2010 to 2023.

Sources: Ministry of Economy, Trade and Industry; Teikoku Databank.