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Global Sourcing and Firm Inventory during the Pandemic***Hongyong ZHANG****Ha Thi Thanh DOAN[†]****Abstract**

Firms hold inventory to manage input shortages and stockout risks. This is particularly true for firms relying on international supply chains and imported inputs. Using a large-scale quarterly government survey of Japanese manufacturing firms (Q1 2015 – Q2 2021), we examine firm-level inventory adjustments to supply chain shocks and focus on firms that sourced inputs globally during the pandemic. We find that before the pandemic, relative to firms that purchase inputs only domestically, importing firms tend to have larger inventories (inventories over sales) in materials, work-in-process (intermediate goods), and finished goods, even after controlling for firm size. After the pandemic, importers significantly and persistently increased their inventories of intermediate inputs, especially in the case of firms with ex-ante higher import intensity and multinational firms that experienced supply chain disruptions in China. These results suggest the possibility of a shift from just-in-time to just-in-case production during the pandemic. We then discuss the role of inventories as a buffer against input shortages and other factors affecting inventory holdings, such as the prefecture-level severity of COVID-19 infections, industry-level input and output prices, and firm-level financial constraints and uncertainties regarding the economic and business outlook.

Keywords: Global Sourcing, Imports, Inventory, COVID-19

JEL classification: F14, F23

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1. Introduction

“Others do not have enough of their products in inventory to avoid running out of stock. The situation has been especially difficult for businesses with complex supply chains, as their production is vulnerable to disruption due to shortages of inputs from other businesses.”

The White House, Why the Pandemic Has Disrupted Supply Chains, June 17, 2021.

Firms hold inventory to manage delivery delays, input shortages, and stockout risks. This is particularly true for firms involved in international trade, which rely on global supply chains and imported inputs. Previous literature shows that importing firms have inventory ratios approximately twice those of firms that purchase materials only domestically (e.g., Alessandria, Kaboski, and Midrigan, 2010a). Supply chain disruptions during the pandemic have garnered wide attention from researchers and policymakers regarding the robustness and resilience of supply chains (e.g., Baldwin and Freeman 2020, Mircoudot 2020). Firms exposed to pandemic shortages and shipping bottlenecks have been forced to rethink their production and inventory management from just-in-time (JIT) to just-in-case (JIC).¹

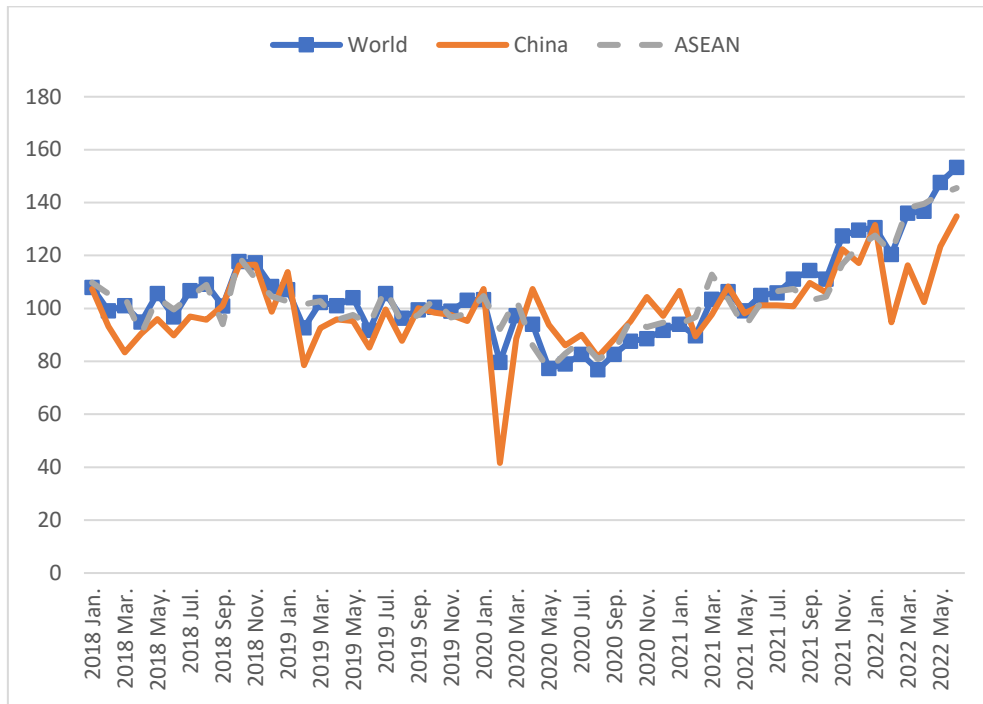
The pandemic has led to a severe disruption of the global supply chain and a sharp accumulation of inventories in the manufacturing industry. **Figure 1** shows the monthly movements of Japan’s import value index from January 2018 to June 2022.² Imports from China dropped sharply in February 2020 after Wuhan was under a lockdown and Covid-19 was rapidly spreading in China. Imports from China soon recovered, but imports from ASEAN countries were hit hard in May 2020 owing to the pandemic. More recently, imports from China declined again in early 2022 owing to the Shanghai lockdown. Supply chain disruptions have pushed the Japanese government and firms to reconsider their dependence on imported inputs (especially from China) and the robustness and resilience of their supply chains.

¹ Financial Times, “Supply chains: companies shift from ‘just in time’ to ‘just in case’” December 20, 2021. <https://www.ft.com/content/8a7cdc0d-99aa-4ef6-ba9a-fd1a1180dc82>. Accessed on November 2, 2022.

JIT production is a management practice that aims to minimize the time between orders. It allows firms to cut costs by placing small and more frequent order batches rather than carrying large stocks of inventories. JIT production was developed in the 1970s by Japanese car manufacturer Toyota (Ohno 1988) and it has been adopted worldwide over the last several decades. By contrast, JIC production is an inventory management strategy that focuses on keeping a large standing inventory. To reduce the risk of stockouts due to large-scale disruptions, firms adopt JIC strategies to build supply chain resilience.

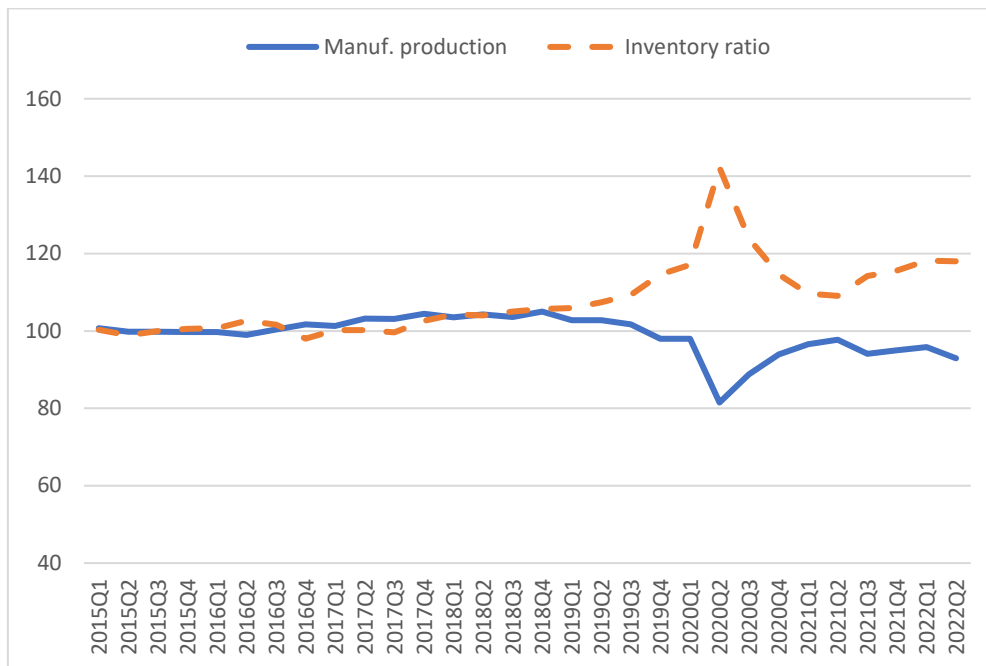
² Seasonally adjusted import value index by country and region is not available.

Figure 1. Supply chain disruptions: Japan's imports



Notes: The year 2015 is standardized to 100. Source: Trade Statistics of Japan, Ministry of Finance (MOF).

Figure 2. Production disruption and increasing inventories in manufacturing industries



Notes: The year 2015 was standardized at 100. The indices were seasonally adjusted. Source: Indices of Industrial Production (IIP), Ministry of Economy, Trade and Industry (METI).

Figure 2 shows the quarterly movements in Japan's manufacturing production and inventory ratio indices (seasonally adjusted) from Q1 2015 to Q2 2022. Manufacturing production was disrupted during Q1-Q2 2020 after the Japanese government took its first emergency measures in April-May in major economic regions. Meanwhile, inventories increased substantially and their magnitudes were much larger than the decline in production. The inventory ratio declined quickly after Q2 2020 but it increased again after early 2021. It is worth noting that the inventory ratio remains persistently high even though production recovered by 2021. In early 2022, the inventory ratio further increased, probably because of the Shanghai lockdown and the Russia-Ukraine war.

Inventory plays an important role in international trade. Because of delivery lags and lumpy trade, importers face severe inventory management problems (Alessandria, Kaboski, and Midrigan, 2010a). During the great trade collapse of 2008-09, international trade declined more drastically than production and inventories and showed a sizable adjustment, especially for imported goods (Alessandria, Kaboski, and Midrigan, 2010b). However, little is known about global sourcing and inventory adjustments in response to supply chain shocks at the firm level. In this study, we define global sourcing as the sourcing of intermediate inputs from suppliers in foreign countries and regions.³ Do importers tend to hold larger inventories of materials, work-in-process, and finished goods than firms that purchase inputs domestically (domestic firms or non-importers)? How do importers adjust their inventory in response to supply chain shocks? To hedge against potential supply chain disruptions, have importers increased their inventory after the pandemic? However, these issues remain largely unexplored. High-quality and timely data containing firm-level information on inventories and trade activities are lacking.

To fill this gap, we explore a large-scale quarterly government survey of Japanese manufacturing firms over the period Q1 2015–Q2 2021 and examine firm-level inventory adjustments in response to supply chain shocks during the pandemic, focusing on firms that source inputs globally. Our data contain detailed quarterly information on each firm's inventory of materials and supplies, work-in-process products, and finished goods. We find that before the pandemic, relative to firms that purchase inputs only domestically, importing firms tend to have higher inventory ratios (inventories over sales) in materials, work-in-process (intermediate goods), and finished goods, even controlling for firm size. Importantly, after the pandemic, importers significantly and persistently increased their inventories of intermediate inputs, especially for firms with ex-ante higher import intensity and multinational firms that experienced supply chain

³ We use global sourcing and imports of intermediate goods interchangeably.

disruptions in China. These results suggest the possibility of a shift from just-in-time to just-in-case production during the pandemic. We then discuss the role of inventories as a buffer against input shortages and other factors affecting inventory holdings, such as the prefecture-level severity of Covid-19 infections, industry-level input and output prices, and firm-level financial constraints and uncertainties regarding the economic and business outlook.

We contribute to the literature by providing evidence of firm-level adjustments to supply chain shocks and the relationship between global sourcing and inventory holdings, using Covid-19 as a case study. Japanese firms are famous for their well-organized JIT production systems and international production networks. Thus, they provide an ideal setting for studying firm-level responses (i.e., inventory adjustments) to supply chain shocks. Importantly, we examine whether and how the pandemic has changed firms' production and inventory management. Due to data constraints, we cannot observe whether a firm adopts JIT or JIC inventory. However, importing firms, especially those that rely heavily on imported inputs, and multinational firms that experience supply chain disruptions increase their inventories of intermediate inputs after the pandemic despite large carrying costs. To the best of our knowledge, this evidence of firm-level adjustments to supply chain disruptions is new and has not been documented elsewhere. Our study is expected to provide evidence-based policy implications for the debate on the robustness and resilience of supply chains, and the possible shift from JIT to JIC production systems post the pandemic.

Related literature: This study is related to three strands of literature. First, our focus on the relationship between trade and inventory dynamics is closely related to the work by Alessandria, Kaboski, and Midrigan (2010ab). Their key findings are that delivery lags and economies of scale in the transaction costs involved in international transactions lead importers to hold a much larger stock of inventories than domestic firms. International trade fluctuated more than production did during the global financial crisis, and inventories played an important role in these fluctuations.⁴ More recently, Lafrogne-Joussier, Martin, and Mejean (2022) found that French firms (engaging in both importing and exporting) with relatively high inventories ex-ante have been able to better absorb the supply shock from the Wuhan lockdown in China. Alessandria, Khan, Khederlarian, Mix, and Ruhl (2023) examine the aggregate effects of supply-chain disruptions in the post-

⁴ Carresras-Valle (2021) find that the increase in reliance on inputs from China explain the increase in inventories of U.S. manufacturing industries from 2005 to 2018. More generally, Blinder and Maccini (1991), Davis and Kahn (2008), and Ortiz (2021) document the relationship between inventories and macroeconomic volatilities.

pandemic period and show that firms optimally hold inventories that depend on the source of supply, domestic or imported. In contrast, we focus on manufacturing firms and study firm-level inventory adjustments to supply chain shocks during the pandemic to examine whether importing firms increased their inventories and possibly changed their inventory management post the pandemic.

Second, it relates to the growing literature on the impacts and propagation effects of exogenous shocks, such as the global financial crisis, the pandemic/epidemic, and natural disasters, on international trade and supply chains (e.g., Barrot and Sauvagnat, 2016; Boehm, Flaaen, and Pandalai-Nayar, 2019; Carvalho, Nirei, Saito, and Tahbaz-Salehi, 2021). In the case of the pandemic, Hayakawa and Mukunoki (2021) show that the exports of final goods decrease if an exporting country imports inputs from countries more seriously affected by Covid-19. Using quarterly data on Japanese multinational firms, Zhang (2021) finds significant negative impacts of Covid-19 on the performance of Japanese foreign affiliates, especially their sales and exports, in Q2 2020. However, few studies have examined the impact on inventory holdings and the relationship between supply chain disruptions and inventory adjustments, probably because of limited data availability.⁵

Third, our study relates to the broad literature on inventory management. Jain, Girotra, and Netessine (2014) find that an increase in global sourcing results in an increase in inventory investment. A 10% shift in sourcing from domestic to global suppliers increases inventory investment by 8.8%. Kesavan, Kushwaha, and Gaur (2016) examine the differences in the behaviors of high inventory turnover (HIT) and low inventory turnover (LIT) retailers in responding to demand shocks.⁶ Furthermore, Gao (2017) explored the role of the JIT inventory system in increasing the cash holdings of U.S. manufacturing firms.⁷ By contrast, we examine the role of inventory holdings during the pandemic and possible changes in firms' (especially importers') inventory management induced by the pandemic.

The remainder of this paper is organized as follows. Section 2 presents the conceptual framework

⁵ Jiang and Zhang (2022) find that the 2003 SARS shock in China reduced firms' markup and increased inventories and demand uncertainty substantially in the SARS-impacted areas. They did not study the case of importing firms.

⁶ They find that HIT retailers respond quickly by changing their purchase quantities in response to demand shocks, whereas LIT retailers primarily rely on price changes to manage demand shocks.

⁷ Recently, using pre-pandemic firm-level data from France and the US, Pisch (2020) and Ortiz (2021) documented the structure of international JIT supply chains and the role of lean inventory, respectively.

for the empirical analysis. Section 3 describes the data and reports descriptive statistics. Section 4 presents the empirical results for global sourcing and inventory holdings before and after the pandemic. Section 5 discusses the role of inventory during the pandemic and other factors affecting firms' inventory holdings. Finally, section 6 concludes the study.

2. Conceptual framework

In this section, we discuss the conceptual framework of the relationship between firm inventory and importing behavior and how Covid-19 affects inventory holdings when global sourcing and supply chains are disrupted.

First, firms participating in international trade and global sourcing face severe inventory management problems. There are nontrivial time lags between the order and delivery of goods in international trade (Hummel, 2001). Because of delivery lags and high transaction costs (document preparation, customs clearing, and port costs), it is optimal for importers to engage in international transactions infrequently (lumpy trade) to take advantage of economies of scale and hold substantial inventories of imported goods (Alessandria, Kaboski and Midrigan, 2010a).⁸ As foreign inputs become cheaper due to trade liberalization or other shocks (e.g., an increase in the productivity of foreign producers), firms choose to source more inputs from abroad, which leads to long delivery times and frequent delays. This increases firms' exposure to volatility in supply and demand, leading to a greater incentive to hold inventory (Carresras-Valle, 2021). Given the increasing imported inputs over the total inputs of Japanese manufacturing industries, especially from China, importing firms are expected to tend to have larger inventories than firms that purchase inputs only domestically. While Alessandria, Kaboski, and Midrigan (2010a) show that Chilean importers have inventory ratios that are roughly twice those of non-importers (similarly Carresras-Valle (2021) for U.S. manufacturing industries), we show that it is also present for Japanese manufacturing firms despite having a well-organized JIT production system and intensive sourcing from a neighboring country (China).

Second, holding (ex-ante) relatively large inventories of imported inputs may help importing firms avoid input shortages and stockout risks due to supply chain disruptions. The prevalence of Covid-19 in exporting (China) and importing (Japan) countries affects their supply chains. Supply chain disruptions between China and Japan negatively affected output through two channels: the supply chain effect and demand shock effect. The former refers to shortages in imported inputs

⁸ It may not be the case of perishable goods but most tradable goods are storable.

from China, and the resulting decline in domestic production in Japan. The latter occurs when the output in an importing country (Japan) decreases following a decline in consumption due to Covid-19. Thus, although all firms in the importing countries face demand shocks, supply chain disruptions are expected to decrease the output of importing firms relative to those purchasing only domestic inputs. In addition, on average, importers are larger than non-importers in terms of sales and employment (e.g., Kasahara and Lapham 2013 for Chilean firms; Sato, Zhang, and Wakasugi 2015 for Japanese firms) and thus, they may face larger demand shocks during the pandemic. Importing firms can expand their inventory holdings to mitigate these risks.

Third, supply chain disruptions provide firms, particularly importing firms, a great incentive to hold large inventories to hedge against another round of potential supply chain shocks. As previously discussed, importers hold large inventories because of delivery lags or delays and high international transaction costs. Such delivery lags or delays and transaction costs have increased substantially owing to Covid-19 infections, lockdown measures, export controls, and other restrictions during the pandemic. Thus, it is optimal for importing firms to hold large inventories even after their sales recover from supply chain and demand shocks. Furthermore, supply chain disruptions and demand shocks induce substantial increases in input and output prices, financial constraints, and uncertainties in economic and business outlooks. These factors may affect firms' inventory holdings and management practices. We examine these related factors in detail in Section 4.

3. Data and descriptive statistics

3.1 Data

To study the relationship between global sourcing, firm inventory, and inventory adjustments to supply chain disruptions during the pandemic, we utilize a unique dataset from a large-scale government survey of manufacturing and non-manufacturing firms in Japan. The survey is Financial Statements Statistics of Corporations by Industry (FSSCI) conducted by the Japanese Ministry of Finance (MOF). The data period is from Q1 2015 to Q2 2021 (26 quarters in total). This survey aimed to clarify the current status of corporations' business activities in Japan. Firms with capital of 500 million yen or more were selected. For those with capital less than JPY 500 million, an equal probability systematic sampling method was employed. We focus on manufacturing firms and construct a panel dataset with approximately 6,000 observations per quarter. This quarterly survey contains information on inventories, sales, capital investment, and the number of employees. Importantly, inventories can be divided into materials and supplies,

work-in-process (intermediate goods), and finished goods. Unfortunately, FSSCI data do not contain information on firms' international trade activities.

To obtain information on firms participating in global sourcing, we use our second dataset, the Basic Survey of Japanese Business Structure and Activities (BSJBSA) conducted by the Japanese Ministry of Economy, Trade, and Industry (METI). This annual dataset contains information about the business activities of Japanese firms and covers firms that employ more than 50 workers and have more than 30 million Japanese yen in total assets in the manufacturing, mining, wholesale, retail, and several service sectors. The data has been used elsewhere in studying the exporting and importing behaviors of Japanese manufacturing firms (e.g., Kimura and Kiyota, 2006; Sato, Zhang, and Wakasugi, 2015). We focus on manufacturing firms from fiscal years 2015 to 2019.⁹ Firms report the total import values by major regions (Asia, China, North America, Europe, the Middle East, and the rest of the world). Although the data are panel data, we need the pre-pandemic (ex-ante) importing status of each firm. We aggregate the data to the 2015-2019 average and define a firm as an importer if it is engaged in importing for at least two years from 2015 to 2019. Therefore, the importer dummy is time invariant in our baseline analysis. However, we cannot examine the interactions between the pandemic and firms' importing behavior (intensive and extensive margins). However, the merit is that we use ex-ante firm characteristics, which helps us avoid potential endogeneity issues. Furthermore, the BSJBSA data contain information on current assets, total assets, and current liabilities, which can be used to measure firms' financial constraints before the pandemic.

These two datasets can be matched using a common firm tax ID. The matching rate between our two main datasets is fair: (1) among 6,783 manufacturing firms in the FSSCI data, 56% (3,808) of firms can be matched with the BSJBSA; (2) the 3,808 matched firms account for approximately 28% ($=3,808/13,784$) of manufacturing firms in the BSJBSA; and (3) our matched sample accounts for more than 81% of total imports and 75% of inventories of manufacturing industries in the BSJBSA during the period 2015-2019. We also plot the aggregated annual imports and inventories, and confirm that the full and matched samples share the same time trend (see Figure A1 in the Appendix). The matched FSSCI-BSJBSA data can be used to compare the differences between importers and domestic firms and to analyze inventory adjustments during the pandemic.

Table 1 presents the summary statistics of the matched FSSCI-BSJBSA data used in the baseline

⁹ Fiscal year in Japan is from April to March.

estimations. The mean inventory ratio is 0.57 and the standard deviation is 0.6, suggesting large variations across firms. The average inventory ratios of the three types of inventories are 0.17 (materials and supplies), 0.15 (work-in-process), and 0.21 (finished goods) with considerable variation. Importers account for 25% of the sample. Owing to data availability, we do not know what is imported (i.e., intermediate and final goods).

Table 1. Summary statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
log(Inventory)	157,052	5.79	2.73	0	13.76
log(Inventory, materials)	157,052	4.39	2.68	0	13.01
log(Inventory, work in process)	157,052	3.70	2.98	0	13.14
log(Inventory, finished)	157,052	4.24	3.07	0	12.57
Inventory ratio	152,157	0.57	0.60	0	4.99
Inventory ratio, materials	152,156	0.17	0.21	0	1.51
Inventory ratio, work in process	152,157	0.15	0.26	0	2.05
Inventory ratio, finished	152,157	0.21	0.30	0	2.31
Importer	157,052	0.25	0.43	0	1
log(Employment)	152,385	4.85	1.80	0	11.41
log(Sales)	153,693	6.92	2.31	0	15.08
Sales growth	86,329	0.02	0.24	-0.65	1.70

Notes: Inventory values are in millions of yen. Inventory ratio is the ratio of inventory stock to sales.

Source: Authors' compilation based on the matched FSSCI-BSJBBSA dataset.

A potential concern regarding our matched FSSCI-BSJBBSA data is that a firm's import status is pre-pandemic and time-invariant. Although the 2019 fiscal year data in the BSJBBSA cover the first quarter of 2020 (i.e., the beginning of Covid-19), it is difficult to identify supply chain disruptions of imported inputs due to the pandemic. To address this potential concern, we focus on supply chain disruptions in multinational enterprises (MNEs) based on a subsample of our data. Specifically, we matched the FSSCI data with a third dataset containing quarterly information on the imports of Japanese MNEs from Q1 2015 to Q3 2020. We study MNEs because they account for a large share of international trade, world output, and employment (Antràs and Yeaple, 2014), and Japanese MNEs are no exception. Our third dataset comes from the Quarterly Survey of Overseas Subsidiaries (QSOS) collected by the METI. This survey covers Japanese foreign affiliates with 50 or more employees in the manufacturing industry.¹⁰ The QSOS data contain

¹⁰ Specifically, this survey targets overseas affiliates of Japanese parent firms that meet all of the following criteria by the end of the surveyed quarter: manufacturing affiliates; affiliates with 50 or more employees, and affiliates with 50% or more of their capital coming from parent firms, including both direct and indirect funds (such as funds provided via local affiliates).

information on foreign affiliates' host countries, industry classification, and total sales, which can be decomposed into local sales, exports to Japan, and exports to third countries. As a parent firm may have more than one manufacturing affiliate, we first aggregate the affiliates' exports to Japan at the parent firm level and then match it with FSSCI data using a common tax ID. We use these matched FSSCI-QSOS data to study inventory adjustments in response to supply chain disruptions in the case of MNEs.

To study how firms' perceptions of uncertainty affect their inventory holdings, we link our matched FSSCI-BSJBSA data (by common tax ID) with a fourth dataset, the Business Outlook Survey (BOS), jointly conducted by the MOF and the Cabinet Office of Japan. The data period is from Q1 2015 to Q2 2021. Similar to the FSSCI, this survey covers all large firms and a representative sample of small- and medium-sized firms in both manufacturing and non-manufacturing industries. The BOS asks about firms' expectations of their business (business outlook) and macroeconomic conditions (economic outlook) in the current quarter. There are four alternative responses (judgements): "improve," "no change," "deteriorate," and "unsure." It is worth mentioning that BOS asks firms to remove seasonality from their judgements. Using matched FSSCI-SBJBSA-BOS data, we discuss the relationship between uncertainty and inventory holdings, with a focus on importing firms.

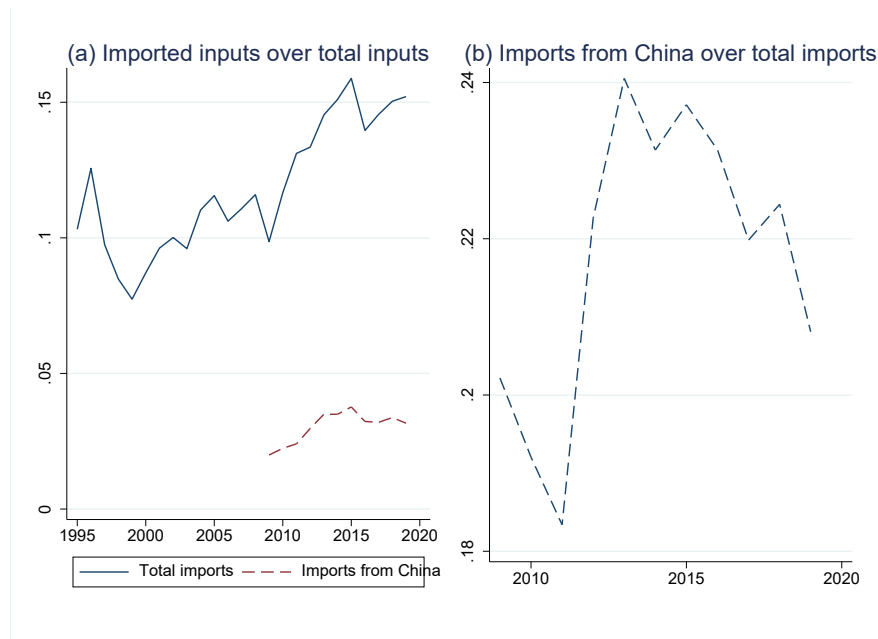
Finally, quarterly data on prefecture-level Covid-19 cases/deaths and their ratios to the population were obtained from the Ministry of Health, Labour, and Welfare of Japan. We also collected two-digit industry-level input and output price indices constructed by the Bank of Japan. The input price index measures the prices of raw and intermediate materials, fuel, and energy (including both domestic goods and imports), and the services consumed in each manufacturing process. The output price index covers the prices of products in each manufacturing sector (including domestic goods and exports, as well as both final and intermediate goods).¹¹ Alternatively, we use the import and producer price indices from Japan Customs and the Bank of Japan. We matched these macro indicators with the FSSCI-BSJBSA data to examine the severity of Covid-19 infections and changes in the input and output prices of inventories across importers and non-importers.

¹¹ These price indexes are constructed by calculating the input price index and the output price index for each sector of the manufacturing industry based on the Input-Output Table compiled by the Ministry of Internal Affairs and Communications. It is used to analyze short-term changes in input costs and price changes in output products in each sector. The base year is 2015 for both price indexes. Alternatively, we also use the import price index and producer price index but the results are quantitatively similar.

3.2 Descriptive evidence

This subsection presents descriptive evidence of the inventory and importing behaviors of Japanese firms before and after the pandemic. **Figure 3** shows the share of imported inputs over total inputs (Panel a) and the share of imports from China in the total imports (Panel b) of manufacturing firms. The share of imported inputs over total inputs increased from 10.3% in 1995 to 15.9% in 2015 and slightly declined to 15.2% in 2019. This trend suggests the emergence of global supply chains and the substitution of domestic inputs with foreign inputs. The increase is driven by the rise in imported inputs from China, which increased from 1.9% in 2009 to 3.8% in 2015 but declined to 3.2% in 2019. Panel A includes importers and non-importers. If we focus solely on the importers, these shares should be much larger. Panel B shows that China accounted for 20.2% of the total imports of manufacturing firms in 2009 and 20.8% in 2019.

Figure 3. Rise of imported inputs over total inputs

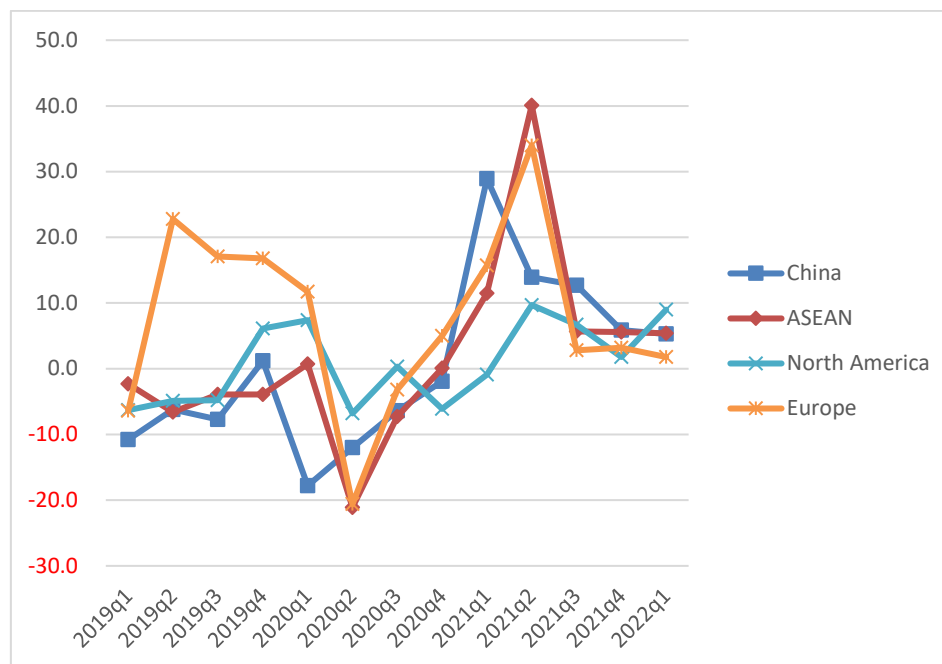


Notes: This figure shows the trend of imported inputs over total inputs and the trend of imported inputs from China over total imported inputs. Data on imports from China prior to 2009 are not available.
Source: Authors' compilation based on the BSJBSA.

The Covid-19 pandemic has disrupted Japanese firms' supply chains and imported inputs, especially in Q1-Q2 2020. **Figure 4** shows the year-on-year (y-o-y) changes in Japanese foreign affiliates' exports to Japan by region from Q1 2019 to Q1 2022. In Q1 2020, owing to the rapid spread of Covid-19 in China, exports from China to Japan decreased substantially by 17.8%.

Covid-19 shocks hit China-Japan trade hard, as the supply chains of Japanese firms rely heavily on China. In Q2 2020, exports from ASEAN and Europe to Japan fell sharply after the rapid spread of Covid-19 across the world.

Figure 4. Supply chain disruptions: the case of MNEs

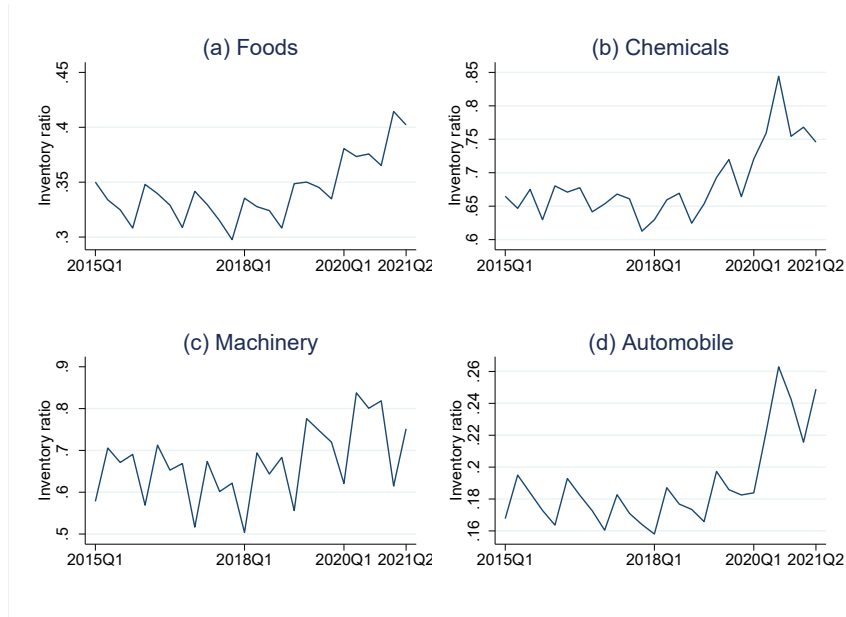


Notes: This figure shows the y-o-y changes (%) in Japanese foreign affiliates' exports to Japan from Q1 2019 to Q1 2022. Source: Authors' compilation based on the QSOS.

Figure 5 shows the seasonally adjusted inventory ratios for the four largest manufacturing industries: food, chemicals, machinery, and automobiles. These industries account for 55% of sales and 53% of inventories in the manufacturing industry (average for our sample period). Although the level of inventory held varies across industries, an increasing trend is observed. Although the inventory ratio was volatile, it significantly increased after the pandemic, particularly in the food, chemical, and automobile industries.¹²

¹² In the food industry, inventories in materials and work-in-process include frozen inputs such as frozen seafood products (unprocessed and packaged).

Figure 5. Rising inventories across industries



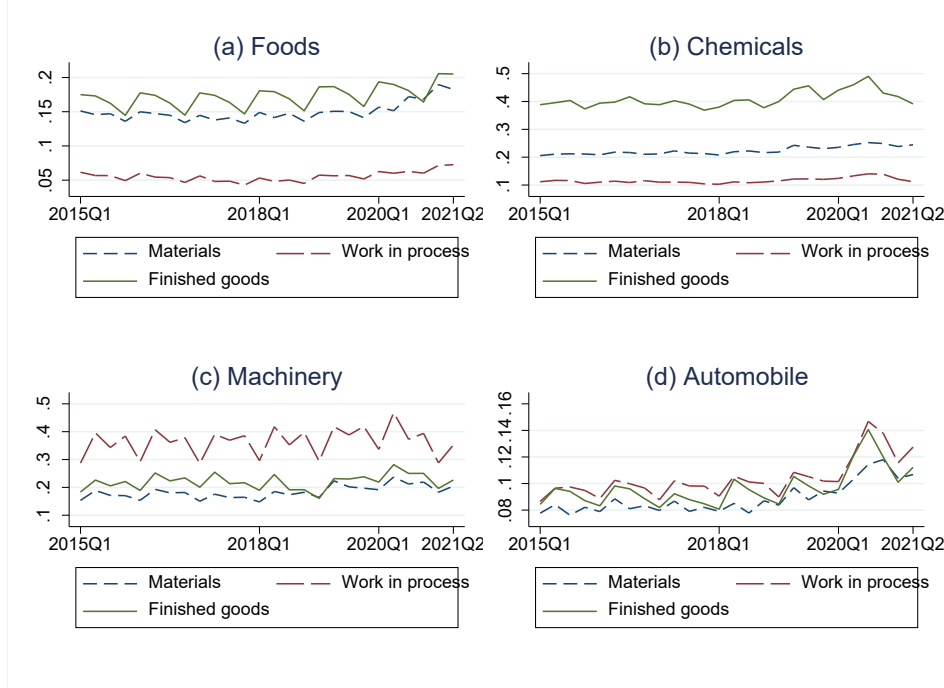
Notes: This figure shows the seasonally adjusted inventory-to-quarterly sales for the four largest and representative industries. Source: Authors' compilation based on the FSSCI.

Firms' inventories consist of three types: materials and supplies, work-in-process, and finished goods. On average, they represented 29%, 31%, and 40% of the total inventory during the sample period, respectively. As shown in **Figure 6**, it is worth noting that there are substantial heterogeneities across all three types of inventories within each industry. For example, in the automobile industry, with prevailing just-in-time production and inventory management, work-in-process inventories (intermediate goods) exhibited a sharp increase during the pandemic, suggesting the importance of parts and components in this industry.¹³ Figure A2 in the Appendix further shows that there are large variations in the inventories of intermediate goods across importers and non-importers in this industry in both pre-Covid and post-Covid periods.

¹³ This is also consistent with some media reports. For example, it is reported that compared to the pre-pandemic period (by year-end 2019), the inventories of automobile parts and components increased by 30% by the year-end of 2021. Due to worldwide supply constraints, automobile parts and components manufacturers significantly increased their inventories despite the rising carrying costs of larger inventories.

Source: Nikkei, <https://www.nikkei.com/article/DGXZQOUC240800U2A220C2000000/> (in Japanese). Accessed on November 2, 2022.

Figure 6. Rising inventories of intermediate goods in the just-in-time automobile industry



Notes: This figure shows the seasonally adjusted average inventory-to-quarterly sales for the three inventory types. Source: Authors' compilation based on the FSSCI.

4. Empirical analysis

4.1 Global sourcing and inventory holdings before the pandemic

This section examines the relationship between global sourcing and inventory holdings before the pandemic. Using a subsample of our matched FSSCI-BSJBSA data from Q1 2015 to Q4 2019, we estimate the following empirical equation:

$$Y_{it} = \alpha_0 + \alpha_1 IM_i + \gamma X_{it} + FE_{st} + FE_{rt} + \varepsilon_{it} \quad (1)$$

where Y_{it} is the log of inventories or inventory ratio of firm i in year-quarter t . The inventory ratio is defined as the ratio of inventories to total sales at the end of the quarter. As discussed previously, inventories can be decomposed into materials and supplies, work-in-process products, and finished goods. The dummy variable IM_i equals 1 if a firm has imports and 0 otherwise. We define a firm as an importer if it engages in imports for at least two years, from 2015 to 2019.¹⁴ X_{it} is a set of control variables such as firm size (number of employees). FE_{st} and FE_{rt} are industry-time and region (prefecture)-time fixed effects, respectively, to control for industry- or

¹⁴ Our results are quantitatively similar with alternative definitions, i.e., at least 1, 3, 4, 5 years.

region-specific macroeconomic shocks, such as growth rates. The coefficient of interest is α_1 . We expect α_1 is positive, suggesting that on average importing firms tend to have larger inventories relative to firms that purchase materials and inputs only domestically.

Table 2. Importing firms tend to have large inventories: Pre-pandemic

	(1)	(2)	(3)	(4)	(5)
	Total	Total	Materials	Work-in-process	Finished
Panel A: log(inventories)					
Importer	2.601*** (0.0486)	0.553*** (0.0322)	0.550*** (0.0450)	0.641*** (0.0634)	0.961*** (0.0616)
Firm size	No	Yes	Yes	Yes	Yes
Fixed effects	industry-time, region-time				
N	121822	118423	118423	118423	118423
R-sq	0.269	0.735	0.638	0.566	0.546
Panel B: Inventory ratio					
Importer	0.109*** (0.0122)	0.113*** (0.0132)	0.0237*** (0.00516)	0.0230*** (0.00676)	0.0591*** (0.00709)
Firm size	No	Yes	Yes	Yes	Yes
Fixed effects	industry-time, region-time				
N	118309	116100	116140	116104	116130
R-sq	0.074	0.074	0.040	0.124	0.094

Notes: The dependent variables are log inventories in Panel A and inventory ratio in Panel B. Firm size is log employment. The sample period is from Q1 2015 to Q4 2019. Standard errors are clustered at the firm level. Significance level: * 0.10 ** 0.05 *** 0.01.

Table 2 shows that on average importers always tend to hold more inventories relative to domestic firms. This is robust after controlling for firm size (log employment).¹⁵ Compared with domestic firms, importers have 55.3% larger inventories (column 2 in Panel A) and 11.3 percentage points higher inventory ratios (column 2 in Panel B). Importantly, relative to domestic firms, importers tend to have larger inventories across all three types of inventories, after controlling for firm size, industry-time fixed effects, and region-time fixed effects. Quantitatively, importers hold larger inventories in materials, work-in-process, and finished goods by approximately 2.37, 2.3, and 5.91 percentage points, respectively (Panel B). As a validation test, we use the pre-matched full sample of BSJBSA data and run similar regressions. As shown in Table A1 in the Appendix, the

¹⁵ Results based on balanced panel data are quantitatively similar.

results are quantitatively similar. While this relationship has been studied by Alessandria, Kaboski, and Midrigan (2010a) for Chilean firms, we show that it is also present for Japanese manufacturing firms.

4.2 Global sourcing and inventory adjustments post the pandemic

To examine whether and how Japanese firms' inventory management changed after the pandemic, we run the following regression:

$$Y_{it} = \alpha_0 + \alpha_1 IM_i + \alpha_2 IM_i \times Post_t + \gamma X_{it} + FE_{st} + FE_{rt} + \varepsilon_{it} \quad (2)$$

where Y_{it} is the inventory ratio of firm i in quarter year t . IM_i has been previously defined. $Post_t$ equals 0 before Q1 2020 and 1 in Q1 2020 and subsequent quarters. The coefficient of interest is α_2 and we expect that α_2 is positive. Relative to domestic firms, importing firms affected by supply chain disruptions tended to increase their inventory holdings post the pandemic. This effect was expected to persist until the end of the sample period (Q2, 2021).

Table 3. Importers increase inventories after the pandemic

	(1)	(2)	(3)	(4)
	Total	Materials	Work-in-process	Finished
Importer	0.112*** (0.0132)	0.0230*** (0.00516)	0.0223*** (0.00673)	0.0588*** (0.00708)
Importer*Post	0.0533*** (0.0112)	0.0148*** (0.00412)	0.0111** (0.00489)	0.0239*** (0.00539)
Firm size	Yes			
Fixed effects	industry-time, region-time			
N	149171	149168	149159	149173
R-sq	0.090	0.053	0.133	0.106

Notes: The dependent variables are inventory ratios in all columns. Firm size is log employment. The sample period is from Q1 2015 to Q2 2021. Standard errors are clustered at the firm level. Significance level: * 0.10 ** 0.05 *** 0.01.

The estimation results are reported in **Table 3**. The estimated coefficients of $IM_i \times Post_t$ are positive and statistically significant in all the columns. Importers had larger inventories and increased their inventory holdings after the pandemic. Quantitatively, importers increased their total inventory by approximately 5.33 percentage points post the pandemic. Similarly, importers increased their inventories of materials, work-in-process, and finished goods by approximately

1.48, 1.11, and 2.39 percentage points, respectively. The total magnitude of the materials and work-in-process is comparable to that of finished goods.

To investigate the dynamic effect of the pandemic on firms' inventory holdings, we estimate an extended version of Equation (2) by allowing Covid-19 to have a flexible quarterly effect on firm inventory. Specifically, we consider a full set of interactions between the importer dummy and the time dummies over our sample period and estimate the following equation:

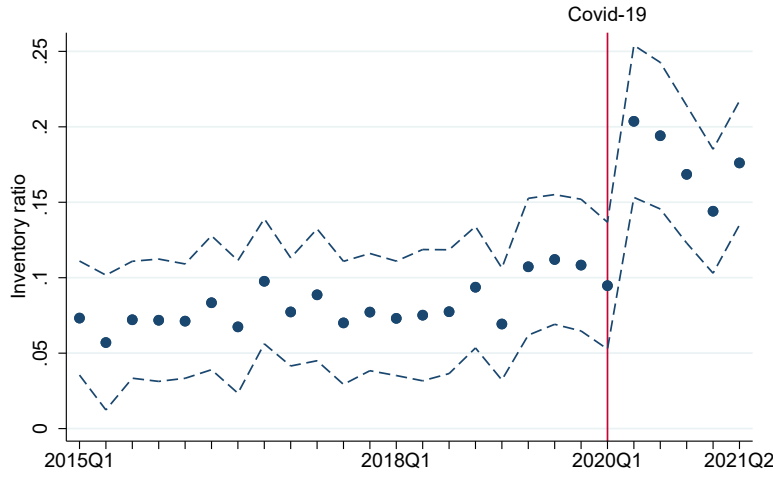
$$Y_{it} = \alpha_0 + \sum_{t=2015Q1}^{2021Q2} \alpha_1 IM_i \times D_t + \gamma X_{it} + FE_{st} + FE_{rt} + \varepsilon_{it} \quad (4)$$

where D_t is the quarter dummy and α_1 represent the differential inventory holdings of importing firms relative to domestic firms in year-quarter t .

Figure 7 shows the differences in inventory ratio changes between importing firms and domestic firms over time, by plotting a set of estimated coefficients from the regression of inventory ratio on $IM_i \times \alpha_1$ along with control variables including firm size and a full set of industry-time and region-time fixed effects. Although importers always had larger inventories than non-importers during the pre-pandemic period, the two groups were balanced in terms of parallel trends, indicating good comparability between importing and domestic firms, conditional on our selected controls. However, in the post-pandemic period, importers experienced a sharp and persistent increase in inventory ratio compared to domestic firms, indicating that the pandemic had a positive effect on inventory holdings in the former group. It is worth noting that inventories declined steadily after Q2 2020, suggesting the gradual recovery of demand and supply from the first Covid-19 shock. However, consistent with Figure 1, despite the recovery in production, inventories increased again in early 2021, because of the second and third emergency measures in Japan, increasing worldwide supply constraints, and perhaps most importantly, the great incentives to hold large inventories as buffers against potential supply chain disruptions.¹⁶

¹⁶ Another possibility is the potential effect of the Russia-Ukraine war that started in February 2022. Though the geopolitical risks might increase from 2021 or even earlier, we believe its effect on our results is small if any because our sample period is till Q2 2021, and Japanese importers have a lower reliance on imported inputs from these two countries. Nevertheless, we conduct robustness checks by (i) excluding firms importing from European countries (firm-level information on imports from Russia and Ukraine is not available) and (ii) excluding sectors, such as foods and chemicals, relying on imported agricultural goods, oils, and other resources. The results are quantitatively similar and available upon request.

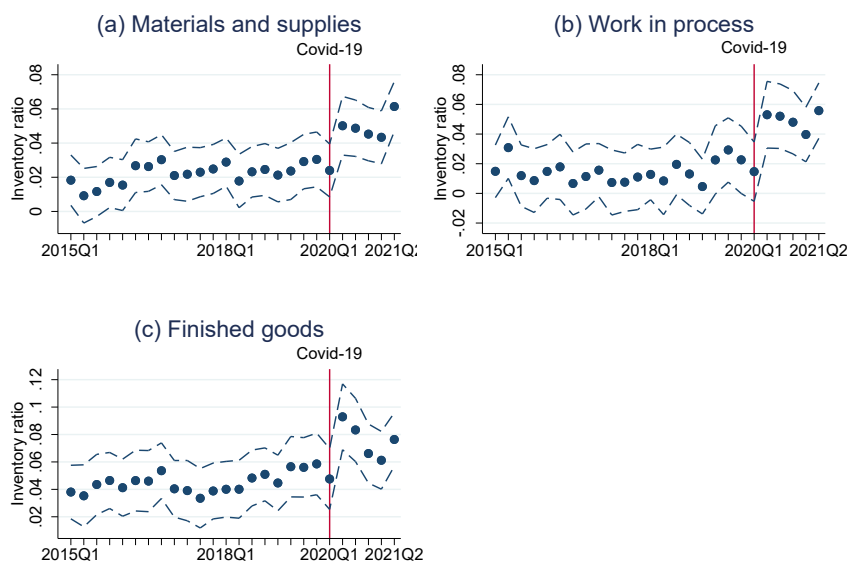
Figure 7. Importers increase inventories after the pandemic: importer-time estimates



Notes: This figure plots the estimates of the importer-time dummy variables for the period from Q1 2015 to Q2 2021, controlling for firm size, industry-time, and region-time fixed effects. Dotted lines represent the 95% confidence intervals.

As mentioned previously, inventories consist of materials and supplies, work-in-process products, and finished goods. As the pandemic combines the aspects of both supply and demand shocks, it may have heterogeneous effects on the three types of inventories. An increase in the inventory of finished goods suggests a negative demand shock. Meanwhile, a decline in the intermediate input inventory following a shock suggests a negative supply shock. **Figure 8** shows the differences in inventory ratio changes in materials and supplies, work-in-process, and finished goods, between importing firms and domestic firms over time, by plotting a set of estimated coefficients from the regression of inventory ratio on $IM_i \times \alpha_1$ along with control variables including firm size, industry-time, and region-time fixed effects. Consistent with Figure 7, importers significantly increased all three types of inventory. Notably, relative to the inventories of materials and intermediate goods, the inventories of finished goods declined quickly after the first Covid-19 shock, suggesting possible differences in inventory adjustments among the three types of inventories.

Figure 8. Importers increase all three types of inventories after the pandemic



Notes: This figure plots the estimates of the importer-time dummy variables for the period from Q1 2015 to Q2 2021, controlling for firm size, industry-time, and region-time fixed effects. Dotted lines represent the 95% confidence intervals.

There are potential concerns regarding our results that importers may increase their inventory after the pandemic. First, inventories could increase (decrease) due to shipping delays and a large increase in lead times for production inputs. According to the Institute for Supply Management (ISM) delivery time index, the average lead time for materials and inputs in the United States has increased by approximately 35 days. Alessandria, Khan, Khederlarian, Mix, and Ruhl (2023) develop a heterogeneous firm model to quantify the aggregate effects of supply-chain delays during the pandemic. In their model, firms use imported and domestically produced goods that take time to arrive after being ordered and are subject to fixed costs. However, the delay is expensive and uncertain. Firms also face idiosyncratic demand shocks; therefore, they optimally hold costly inventory to guard against stocking-out and missing sales.¹⁷ Our empirical results for manufacturing firms are consistent with Alessandria et al. 's (2023) theoretical predictions. In our estimations, we simply include industry-time and region-time fixed effects to control for the effects of shipping delays because we do not have firm- and industry-level information on lead time.

¹⁷ Alessandria, Khan, Khederlarian, Mix, and Ruhl (2023) quantitatively show that increases in shipping times are contractionary, raise prices, and increase stockouts, particularly for goods intensive in delayed inputs.

Second, a potential concern regarding inventory adjustment is that the inventory ratio increases if sales decline, even though inventories remain unchanged. To address this concern, we use the log of inventories as the outcome variable and re-run Equation (4), controlling for firm size: As shown in Figures A3-A4 in the Appendix, the increases in total inventories, inventories of materials, and intermediate goods in post-Covid period were even more significant without considering the changes in sales. Notably, the increase in finished goods inventories is not significant, implying that materials and intermediate goods (but not finished goods) account for a large part of firm-level inventory adjustments.

Finally, a related argument is that changes in the firm-level inventory ratio (i.e., inventory adjustment) are *intentionally* conducted by firms' inventory management or *unintentionally* induced by demand volatility. Here, we do not intend to distinguish between the two. Our aim is to examine whether firms relying on imported inputs increased their inventories after the pandemic relative to firms that only purchased their inputs domestically.

5. Discussion

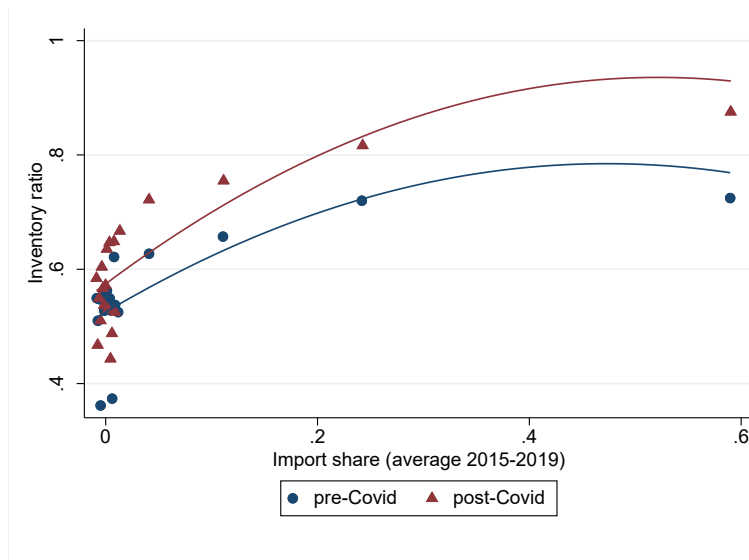
In this section, we first examine inventory adjustments to supply chain shocks across firms through (1) ex-ante import intensity and (2) supply chain disruptions between China and Japan. We then discuss (3) the role of inventory as a buffer against input shortages. We further discuss the potential factors affecting inventories, including (4) the prefecture-level severity of the Covid-19 infections, (5) industry-level input and output prices, (6) firm-level financial constraints, and (7) firm-level uncertainties over economic and business outlooks.

5.1 Import intensity and inventory holdings

In our baseline estimations, we used an importer dummy as the main variable. Because there are large variations in firms' exposure to supply chain disruptions, firms that rely heavily on imported inputs (particularly from China) are likely to have larger inventories. **Figure 9** shows the binned scatterplots of the relationship between *ex-ante* import share (defined as the average share of imported inputs in total sourcing from 2015 to 2019) and inventory ratio for the pre-Covid and post-Covid samples. There is a strong positive correlation between ex-ante import share and inventory ratio in both pre-Covid and post-Covid periods. Firms tended to increase their inventory holdings after the pandemic, especially those with higher ex-ante import shares. In the Appendix, we also show that inventories increase with ex-ante imports from China (Figure A5 of the

Appendix) and that all three types of inventories increase with ex-ante import intensity (Figure A6 of the Appendix). Importantly, the relationship between import share and inventory ratio is nonlinear, suggesting the existence of an optimal inventory level.

Figure 9. Inventories significantly increase with ex-ante imports after the pandemic



Notes: This figure plots the relationship between the ex-ante firm import share (imported inputs in total sourcing) and inventory ratio in the pre-Covid (Q1 2015 – Q4 2019) and post-Covid (Q1 2020 – Q2 2021) periods, controlling for industry-time and region-time fixed effects. Each dot indicates a bin of firm observations.

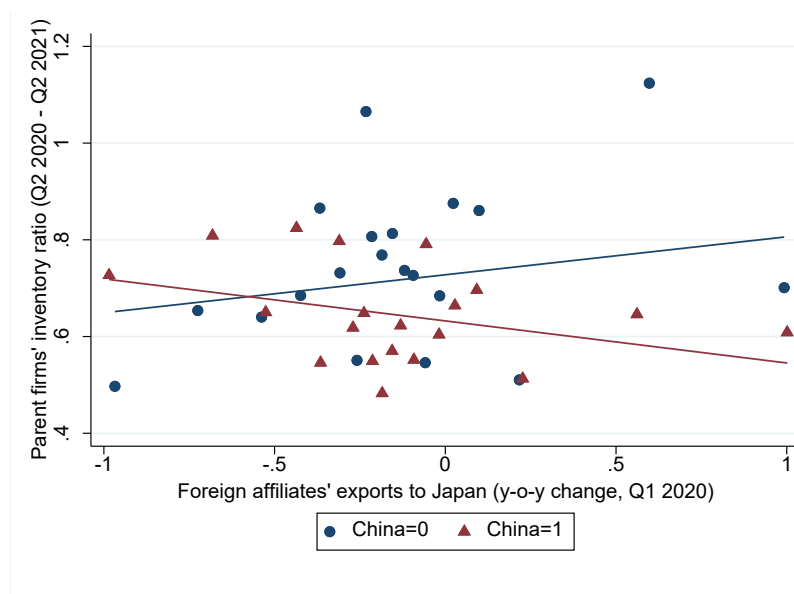
5.2 Supply chain disruptions and inventory holdings: the case of MNEs

As discussed previously, Japan's imports dropped sharply in Q1 2020, especially imports from China when Covid-19 spread fast in China and Wuhan was locked down. Using quarterly data on foreign affiliates' exports to Japan, we study inventory adjustments in response to the first shock of Covid-19 with a focus on MNEs. We hypothesized that MNEs that relied on imported inputs from China and experienced supply chain disruptions tended to increase their inventories after the recovery of their supply chains.

Figure 10 shows the relationship between supply chain disruptions and *ex-post* inventory holdings. The horizontal axis represents the y-o-y changes in foreign affiliates' exports to Japan in Q1 2020, and the vertical axis represents parent firms' inventories after Q2 2020. The red triangles and fitted lines show that the lower the growth of exports to Japan by manufacturing affiliates in China in Q1 2020, the larger the inventories held by parent firms after Q2 2020. In

other words, Japanese MNEs that experienced a sharp drop in sourcing inputs from China tended to increase their inventories after supply chain shocks. In contrast, the blue dots and fitted line show the opposite pattern: the higher the growth of exports to Japan by manufacturing affiliates in other countries in Q1 2020, the larger the inventories held by their parent firms after Q2 2020. These results suggest that supply chain disruptions during the early stages of the Covid-19 pandemic had a large and persistent effect on importer inventory management.

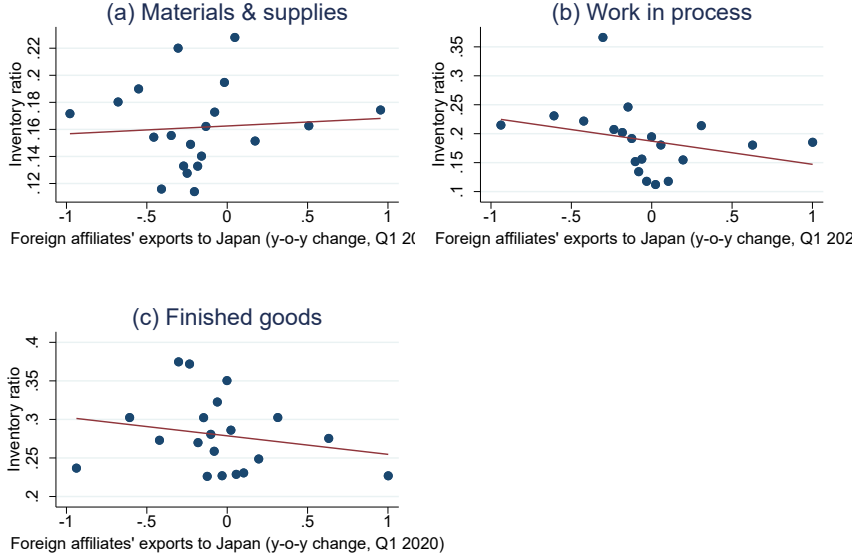
Figure 10. Supply chain disruptions in China led to an increase in inventories after the shock



Notes: This figure plots the relationship between the y-o-y changes in foreign affiliates' exports to Japan in Q1 2020 and parent firms' inventory ratios during Q2 2020 – Q2 2021, controlling for industry-time and region-time fixed effects. Each dot indicates a bin of parent firm observations.

Figure 11 further shows that after Japanese MNEs experienced supply chain disruptions of manufacturing affiliates in China in Q1 2020, parent firms in Japan tended to increase their inventories in work-in-process (intermediate goods) rather than materials and finished goods. This highlights the importance of imported intermediate inputs and global supply chains.

Figure 11. Supply chain disruptions in China led to an increase in intermediate goods inventories after the shock



Notes: This figure plots the relationship between the y-o-y changes in foreign affiliates' exports to Japan in Q1 2020 (the first Covid-19 shock in China) and parent firms' inventory ratios across three types of inventories during Q2 2020 – Q2 2021, controlling for industry-time and region-time fixed effects. Each dot indicates a bin of parent firm observations.

5.3 The role of inventories in the pandemic

Inventories are expected to play an important role in providing buffers against supply chain disruptions and input shortages. The previous study shows that among French firms exposed to the Chinese lockdown, those holding more inventories ex-ante performed better in the aftermath of the shock (Lafrogne-Joussier, Martin, and Mejean, 2022). To examine whether Japanese importers outperformed non-importers before and after the pandemic and the role of inventories in firm performance, we run the regression as follows:

$$Y_{it} = \alpha_0 + \alpha_1 IM_i + \alpha_2 IM_i \times Post_t + \alpha_3 Inventory_{it-1} + \alpha_4 Inventory_{it-1} \times Post_t + \alpha_5 IM_i \times Inventory_{it-1} + \alpha_6 IM_i \times Post_t \times Inventory_{it-1} + \gamma X_{it} + FE_{st} + FE_{rt} + \varepsilon_{it} \quad (3)$$

where Y_{it} is the logarithm of the sales of firm i in year-quarter t . $Inventory_{it-1}$ is the lagged one-period (quarter) inventory ratio. Alternatively, we used the ex-ante (pre-pandemic) average inventory ratio. We include a full set of interaction terms among the importer dummy IM_i , inventory ratio, and $Post_t$ to examine the heterogeneous effects of import status and inventory

holding levels.¹⁸

Table 4. Importers were hit by the pandemic but inventory holdings may mitigate the negative effect

Dep. var.: log(Sales)	(1)	(2)	(3)	(4)	(5)
		lagged inventory ratio		pre-Covid inventory ratio	
Importer	0.167*** (0.0223)	0.290*** (0.0291)	0.247*** (0.0304)	0.388*** (0.0298)	0.287*** (0.0313)
Importer*Post	0.00468 (0.0167)	-0.0340 (0.0226)	-0.0234 (0.0257)	-0.108*** (0.0229)	-0.0893*** (0.0261)
Inventory ratio			-0.0833*** (0.0149)		-0.194*** (0.0174)
Inventory ratio*Post			0.0258 (0.0195)		0.0400* (0.0217)
Importer*Inventory ratio		-0.201*** (0.0284)	-0.122*** (0.0317)	-0.311*** (0.0301)	-0.128*** (0.0343)
Importer*Inventory ratio*Post		0.0638*** (0.0210)	0.0396 (0.0278)	0.0625** (0.0260)	0.0249 (0.0330)
Firm size			Yes		
Fixed effects			industry-time, region-time		
N	150671	126384	126384	143394	143394
R-sq	0.848	0.852	0.853	0.849	0.850

Notes: The dependent variable is log sales in all estimations. Firm size is log employment. Inventory ratios are lagged by one quarter in columns (2)–(3) and the pre-Covid (Q1 2015 – Q4 2019) average in columns (4)–(5). The sample period is from Q1 2015 to Q2 2021. Standard errors are clustered at the firm level. Significance level: * 0.10 ** 0.05 *** 0.01.

Table 4 reports the estimation results. First, relative to domestic firms, importers have larger sales but the estimated coefficients of $IM_i \times Post_t$ are negative in columns 2-5, suggesting that importers were hit harder by the pandemic probably due to international supply chain disruptions. Second, firms with large inventories (lagged or pre-pandemic average) tend to have less sales before the pandemic but they tend to have more sales after the pandemic, suggesting the importance of holding inventories during the pandemic. This is also true for importers: the estimated coefficients of triple interaction terms $IM_i \times Post_t \times Inventory_{it-1}$ are positive and significant in columns 2 and 4, implying that importers holding large inventories tend to have more sales after the pandemic. These results suggest that holding inventories may help firms

¹⁸ $Post_t$ is not included (will be dropped) as we control for industry-time and region-time fixed effects.

mitigate the impact of Covid-19.

5.4 Covid-19 infections and lockdown policies

There are concerns that the demand and supply shocks induced by Covid-19 infections and lockdown policies may affect firms' inventory holdings. To address these potential concerns, we control for industry and region-time fixed effects in our estimation results. In this section, we use prefecture-level variations in the severity of the Covid-19 shock to examine how the pandemic influenced inventory holdings of importers and non-importers across the three types of inventory. Specifically, we used the prefecture-level number of newly confirmed Covid-19 cases and the number of deaths due to Covid-19 or their ratios to the population. Because the results were quantitatively similar, we only report the results for Covid-19 cases to save space. We further controlled for the lockdown policies in Japan. For example, the Japanese government implemented its first emergency measures from April to May 2020 in the major economic regions of Tokyo, Saitama, Chiba, Kanagawa, Osaka, Hyogo, and Fukuoka. These regions account for large shares of Japan's imports and outputs. Although it was a voluntary lockdown, most plants and stores were closed.¹⁹

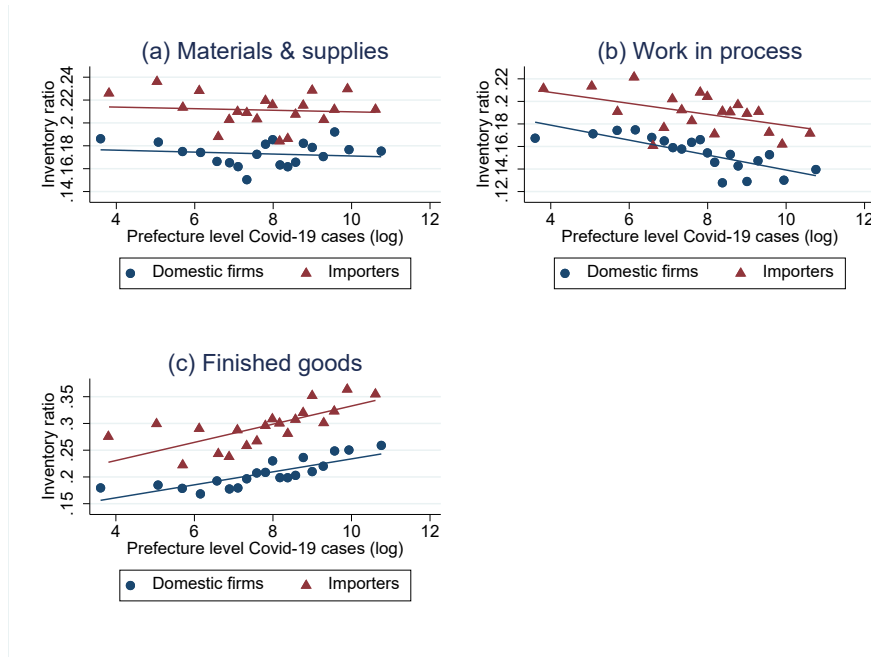
The results are shown in **Figure 12**. The horizontal axis represents prefecture-level Covid-19 cases (the logarithm of newly confirmed cases), and the vertical axis represents the inventory ratio of materials, work-in-process, and finished goods. The pandemic had heterogeneous effects on the inventories of intermediate (work-in-process) and finished goods. A decrease in intermediate goods inventories suggests a negative supply shock, whereas an increase in finished goods suggests a negative demand shock. After controlling for the prefecture-level severity of the pandemic, importers still had larger inventories than domestic firms (non-importers).

As our analysis is based on firm-level (as opposed to plant-level) data, one potential concern regarding our results is that the headquarters' location might not be the location of real production activities, as some firms may have more than one establishment in different regions of Japan. Although the FSSCI-BSJBSA data do not contain information on plant locations, the BSJBSA data report the number of manufacturing plants operated by each firm. Thus, we use this information and rerun our regressions on the subsample of single-plant firms (i.e., headquarters and plant

¹⁹ The emergency measures by Japanese government in Q2 2020 generated a large negative shock to firms located in regions that were targeted by emergency measures but much less shock to firms in other regions.

locations coincide). The results are presented in Figure A7 of the Appendix. As the figure indicates, the results are similar to those shown in Figure 12. In addition to intermediate goods, firm-level inventories of materials decreased with region-level Covid-19 cases, suggesting a negative supply shock to firms.

Figure 12. Finished goods inventories increased due to the demand shock while work-in-process inventories decreased due to the supply shock



Notes: This figure plots the relationship between prefecture-level Covid-19 cases (log) and the firm-level inventory ratio across the three types of inventory during Q2 2020 – Q2 2021, controlling for firm size, lockdown policies, industry, and time fixed effects. Each dot indicates a bin of firm observations.

5.5 Input and output prices

Firms' inventory holdings depend on input and output prices. First, inventories in materials are responsive to input prices because raw materials are usually homogeneous goods, reference-priced, and internationally traded on an organized exchange (Rauch, 1998). This means that an increase in the input price (a negative supply shock) during the pandemic does not necessarily incentivize firms to hold more inventory in materials. Second, relative to raw materials, intermediate goods are not responsive to input prices because trade in intermediate inputs is more relationship specific. Price elasticity may remain relatively low when firms face changes in input prices (negative or positive supply shocks) during the pandemic. Third, firms respond to an

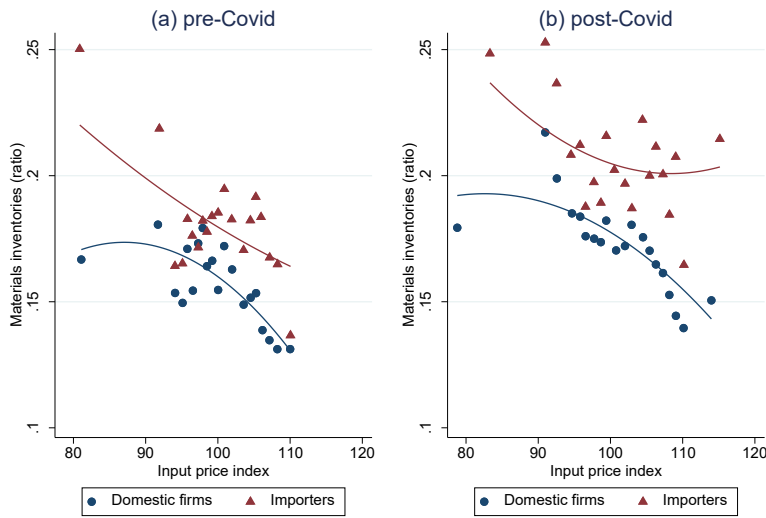
increase in output price (positive demand shock) by selling their finished goods and to a decrease in output price (negative demand shock) by reducing inventories of finished goods and cutting carrying costs. Thus, firms may adjust their inventories of materials, intermediate goods, and finished goods differently according to input and output prices.

The input and output price indexes in Japan significantly declined in 2020 due to the pandemic, but they began to soar from the beginning of 2021, accompanied by increasing prices of resources and imported inputs and the recovery of the world economy. The data on inventories and output (sales) used in our analysis are of monetary value, and unfortunately do not contain information on quantity and price. In our main estimation results, we control for industry- and region-time fixed effects to address the potential effects of input and output prices. To examine price effects on inventories, we consider the effects of industry-level input and output prices on firm-level inventory holdings.

Figures 13-14 show the relationship between *input* price and inventories in materials and work-in-prog, and **Figure 15** shows the relationship between *output* price and inventories in finished goods. The relationships between inventories and input/output prices are nonlinear, and there are significant differences across importers and domestic firms.

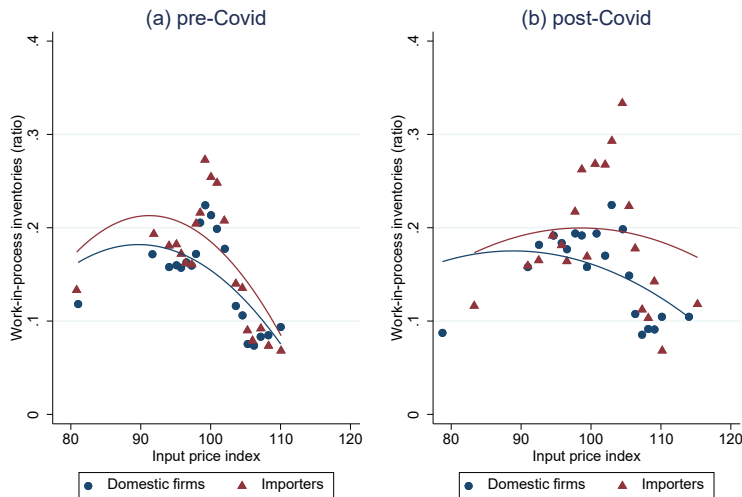
First, Figure 13 shows that the inventories of materials decrease with input price, suggesting the responsiveness of raw materials to input prices. However, for importers, the fitted lines were relatively flat in the post-Covid period relative to the pre-Covid period. Second, as shown in Figure 14, the inventories of intermediate goods decreased significantly when the input price index reached 100 for both importers and domestic firms in the pre-Covid period. However, this was not the case during the post-Covid period. The inventories of intermediate goods held by importers do not decline significantly with the input price, suggesting the possibility of holding inventories as a buffer against input price risks.

Figure 13. Inventories in materials decreased with input price during the pandemic



Notes: This figure plots the relationship between the industry-level input price index and firm-level inventories of materials and supplies in the pre-Covid (Q1 2015 – Q4 2019) and post-Covid (Q1 2020 – Q2 2021) periods, controlling for firm size, region, and time fixed effects. Each dot indicates a bin of firm observations.

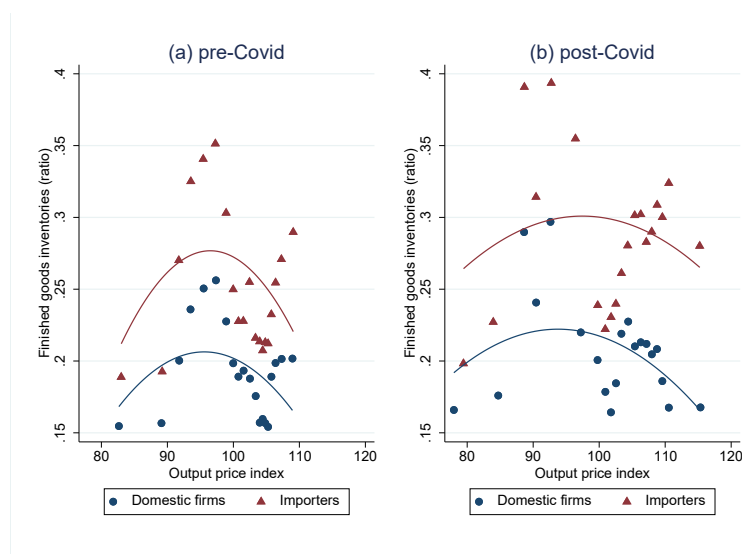
Figure 14. Inventories in intermediate goods did not decrease significantly with input price during the pandemic



Notes: This figure plots the relationship between the industry-level input price index and firm-level inventories in intermediate goods in the pre-Covid (Q1 2015 – Q4 2019) and post-Covid (Q1 2020 – Q2 2021) periods, controlling for firm size, region, and time fixed effects. Each dot indicates a bin of firm observations.

Finally, Figure 15 indicates that there is a strong non-linear relationship between output price and inventories of finished goods for both importer and domestic firms in both the pre-Covid and post-Covid periods. Inventories of finished goods are more sensitive to output price: they first increase quickly and then decrease rapidly with output prices. These results suggest that inventory adjustment for finished goods is more sensitive to price than it is to intermediate goods.²⁰

Figure 15. Importers' finished goods inventories decrease with the output price



Notes: This figure plots the relationship between the industry-level output price index and firm-level inventories of finished goods in the pre-Covid (Q1 2015 – Q4 2019) and post-Covid (Q1 2020 – Q2 2021) periods, controlling for firm size, region, and time fixed effects. Each dot indicates a bin of firm observations.

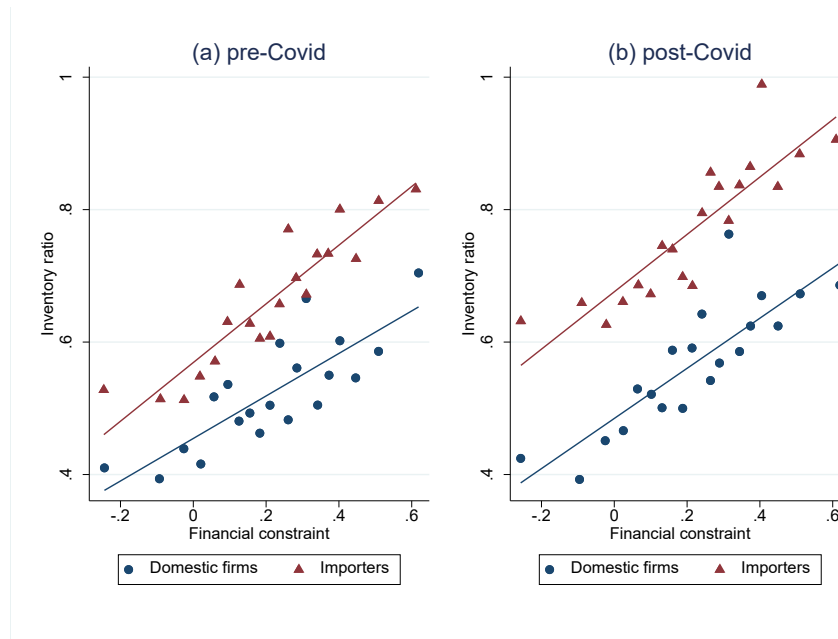
5.6 Financial constraints and inventory holdings

Holding larger inventories incurs higher costs. Thus, a firm's inventory level depends on its financial constraints. This is important, as firms' financial conditions deteriorated, and financially constrained firms were hit hard during the pandemic. To address the heterogeneous effects of the financial constraints faced by firms, we use pre-pandemic financial data to calculate the difference between current assets and liabilities (scaled by total assets) as a measure of firm-level financial constraints. The smaller the ratio, the greater the financial constraints faced by a firm.

²⁰ We find quite similar patterns when we use import price index for inventories in materials and intermediate goods, and producer price index for inventories in finished goods. The results are available upon request.

Figure 16 illustrates the relationship between financial constraints and inventory holdings. The horizontal axis represents financial constraints and the vertical axis represents the inventory ratio before and after Q1 2020. Inventories decreased with financial constraints for both importers and non-importers in both periods. Importantly, given the same level of ex ante financial constraints, firms, especially importers, tended to hold larger inventories in the post-Covid period than in the pre-Covid period.

Figure 16. Inventories decrease with financial constraints



Notes: This figure plots the relationship between financial constraints and inventory ratio in the pre-Covid (Q1 2015 – Q4 2019) and post-Covid (Q1 2020 – Q2 2021) periods, controlling for firm size, region, and time fixed effects. Each dot indicates a bin of firm observations.

5.7 Firm-level uncertainty and inventory holdings

The Covid-19 pandemic has created an enormous uncertainty shock and caused a large fraction of the contraction in economic activities (U.S. real GDP) (Baker, Bloom, Davis, and Terry, 2020). In Japan, an increase in firm-level uncertainty (uncertainty about the business or economic outlook) is negatively associated with investment (Morikawa, 2022). However, recent studies also show that firm-level uncertainty and economic policy uncertainty are positively correlated with current assets, such as cash holdings and inventory holdings.²¹ Dbouk et al. (2020) show that

²¹ Khan and Senga (2019) find that uncertainty faced by firms (sales volatilities) positively correlated

Economic Policy Uncertainty (EPU) drives high inventory levels in US manufacturing firms, thus corroborating existing theories about random disruptions raising safety stock levels. Notably, the outbreak of Covid-19 in late January 2020 led to a substantial increase in the subjective uncertainty of Japanese firms, especially for firms that have direct exposure to China through imported inputs (Chen, Senga, and Zhang, 2021). Importers are expected to increase their inventories as a buffer against great uncertainties in supply chains.

Motivated by this, we examine whether an increase in uncertainty could explain the increase in inventory holdings, especially for importers, during the pandemic. Following Morikawa (2022), we use firms' responses "unsure" about their business outlook (BO) and domestic economic outlook (EO) as a measure of uncertainty faced by firms.²² Figure A8 in the Appendix depicts the movements of the share of firms unsure about their business outlook and the share of firms unsure about their economic outlook. Both shares increased significantly in Q2 2020 when Covid-19 spread fast and the first "State of Emergency" measures were taken in Japan. In Q2 2020, about 30% of the firms were unsure of their business and economic outlooks. The shares declined significantly but remained high until the end of our sample (Q2 2021). We estimate whether the uncertainty over the one-quarter-ahead ($t+1$) business outlook or the economic outlook at the time of survey (t) is associated with the realized inventory ratio one-quarter-ahead ($t+1$). We include an interaction term between the uncertainty dummy and the importer dummy to explore the differences in inventory holdings under uncertainty between importers and domestic firms. We control for firm and time fixed effects. Because the importer dummy is time-invariant, it is dropped from the estimations.

Table 5 shows that the uncertainty of business condition (unsure BO) is positively correlated with inventory holdings (column 1) but is not statistically significant. However, the estimated coefficient of the interaction term between unsure BO and importer is positive and statistically significant in column 6, suggesting that importers tend to increase their inventories under uncertainty in business outlook. In contrast, the uncertainty in the economic outlook does not significantly affect importers' inventory holdings. We further estimate the effects of uncertainty across three types of inventories.

with cash holdings of publicly listed firms in Japan.

²² As Morikawa (2022) points out, the concept of uncertainty can be classified into (1) risk or Bayesian uncertainty when the probability is known and (2) ambiguity or Knightian uncertainty when the probability is unknown. Thus, our measure reflects Knightian uncertainty.

Table 5. The uncertainty faced by importers increases inventories

	(1)	(2)	(3)	(4)	(5)	(6)
Unsure BO	0.00461 (0.00510)		0.00740 (0.00628)	-0.00209 (0.00778)		-0.00457 (0.00933)
Unsure EO		-0.000677 (0.00483)	-0.00494 (0.00591)		0.000472 (0.00649)	0.00313 (0.00771)
Unsure BO*Importer				0.0136 (0.0100)		0.0269** (0.0125)
Unsure EO*Importer					-0.00236 (0.00938)	-0.0192 (0.0117)
Fixed effects	firm, time					
N	57516	54105	54105	57516	54105	54105
R-sq	0.796	0.800	0.800	0.796	0.800	0.800

Notes: The dependent variable is the inventory ratio one-quarter ahead (t+1) in all estimations. BO = Business Outlook, EO = Economic Outlook. Unsure BO and unsure EO are the uncertainties firms face over a one-quarter-ahead (t+1) business or economic outlook at the time of the survey (t). The sample period is from Q1 2015 to Q2 2021. Standard errors are clustered at firm level. Significance level: * 0.10 ** 0.05 *** 0.01.

Table 6 presents the estimation results. Columns 4 and 6 in Panel B show that the estimated coefficient on the interaction term between unsure BO and importers is positive and statistically significant. These results suggest that under uncertainty, importers tend to increase their inventories of intermediate goods rather than materials and finished goods. This finding provides evidence of the importance of intermediate inputs and supply chains during the pandemic.

Table 6. The uncertainty faced by importers increases work-in-process inventories

	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Materials and supplies						
Unsure BO	0.00244 (0.00163)		0.000573 (0.00190)	0.00175 (0.00248)		-0.000522 (0.00272)
Unsure EO		0.00312** (0.00156)	0.00279 (0.00183)		0.00368 (0.00246)	0.00398 (0.00271)
Unsure BO*Importer				0.00141 (0.00326)		0.00254 (0.00380)
Unsure EO*Importer					-0.00114 (0.00311)	-0.00273 (0.00360)
N	57421	54018	54018	57421	54018	54018
R-sq	0.858	0.864	0.864	0.858	0.864	0.864
Panel B: Work in process						
Unsure BO	0.00232 (0.00250)		0.00445 (0.00333)	-0.00312 (0.00344)		-0.00219 (0.00460)
Unsure EO		-0.00144 (0.00206)	-0.00401 (0.00279)		-0.00342 (0.00262)	-0.00213 (0.00368)
Unsure BO*Importer				0.0111** (0.00493)		0.0145** (0.00659)
Unsure EO*Importer					0.00407 (0.00406)	-0.00509 (0.00557)
N	57394	53988	53988	57394	53988	53988
R-sq	0.842	0.848	0.848	0.842	0.848	0.848
Panel C: Finished goods						
Unsure BO	0.00383 (0.00249)		0.00419 (0.00321)	0.00155 (0.00332)		0.00149 (0.00441)
Unsure EO		0.00225 (0.00233)	-0.000163 (0.00304)		0.000492 (0.00315)	-0.000248 (0.00419)
Unsure BO*Importer				0.00464 (0.00487)		0.00576 (0.00633)
Unsure EO*Importer					0.00361 (0.00461)	-0.000226 (0.00602)
N	57558	54156	54156	57558	54156	54156
R-sq	0.854	0.860	0.860	0.854	0.860	0.860

Notes: The dependent variables are the inventory ratios for all estimations. BO = Business Outlook, EO = Economic Outlook. Unsure BO and unsure EO are the uncertainties firms face over the one-quarter-ahead (t+1) business or economic outlook at the time of the survey (t). Firm and time fixed effects are included in all panels and columns. The sample period is from Q1 2015 to Q2 2021. Standard errors are clustered at the firm level. Significance level: * 0.10 ** 0.05 *** 0.01.

6. Conclusion

Inventory management is important for firms participating in international trade and relying on imported inputs. Using the Covid-19 pandemic as a case study, this study examines the firm-level relationship between global sourcing and inventory holdings, and firm-level adjustments to supply chain disruptions. We utilize a large dataset of Japanese manufacturing firms covering both pre-Covid and post-Covid periods. Relative to firms that purchase inputs domestically only, importing firms tend to hold larger inventories, even when controlling for firm size. This result is consistent with previous studies on Chilean firms. More importantly, after the shock, importers reacted to potential input shortages by increasing their inventories of materials, intermediate inputs, and finished goods. This is more prominent for firms with higher ex-ante import intensity and multinational firms that experienced supply chain disruptions in China. These results suggest the possibility of a shift from just-in-time to just-in-case production during the pandemic. We further discuss the role of inventories as a buffer for firm performance and the various factors affecting inventory holdings, such as the severity of the Covid-19 infections, input and output prices, financial constraints, and economic and business uncertainties faced by firms.

These findings have important policy implications. Inventories can act as buffers against supply chain disruptions and input shortages during pandemics and other supply chain shocks. However, increasing inventory is accompanied by increasing costs, which are crucial for firms with financial constraints. As shown in Figure 16, inventories decrease significantly with financial constraints. Thus, policies that relax financial constraints are required. More importantly, policies in the post-pandemic era should support business efforts to build robust and resilient supply chains. It is also worth noting that because our sample period is until Q2 2021, it is premature to conclude that manufacturing firms have completely shifted from JIT to JIC production. It is necessary to monitor firm-level inventory adjustments and the macroeconomic inventory cycle.

There are some rewarding avenues for future studies. First, due to data availability, we cannot examine the possible changes in sourcing behaviors after the shock, such as intensive margins, extensive margins, foreign sourcing, and domestic sourcing. Second, increasing inventory involves considerable carrying costs and possible production inefficiencies, which may affect firm-level productivity and business cycles. We leave these questions for future research.

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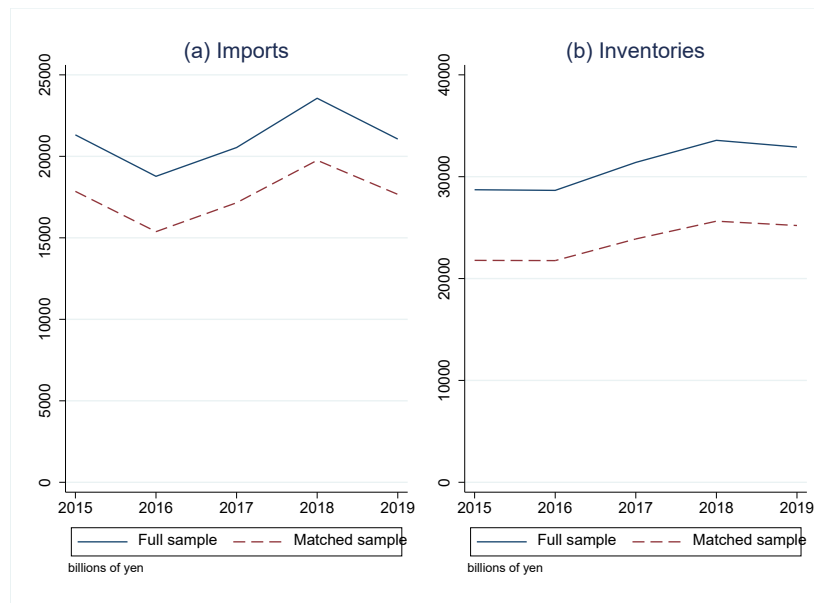
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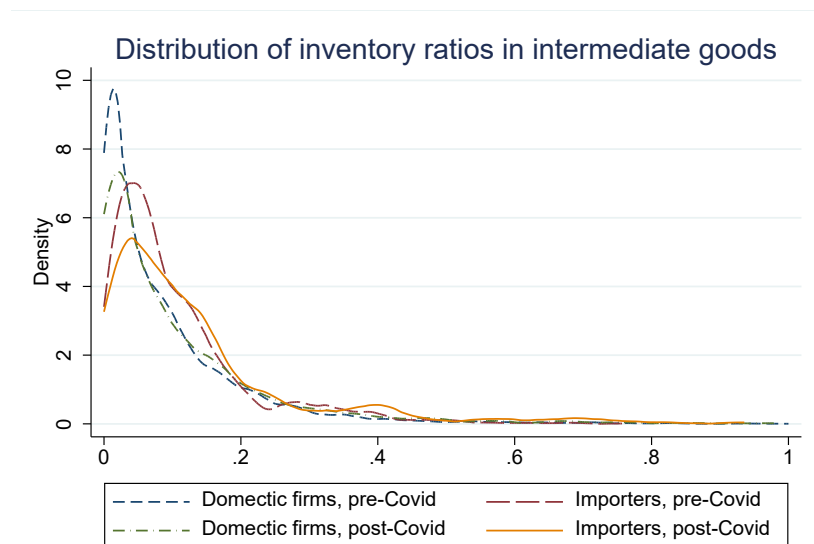
Appendix.: Additional Figures and Tables

Figure A1. Data validation: Full sample and matched sample are comparable



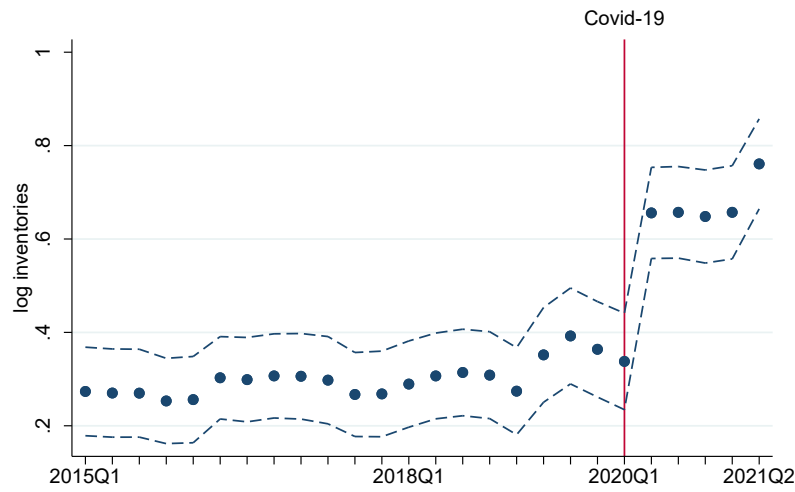
Source: Authors' compilation based on the BSJBSA and the FSSCI.

Figure A2. Large variations in inventories of intermediate goods across firms in the automobile industry



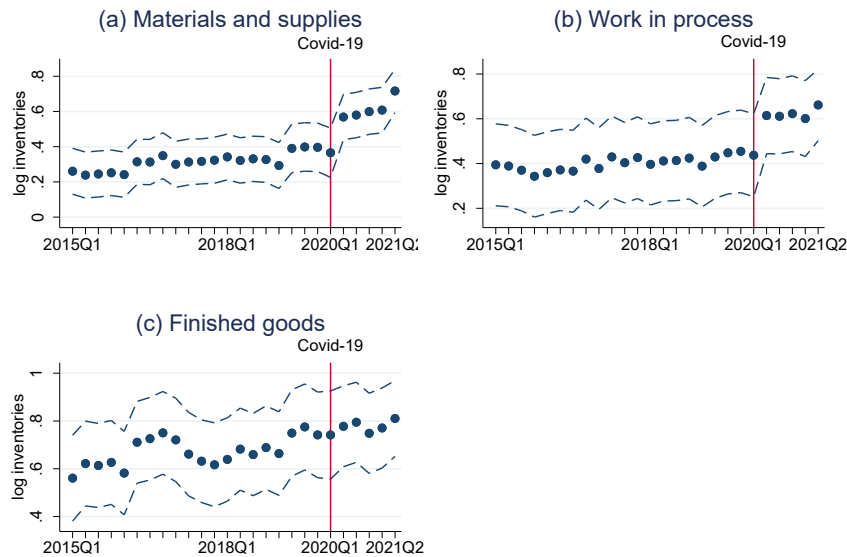
Notes: This figure plots the distributions of inventory ratios of intermediate goods by importers and non-importers in the automobile industry in the pre-Covid (Q1 2015 – Q4 2019) and post-Covid (Q1 2020 – Q2 2021) periods.

Figure A3. Importers increase inventories after the pandemic: log inventories



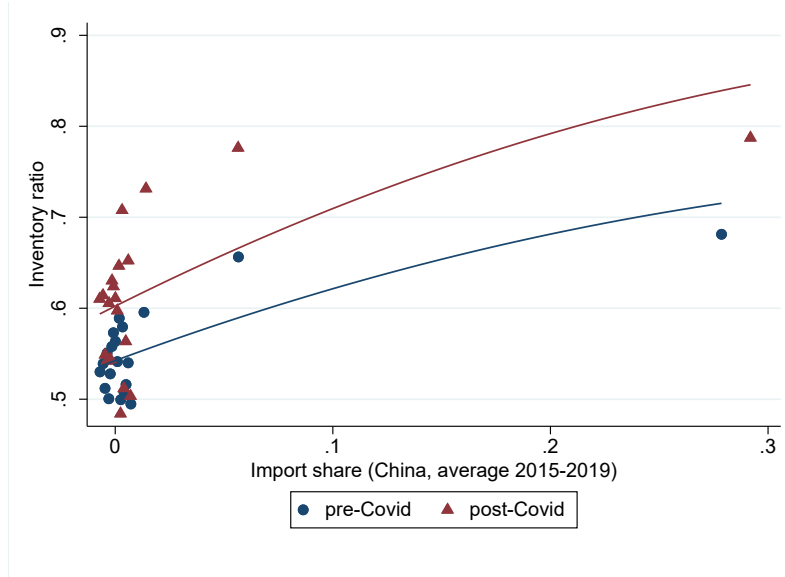
Notes: This figure plots the estimates of the importer-time dummy variables for the period from Q1 2015 to Q2 2021, controlling for firm size, industry-time, and region-time fixed effects. Dotted lines represent the 95% confidence intervals.

Figure A4. Importers increase all three types of inventories after the pandemic: log inventories



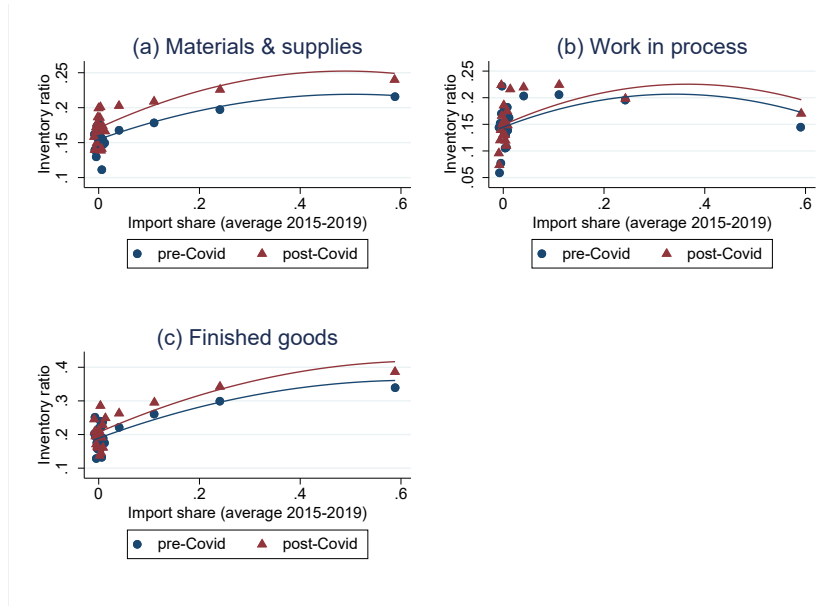
Notes: This figure plots the estimates of the importer-time dummy variables for the period from Q1 2015 to Q2 2021, controlling for firm size, industry-time, and region-time fixed effects. Dotted lines represent the 95% confidence intervals.

Figure A5. Inventories increase with ex-ante imports from China



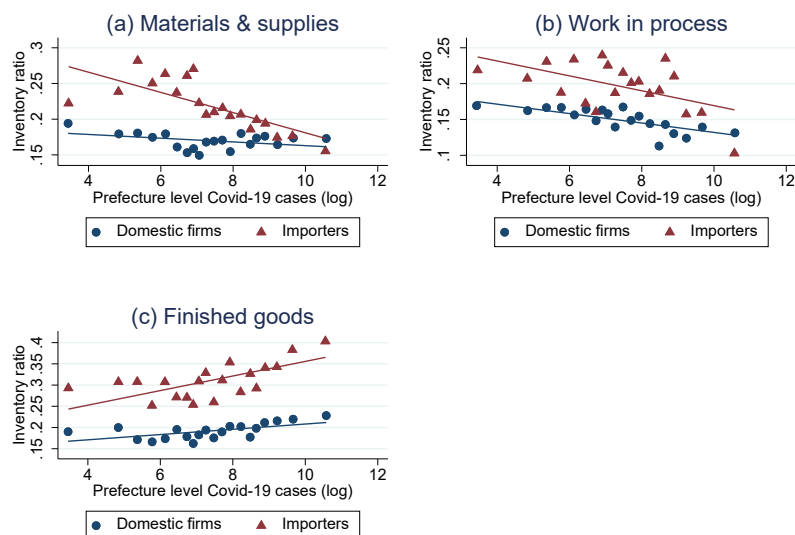
Notes: This figure plots the correlation between the ex-ante import share from China (imported inputs from China in total inputs) and inventory ratio in the pre-Covid (Q1 2015 – Q4 2019) and post-Covid (Q1 2020 – Q2 2021) periods, controlling for industry-time and region-time fixed effects. Each dot indicates a bin of firm observations.

Figure A6. All three types of inventories increased with ex-ante imports after the pandemic



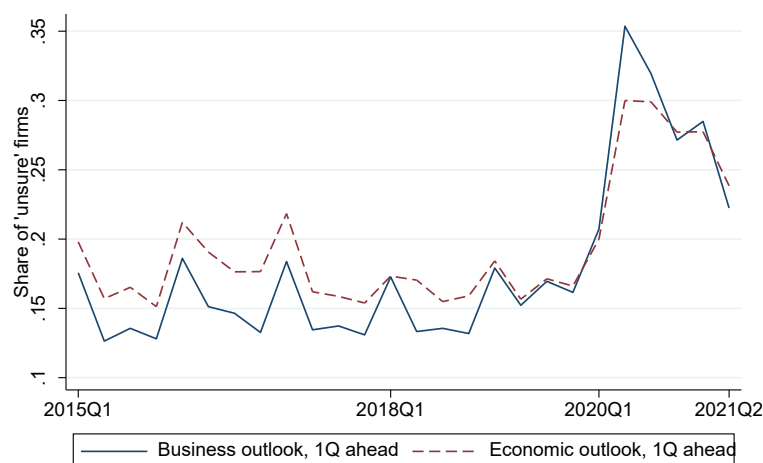
Notes: This figure plots the relationship between the ex-ante firm import share (imported inputs in total sourcing) and inventory ratio in the pre-Covid (Q1 2015 – Q4 2019) and post-Covid (Q1 2020 – Q2 2021) periods, controlling for industry-time and region-time fixed effects. Each dot indicates a bin of firm observations.

Figure A7. Finished goods inventories increased due to the demand shock while work-in-process inventories decreased due to the supply shock: Single-plant firms



Notes: This figure plots the relationship between prefecture-level Covid-19 cases (log) and the firm-level inventory ratio across the three types of inventory during Q2 2020 – Q2 2021, controlling for firm size, lockdown policies, industry, and time fixed effects. Each dot indicates a bin of firm observations.

Figure A8. Increase in firm-level uncertainty after the pandemic



Notes: This figure plots the share of manufacturing firms answering “unsure” about business outlook and economic outlook for the period of Q1 2015 to Q2 2021. Source: Authors’ compilation based on the BOS.

Table A1. Importing firms tend to have large inventories: Validation using BSJBSA data

	(1)	(2)	(3)	(4)
	log(Inventories)		Inventory ratio	
Importer	1.180*** (0.0318)	0.721*** (0.0254)	0.0352*** (0.00164)	0.0375*** (0.00168)
Firm size	No	Yes	No	Yes
Fixed effects	industry-year, region-year			
N	61282	61282	60670	60670
R-sq	0.171	0.412	0.153	0.155

Notes: Firm size is log employment. The estimation results are based on annual data from the BSJBSA (2015-2019). Standard errors are clustered at the firm level. Significance level: * 0.10 ** 0.05 *** 0.01.