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Global Sourcing and Firm Inventory During the Pandemic*

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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 for 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

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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 (Helper and Soltas, 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 has shown that importing firms have inventory (ratios) about 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; Miroudot, 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) (Masters and Edgecliffe-Johnston, 2021).[1]

The pandemic has led to a severe disruption of the global supply chain and a sharp accumulation of inventories in the manufacturing industry. Japanese firms heavily rely on imports from China, which accounted for about 19.8% of Japan's total imports of intermediate goods in 2019.[2] Figure 1 shows the monthly movements of Japan's import value index from January 2018 to June 2022.[3] Imports from China dropped sharply in February 2020 after Wuhan was under a lockdown and the coronavirus disease (COVID-19) was rapidly spreading in China. Imports from China soon recovered, but imports from the Association of Southeast Asian Nations (ASEAN) Member States 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.

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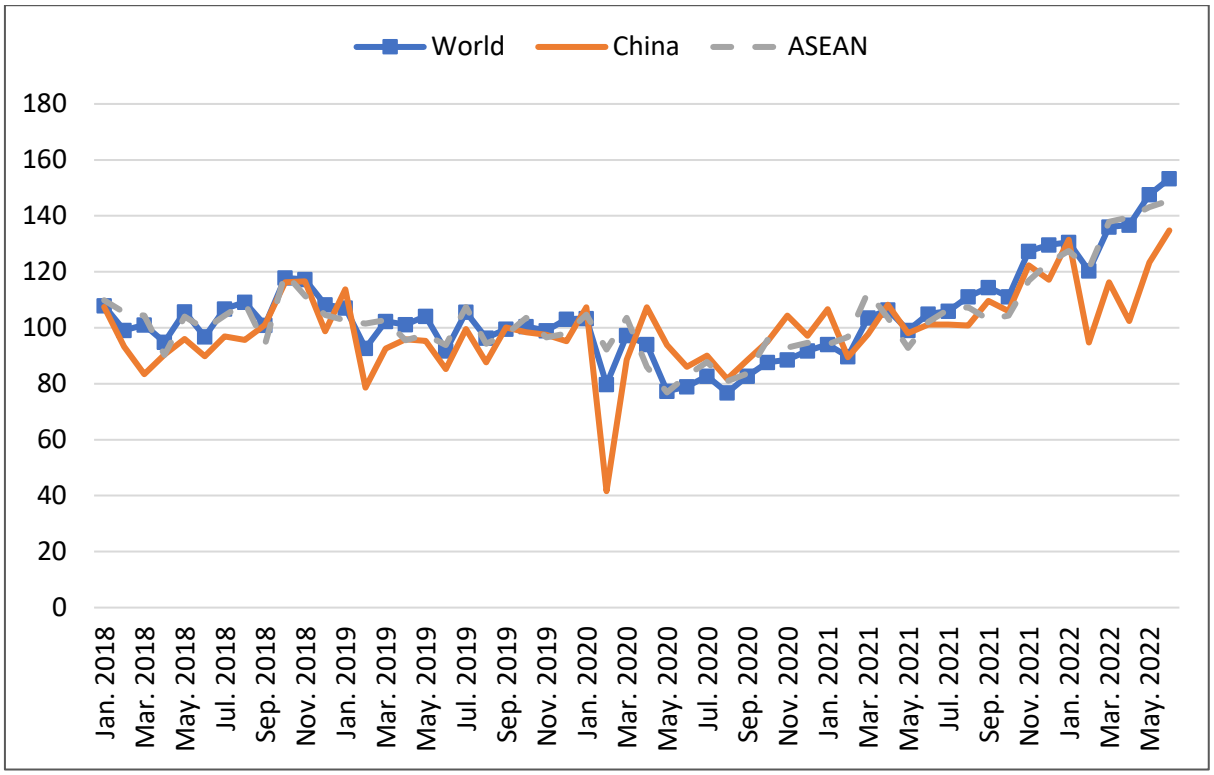
[1] JIT production is a management practice that aims to minimise the time between orders. It allows firms to cut costs by placing small and more frequent order batches rather than carrying large stocks of inventories. JIT production was developed in the 1970s by Japanese car manufacturer Toyota (Ohno, 1988) and 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] Source: World Integrated Trade Solution, https://wits.worldbank.org/ (accessed 1 April 2023).

[3] A seasonally adjusted import value index by country and region is not available.

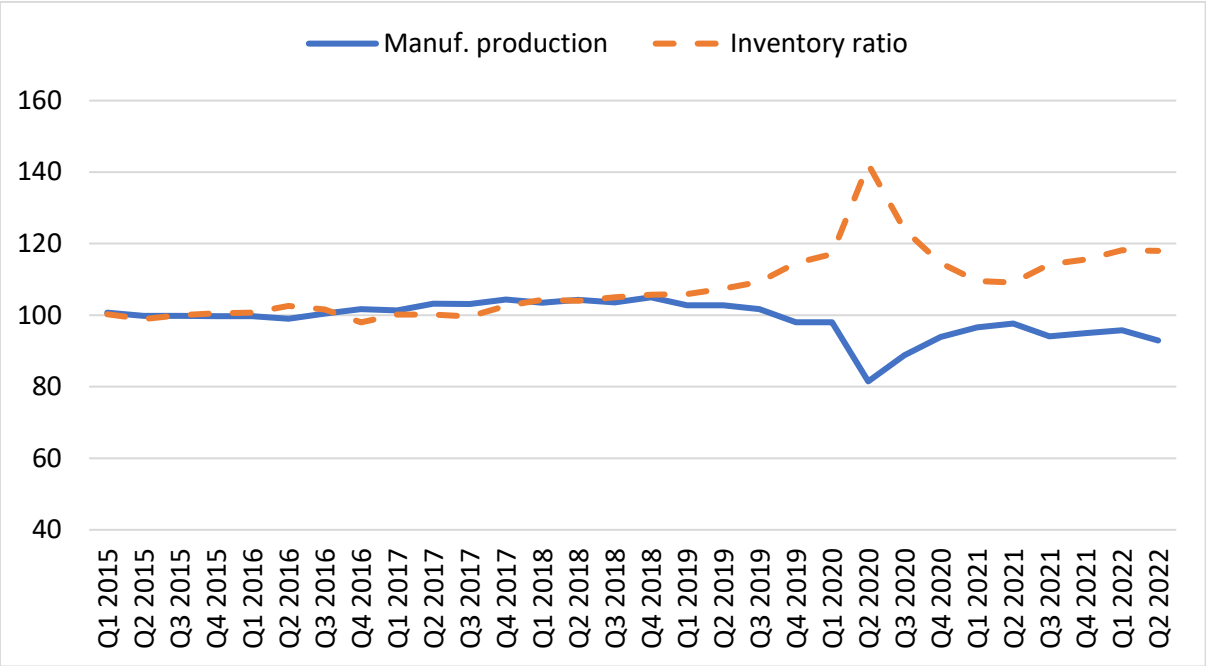
Figure 1: Supply Chain Disruptions – Japan's Imports



ASEAN = Association of Southeast Asian Nations.
Notes: The year 2015 is standardised to 100.
Source: Trade Statistics of Japan, Ministry of Finance. https://www.customs.go.jp/toukei/info/index_e.htm (accessed 1 April 2023).

Figure 2 shows the quarterly movements in Japan's manufacturing production and inventory ratio indices (seasonally adjusted) from the first quarter (Q1) of 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 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 increased further, probably because of the Shanghai lockdown and the Russia–Ukraine war.

Figure 2: Production Disruption and Increasing Inventories in Manufacturing Industries



Notes: The year 2015 was standardised at 100. The indices were seasonally adjusted.
Source: Indices of Industrial Production, Ministry of Economy, Trade and Industry. https://www.meti.go.jp/english/statistics/tyo/iip/index.html (accessed 1 April 2023).

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 sizeable 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.[4] Do importers tend to hold larger inventories of materials, work in process, and finished goods than firms that purchase inputs domestically (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.

[4] We use global sourcing and imports of intermediate goods interchangeably.

To fill this gap, we explore a large-scale quarterly government survey of Japanese manufacturing firms over 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 disruptions in China. These results suggest the possibility of a shift from JIT to JIC 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-organised 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 after the pandemic.

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 (2010a; 2010b). 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 non-importers. International trade fluctuated more than production during the global financial crisis, and inventories played an important role in these fluctuations.[5] 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 et al. (2023) examined the aggregate effects of supply chain disruptions in the post-pandemic period and showed 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 after 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 et al., 2021). In the case of the pandemic, Hayakawa and Mukunoki (2021a) showed 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) found 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.[6]

Third, our study relates to the broad literature on inventory management. Jain, Girotra, and Netessine (2014) found 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) examined the differences in the behaviours of high inventory turnover (HIT) and low inventory turnover (LIT) retailers

[5] Carreras-Valle (2021) found that the increase in reliance on inputs from China explains the increase in inventories of United States (US) manufacturing industries from 2005 to 2018. More generally, Blinder and Maccini (1991), Davis and Kahn (2008), and Ortiz (2022) documented the relationship between inventories and macroeconomic volatilities.

[6] Jiang and Zhang (2022) found 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.

in responding to demand shocks.[7] Furthermore, Gao (2017) explored the role of the JIT inventory system in increasing the cash holdings of United States (US) manufacturing firms.[8] 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 organised as follows. Section 2 presents the conceptual framework 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 behaviour 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 non-trivial time lags between the order and delivery of goods in international trade (Hummels, 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). Moreover, as foreign inputs become cheaper due to trade liberalisation 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 (Carreras-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) showed that Chilean importers have inventory ratios that are roughly twice those of non-importers (similarly, Carreras-Valle (2021) for US manufacturing industries), we show that it is also present for Japanese manufacturing firms despite having a

[7] They found 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.
[8] 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.

well-organised JIT production system and intensive sourcing from a neighbouring country (China).

Second, holding (*ex ante*) relatively large inventories of imported inputs may help importing firms avoid input shortages and stock-out 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 the demand shock effect. The former refers to shortages in imported inputs 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), 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 utilise a unique data set from a large-scale government survey of manufacturing and non-manufacturing firms in Japan. The

survey is the Financial Statements Statistics of Corporations by Industry (FSSCI) conducted by the Japanese Ministry of Finance (MOF).[9] The data period is Q1 2015–Q2 2021 (26 quarters in total). This survey aimed to clarify the status of corporations' business activities in Japan. Firms with capital of ¥500 million or more were selected. For those with capital of less than ¥500 million, an equal probability systematic sampling method was employed. We focus on manufacturing firms and construct a panel data set with about 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. Our sample covers firms in all 19 two-digit manufacturing industries and 47 prefectures in Japan.

To obtain information on firms participating in global sourcing, we use our second data set, the Basic Survey of Japanese Business Structure and Activities (BSJBSA) conducted by the Japanese Ministry of Economy, Trade, and Industry (METI).[10] This annual data set contains information about the business activities of Japanese firms and covers firms that employ more than 50 workers and have more than ¥30 million in total assets in the manufacturing, mining, wholesale, retail, and several service sectors. The data have been used elsewhere in studying the exporting and importing behaviours of Japanese manufacturing firms (e.g. Kimura and Kiyota, 2006; Sato, Zhang, and Wakasugi, 2015). We focus on manufacturing firms from fiscal year (FY) 2015 to FY2019.[11] 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 2 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 behaviour (intensive and extensive margins). Nevertheless, 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.

[9] https://www.mof.go.jp/english/pri/reference/ssc/index.htm
[10] https://www.meti.go.jp/english/statistics/tyo/kikatu/index.html
[11] The fiscal year in Japan is from April to March.

These two data sets can be matched using a common firm tax ID. The matching rate between our two main data sets is fair: (i) amongst 6,783 manufacturing firms in the FSSCI data, 56% (3,808) of firms can be matched with the BSJBSA; (ii) the 3,808 matched firms account for about 28% (=3,808/13,784) of manufacturing firms in the BSJBSA; and (iii) our matched sample accounts for more than 81% of total imports and 75% of inventories of manufacturing industries in the BSJBSA during 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 non-importers and to analyse inventory adjustments during the pandemic.

Table 1 presents the summary statistics of the matched FSSCI–BSJBSA data used in the baseline 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–BSJBSA data set.

A potential concern regarding our matched FSSCI–BSJBSA data is that a firm's import status is pre-pandemic and time-invariant. Although the FY2019 data in the BSJBSA cover Q1 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 data set 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 data set comes from the Quarterly Survey of Overseas Subsidiaries (QSOS) collected by METI.[12] This survey covers Japanese foreign affiliates with 50 or more employees in the manufacturing industry.[13] The QSOS data contain 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 data set, the Business Outlook Survey (BOS), jointly conducted by the MOF and the Cabinet Office of Japan.[14] The data period is Q1 2015–Q2 2021. Like 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 the 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.

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[12] https://www.meti.go.jp/english/statistics/tyo/genntihou/index.html

[13] Specifically, this survey targets overseas affiliates of Japanese parent firms that meet all 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).

[14] https://www.mof.go.jp/english/pri/reference/bos/index.htm

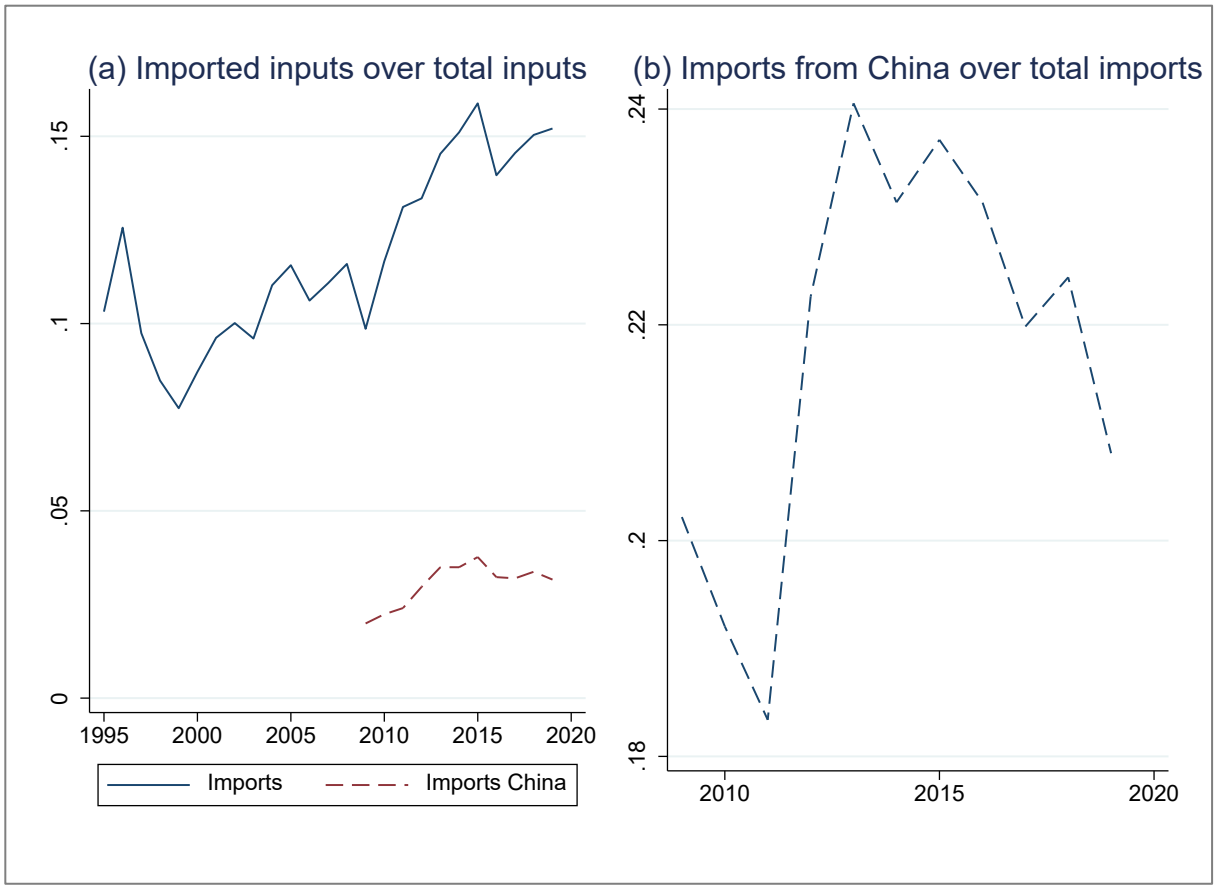
Finally, quarterly data on prefecture-level COVID-19 cases/deaths and their ratios to the population were obtained from the Ministry of Health, Labour, and Welfare of Japan. We also collected two-digit industry-level input and output price indices constructed by the Bank of Japan. The input price index 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).[15] As an alternative, 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.

3.2. Descriptive Evidence

This subsection presents descriptive evidence of the inventory and importing behaviours 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 declined slightly 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.

[15] 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 analyse short-term changes in input costs and price changes in output products in each sector. The base year is 2015 for both price indexes. As an alternative, we also use the import price index and producer price index, but the results are quantitatively similar.

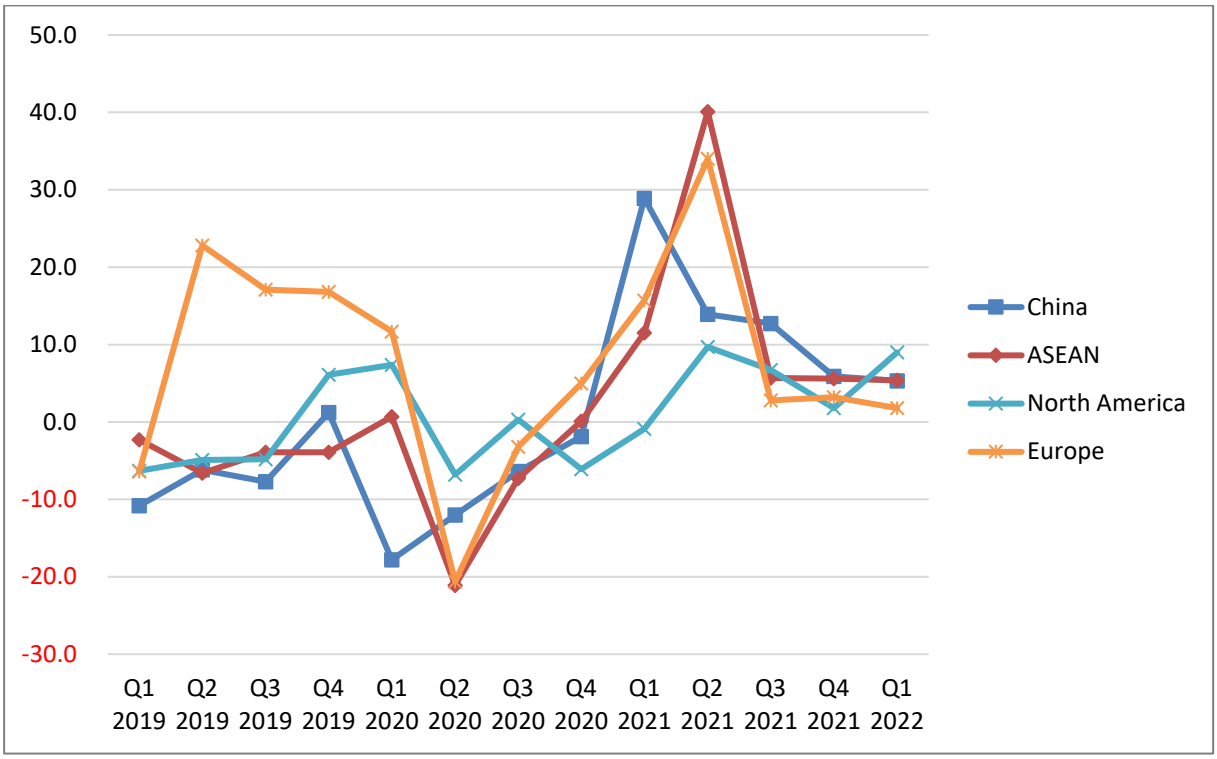
Figure 3: Rise in Imported Inputs Over Total Inputs



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 (yoy) 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

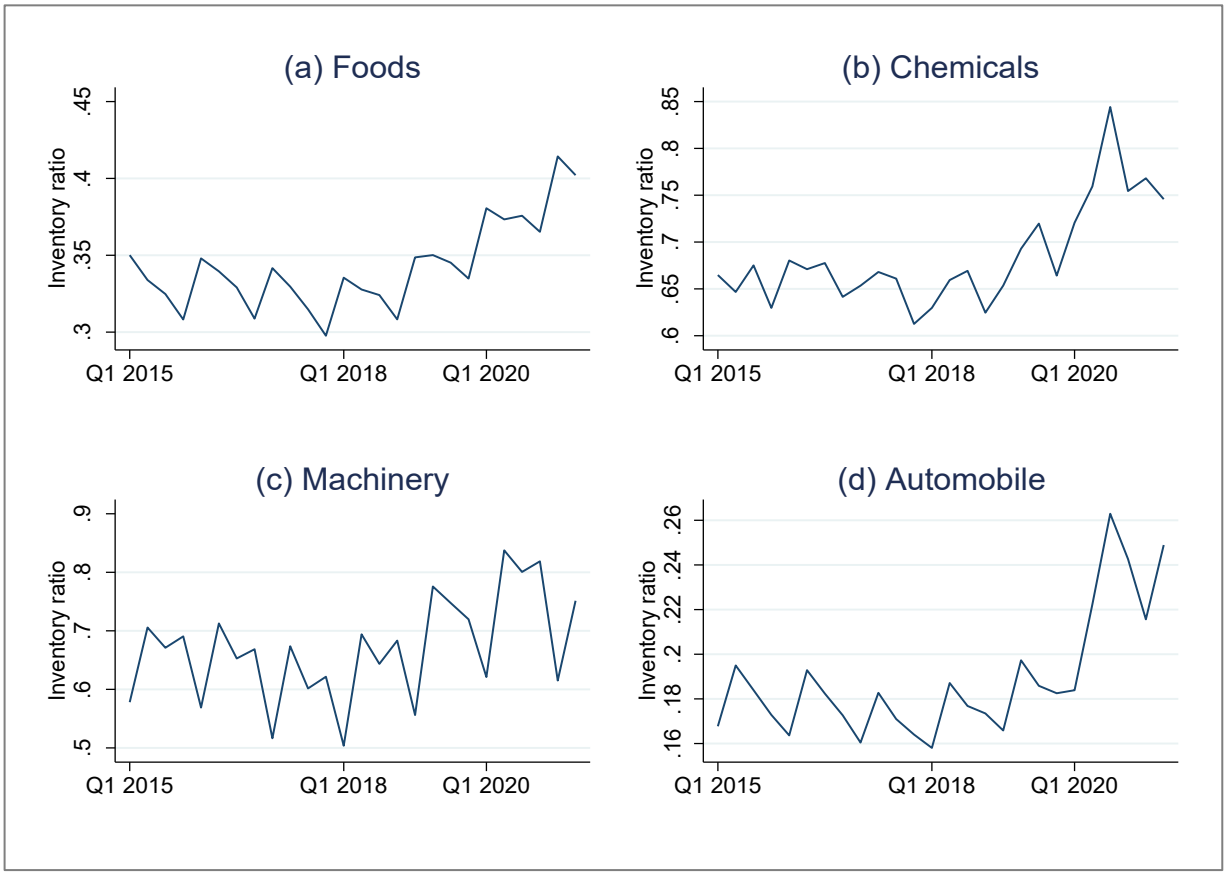


ASEAN = Association of Southeast Asian Nations, MNE = multinational enterprise, Q = quarter.
Notes: This figure shows the year-on-year changes (%) in Japanese foreign affiliates' exports to Japan from Q1 2019 to Q1 2022.
Source: Authors' compilation based on the QSOS.

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 and the inventory ratio was volatile, an increasing trend is observed especially after the pandemic, particularly in the food, chemical, and automobile industries.[16]

[16] 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

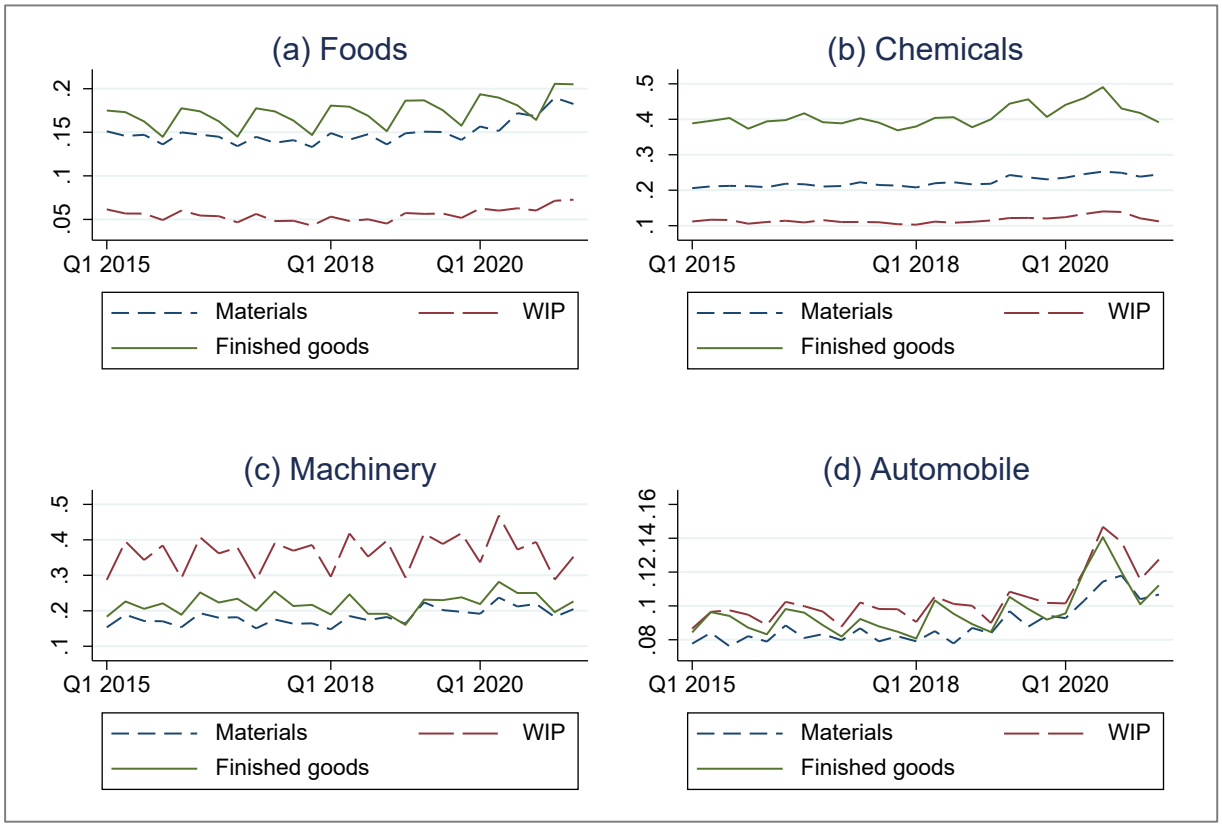


Q = quarter.
Notes: This figure shows the seasonally adjusted inventory-to-quarterly sales for the four largest and representative industries.
Source: Authors' compilation based on the FSSCI.

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 JIT 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.[17] 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-19 and post-COVID-19 periods.

[17] This is consistent with some media reports. For example, it is reported that compared with the pre-pandemic period (by year-end 2019), the inventories of automobile parts and components increased by 30% by year-end 2021. Due to worldwide supply constraints, automobile parts and components manufacturers significantly increased their inventories despite the rising carrying costs of larger inventories (Nikkei, 2022).

Figure 6: Rising Inventories of Intermediate Goods in the JIT Automobile Industry



JIT = just in time, WIP = work in process, Q = quarter.
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 2 years, from

2015 to 2019.[18] 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 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: Larger Inventories in Importing Firms – Pre-Pandemic

	(1)	(2)	(3)	(4)	(5)
Dep. Var.	Total	Total	Materials	Work-in-process	Finished
Panel A: log(inventories)					
Importer	2.601***	0.553***	0.550***	0.641***	0.961***
	(0.0486)	(0.0322)	(0.0450)	(0.0634)	(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***	0.113***	0.0237***	0.0230***	0.0591***
	(0.0122)	(0.0132)	(0.00516)	(0.00676)	(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

Q = quarter.
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 Q1 2015–Q4 2019. Standard errors are clustered at the firm level. Significance level: * 0.10, ** 0.05, and *** 0.01.
Source: Authors' calculation.

Table 2 shows that on average importers always tend to hold more inventories relative to non-importers. This is robust after controlling for firm size (log employment).[19] Compared with non-importers, importers have 55.3% larger inventories (column 2 in Panel A) and their

[18] Our results are quantitatively similar with alternative definitions, i.e. at least 1, 3, 4, and 5 years.
[19] Results based on balanced panel data are quantitatively similar.

inventory ratios are 11.3 percentage points higher (column 2 in Panel B). Importantly, relative to non-importers, 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 about 2.37, 2.30, 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 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 during 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 non-importers, importing firms affected by supply chain disruptions tended to increase their inventory holdings after the pandemic. This effect was expected to persist until the end of the sample period (Q2 2021).

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 about 5.33 percentage points after the pandemic. Similarly, importers increased their inventories of materials, work in process, and finished goods by about 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.

Table 3: Increased Importers' Inventories After the Pandemic

	(1)	(2)	(3)	(4)
Dep. Var.	Total	Materials	Work-in-process	Finished
Importer	0.112***	0.0230***	0.0223***	0.0588***
	(0.0132)	(0.00516)	(0.00673)	(0.00708)
Importer*Post	0.0533***	0.0148***	0.0111**	0.0239***
	(0.0112)	(0.00412)	(0.00489)	(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

Q = quarter.
Notes: The dependent variables are inventory ratios in all columns. Firm size is log employment. The sample period is Q1 2015–Q2 2021. Standard errors are clustered at the firm level. Significance level: * 0.10, ** 0.05, and *** 0.01.
Source: Authors' calculation.

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:

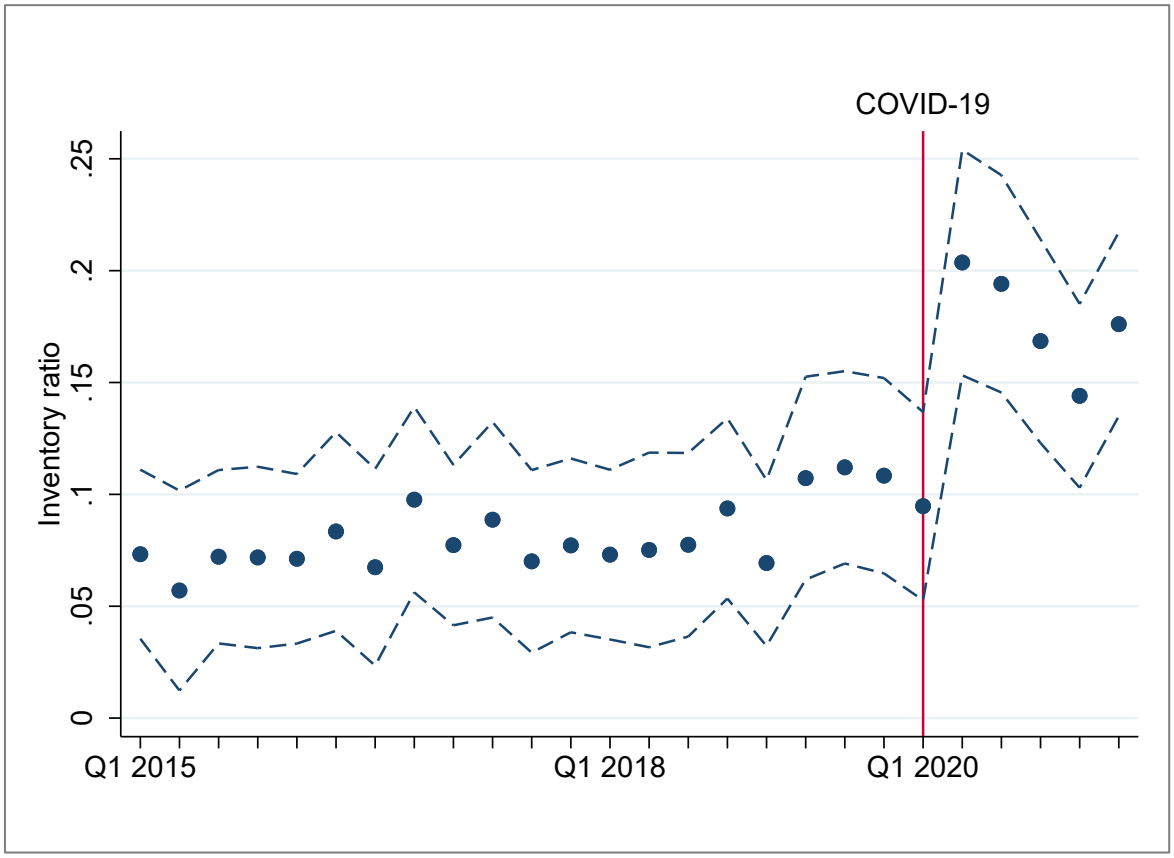
$$Y_{it} = \alpha_0 + \sum_{t=2015Q1}^{2021Q2} \alpha_1 IM_i \times D_t + \gamma X_{it} + FE_{st} + FE_{rt} + \varepsilon_{it} \quad (4)$$

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

Figure 7 shows the differences in inventory ratio changes between importing firms and non-importers over time, by plotting a set of estimated coefficients from the regression of the 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 importers and non-importers, conditional on our selected controls. However, in the post-pandemic period, importers experienced a sharp and persistent increase in the inventory ratio compared with non-importers, 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.[20]

Figure 7: Increased Importers' Inventories After the Pandemic – Importer-Time Estimates

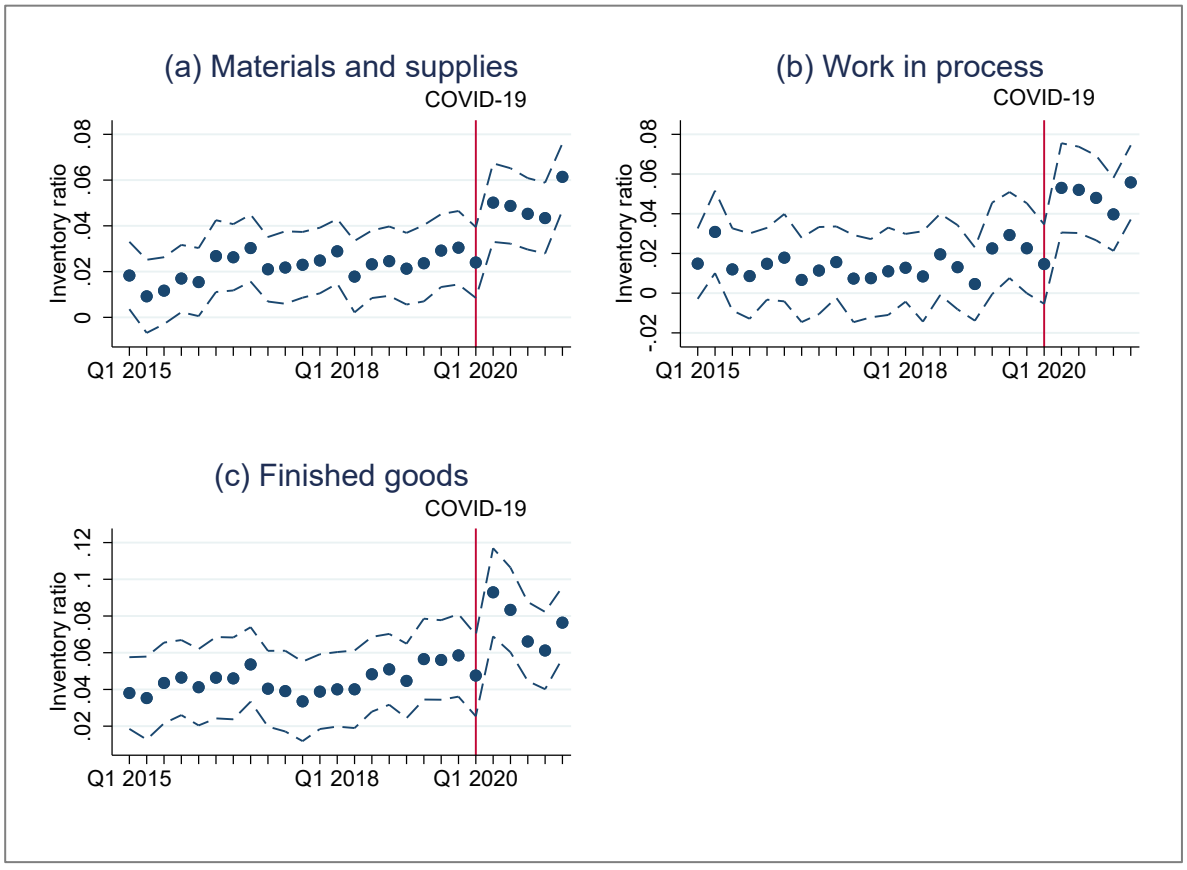


Q = quarter.
Notes: This figure plots the estimates of the importer-time dummy variables for Q1 2015–Q2 2021, controlling for firm size, industry-time, and region-time fixed effects. Dotted lines represent the 95% confidence intervals.
Source: Authors' calculation.

[20] 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, as our sample period is until Q2 2021 and Japanese importers have 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, which rely on imported agricultural goods, oils, and other resources. The results are quantitatively similar and available upon request.

As mentioned previously, inventories consist of materials and suppliers, 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 importers and non-importers 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 amongst the three types of inventories.

Figure 8: Increase in All Three Types of Importers' Inventories During the Pandemic



Q = quarter.
Notes: This figure plots the estimates of the importer-time dummy variables for Q1 2015–Q2 2021, controlling for firm size, industry-time, and region-time fixed effects. Dotted lines represent the 95% confidence intervals.
Source: Authors' calculation.

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 delivery time index, the average lead time for materials and inputs in the US increased by about 35 days from the start of the pandemic to the beginning of 2022. Alessandria et al. (2023) developed 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.[21] Our empirical results for manufacturing firms are consistent with the theoretical predictions of Alessandria et al. (2023). Because the delivery and lead time vary substantially across industries (e.g. chemicals versus automobile) and regions (either between prefectures within Japan or between Japan and its foreign trading partners) before and after the pandemic, we include industry-time and region-time fixed effects in our estimations to control for the potential effects of shipping delays.[22]

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 rerun 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 the post-COVID-19 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, not finished goods, account for a large part of firm-level inventory adjustments. A related argument is that inventory adjustment (i.e. changes in the firm-level inventory ratio) is *intentionally* conducted by firms' inventory management or *unintentionally* induced by demand volatility. Hayakawa and Mukunoki (2021b) pointed out that inventory adjustment helped Japanese firms in Asia export without the need for production operations under workplace closure orders during the pandemic. According to the questionnaire surveys conducted by the Japan External Trade Organization (JETRO) in May–June 2020, about 50% of Japanese manufacturing firms carried

[21] Alessandria et al. (2023) quantitatively showed that increases in shipping times are contractionary, raise prices, and increase stockouts, particularly for goods intensive in delayed inputs.
[22] Ideally, we need detailed information on lead time at the firm level or industry/region level. Unfortunately, the data are not available.

out inventory adjustment measures in Malaysia, Indonesia, and the Philippines. 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.[23]

Third, another potential concern is that our results on global sourcing and inventory adjustment may depend on industry 'upstreamness' or average distance from final use. Firms in the upstream industries use imported and domestic materials to produce intermediate or final goods and then ship them to firms in the downstream industries. Therefore, firms in the upstream industries may have greater incentive to hold inventories to avoid stockout risks. To address this concern, we use a measure of industry upstreamness developed by Antràs et al. (2012) to examine the relationship between production upstreamness and inventory holdings before and after the pandemic (see Figures A5–A7 in the Appendix).[24] The inventory of materials increases significantly with production upstreamness in both the pre-pandemic and post-pandemic periods, especially for importers (Figure A5). In contrast, the inventory of intermediate goods does not increase (even slightly decrease) with production upstreamness, suggesting the low importance of work-in-process (relative to materials) inventories in upstream industries (Figure A6). Furthermore, in the case of importers, the inventory of finished goods increases with production upstreamness in both the pre-pandemic and post-pandemic periods (Figure A7). Importantly, compared with non-importers, importers increased all three types of inventory after the pandemic regardless of industry upstreamness.

5. Discussion

In this section, we first examine inventory adjustments to supply chain shocks across firms through (i) *ex ante* import intensity, and (ii) supply chain disruptions between China and Japan. We then discuss (iii) the role of inventory as a buffer against input shortages. We further discuss the potential factors affecting inventories, including (iv) the prefecture-level severity of

[23] Due to data limitations, we cannot identify what a firm imports, i.e. raw materials, intermediate goods, or finished goods. This is not a serious problem because our analysis focuses on manufacturing firms that are more likely to import intermediate inputs rather than final products. Using transaction-level customs data, previous studies (e.g. Ara and Zhang 2020) have shown that Chinese manufacturing firms import more intermediate goods than final goods.

[24] This measure is closely related to the concept of forward linkage in input–output analysis, and it has been used to capture the relative production-line position of industries, countries, and even firms. A larger value of upstreamness is associated with a higher level of upstreamness of an industry's output. The least upstream industry is textile products and footwear (1.441), and the most upstream industry is iron and steel (3.335) in our sample.

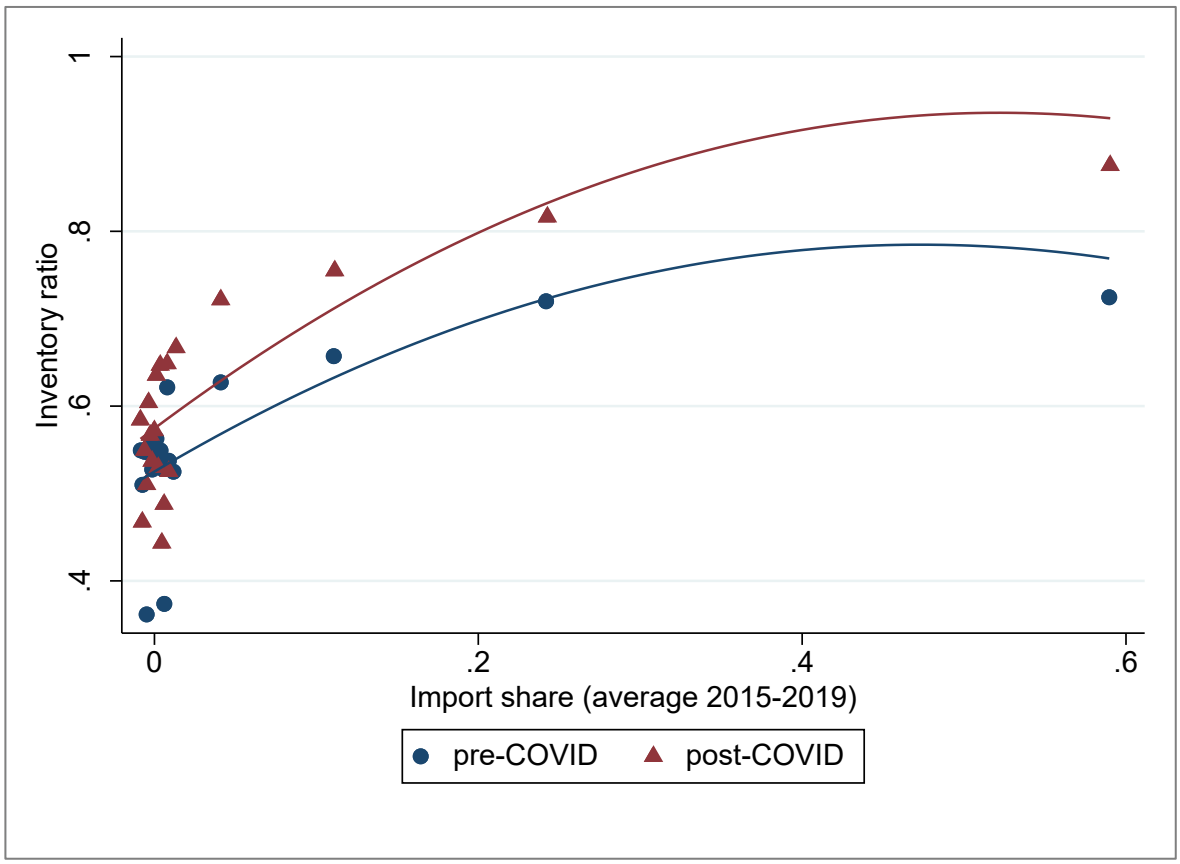
the COVID-19 infections, (v) industry-level input and output prices, (vi) firm-level financial constraints, and (vii) firm-level uncertainties over economic and business outlooks.

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 the *ex ante* import share (defined as the average share of imported inputs in total sourcing from 2015 to 2019) and the inventory ratio for the pre-COVID-19 and post-COVID-19 samples. There is a strong positive correlation between the *ex ante* import share and the inventory ratio in both the pre-COVID-19 and post-COVID-19 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 A8 of the Appendix) and that all three types of inventories increase with *ex ante* import intensity (Figure A9 of the Appendix). Importantly, the relationship between import share and inventory ratio is non-linear, suggesting the existence of an optimal inventory level.

Figure 9: Significant Increase in Inventories with *Ex Ante* Imports After the Pandemic



COVID-19 = coronavirus disease, Q = quarter.

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-19 (Q1 2015–Q4 2019) and post-COVID-19 (Q1 2020–Q2 2021) periods, controlling for industry-time and region-time fixed effects. Each dot indicates a bin of firm observations.

Source: Authors' calculation.

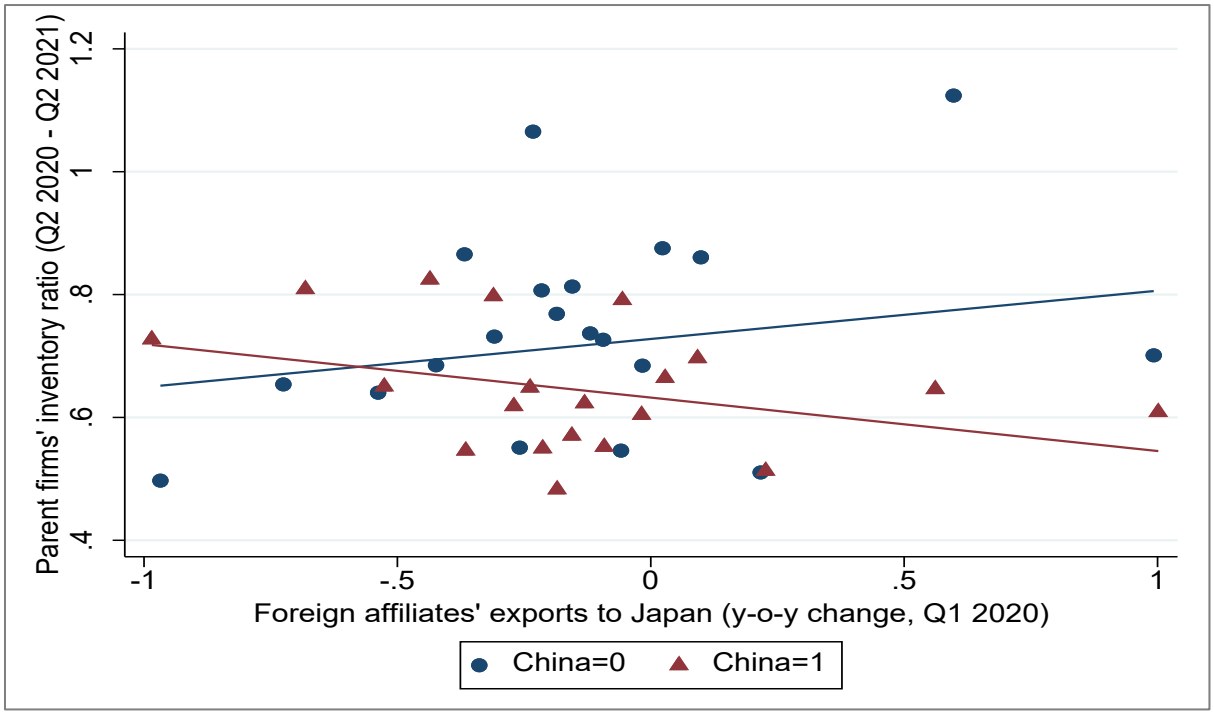
5.2. Supply Chain Disruptions and Inventory Holdings: the Case of MNEs

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 hypothesised 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. A potential concern is that MNEs conduct multinational production and usually have more than one production base and hence may not have incentives to hold large inventory. This might be true if these production bases produce the same product. However, if the headquarters in Japan and foreign affiliates engage in different production stages of the supply chains, e.g. foreign affiliates produce and export intermediate goods to Japan for final goods production, the headquarters may have

greater incentive to hold inventory. To examine the relationship between MNE status and inventory holdings, we use firm-level information on multinational activities in the BSJBSA data and estimate Equation (1). We find that MNEs tend to have about 30% larger inventories than non-MNEs, though MNEs tend to have smaller inventory than importers.

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.

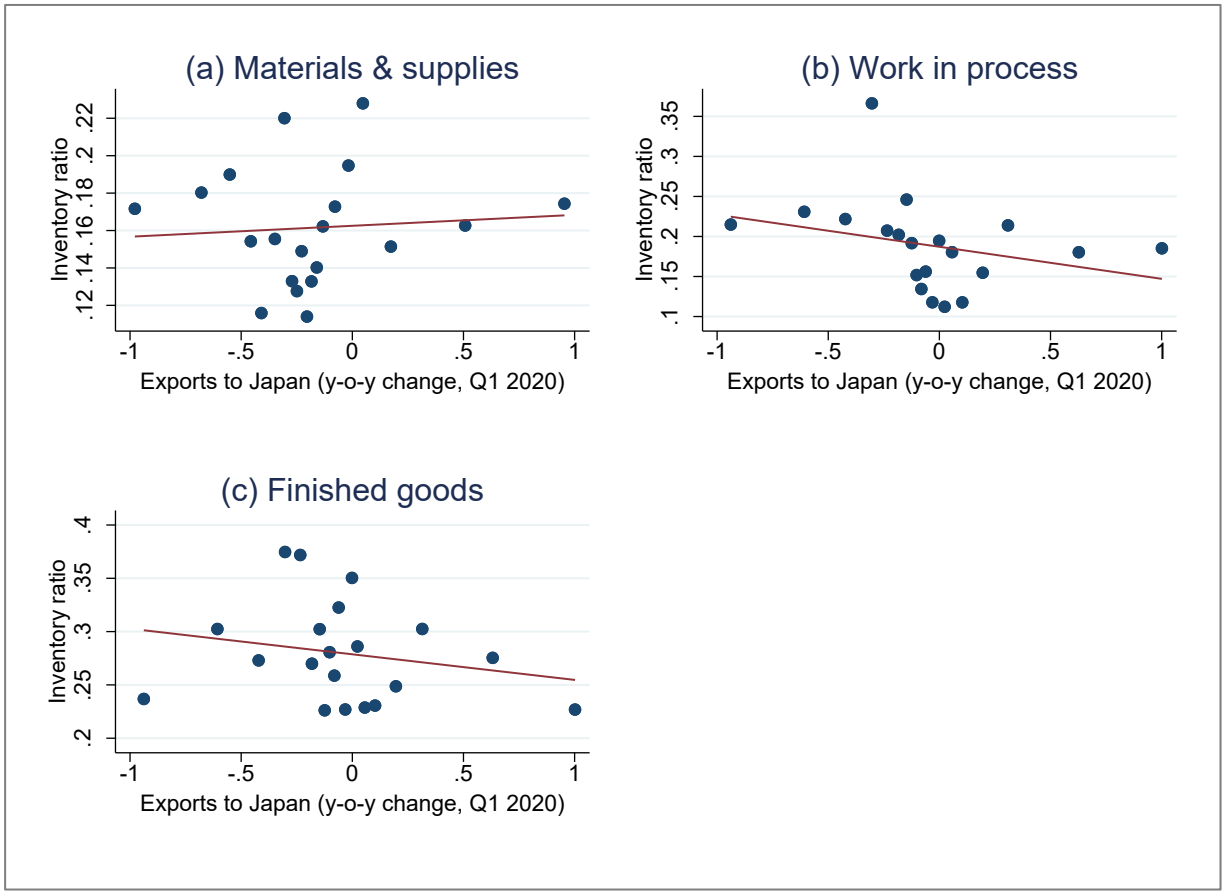
Figure 10: Increase in Inventories After the Shock Caused by Supply Chain Disruptions in China



Q = quarter, y-o-y = year on year.
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.
Source: Authors' calculation.

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: Increase in Intermediate Goods Inventories After the Shock Caused by Supply Chain Disruptions in China



COVID-19 = coronavirus disease, Q = quarter, y-o-y = year on year.
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.
Source: Authors' calculation.

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. Lafrogne-Joussier, Martin, and Mejean (2022) showed that amongst French firms exposed to the Chinese lockdown, those holding more inventories *ex ante* performed better in the aftermath of the shock. 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 amongst the importer dummy IM_i, inventory ratio, and $Post_t$ to examine the heterogeneous effects of import status and inventory holding levels.[25]

Table 4: Possible Mitigation of the Negative Effect on Importers through Inventory Holdings

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

COVID-19 = coronavirus disease, Q = quarter, y-o-y = year on year.
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-19 (Q1 2015–Q4 2019) average in columns (4)–(5). The sample period is Q1 2015–Q2 2021. Standard errors are clustered at the firm level. Significance level: * 0.10, ** 0.05, and *** 0.01.
Source: Authors' calculation.

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

Table 4 reports the estimation results. First, importers have larger sales than non-importers, 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 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 mitigate the impact of COVID-19. Our findings are also consistent with Brussevich, Papageorgiou, and Wibaux (2022), which show that French firms in the most inventory-intensity industries increased their imports and exports during the pandemic.

5.4. COVID-19 Infections and Lockdown Policies

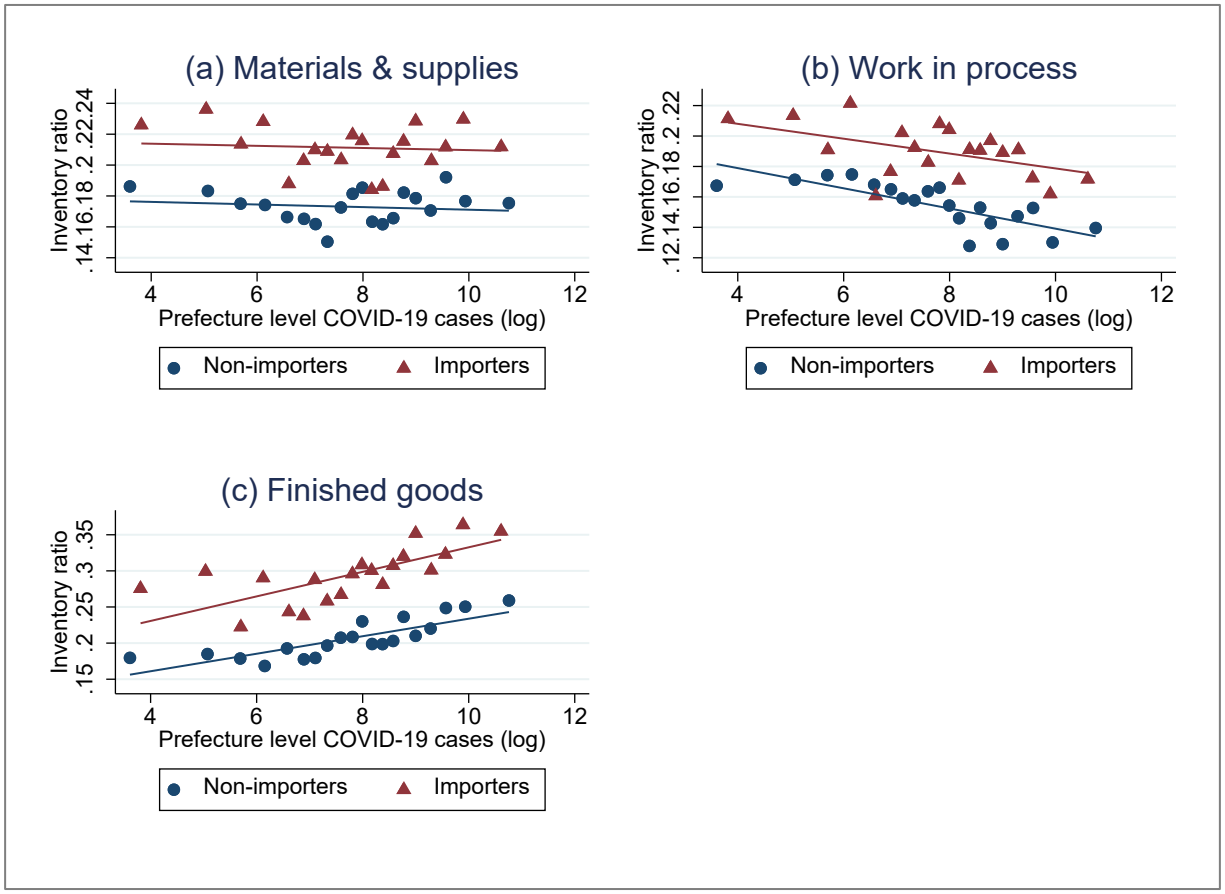
There are concerns that the demand and supply shocks induced by COVID-19 infections and lockdown policies may affect firms' inventory holdings. To address these potential concerns, we control for industry and region-time fixed effects in our estimation results. In this section, we use prefecture-level 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.[26]

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.

[26] 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.

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 non-importers.

Figure 12: Increase in Finished Goods Inventories due to the Demand Shock and Decrease in Work-in-Process Inventories due to the Supply Shock



COVID-19 = coronavirus disease, Q = quarter.
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.
Source: Authors' calculation.

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 locations coincide). The results are presented in Figure A10 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.

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 organised exchange (Rauch, 1999). This means that an increase in the input price (a negative supply shock) during the pandemic does not necessarily incentivise 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.

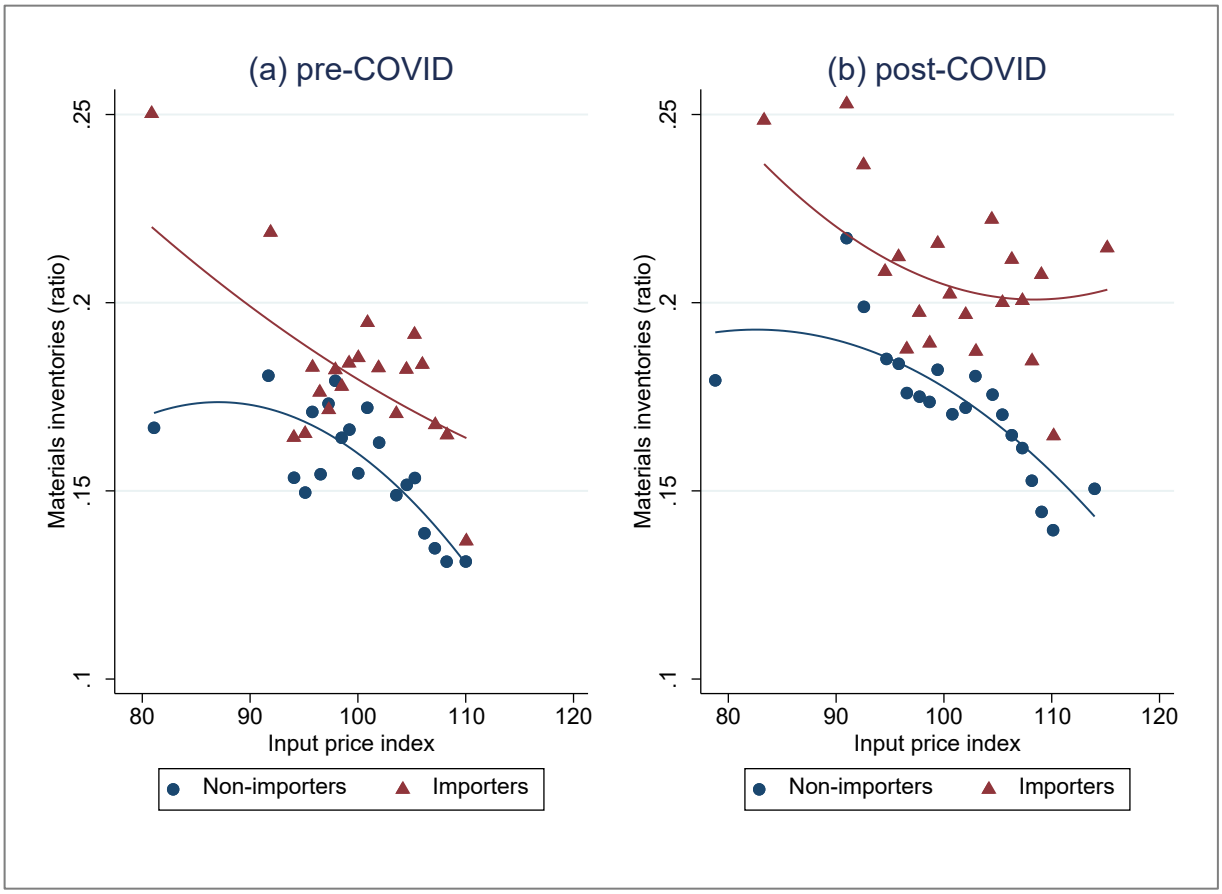
The input and output price indexes in Japan declined significantly in 2020 due to the pandemic, but began to soar from the beginning of 2021, accompanied by increasing prices of resources and imported inputs and the recovery of the world economy. The data on inventories and output (sales) used in our 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 progress, and Figure 15 shows the relationship between *output* price and inventories in finished goods. The relationships between inventories and input/output prices are non-linear, and there are significant differences across importers and non-importers.

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-19 period relative to the pre-COVID-19 period. Second, as shown in Figure 14, the inventories of intermediate goods decreased

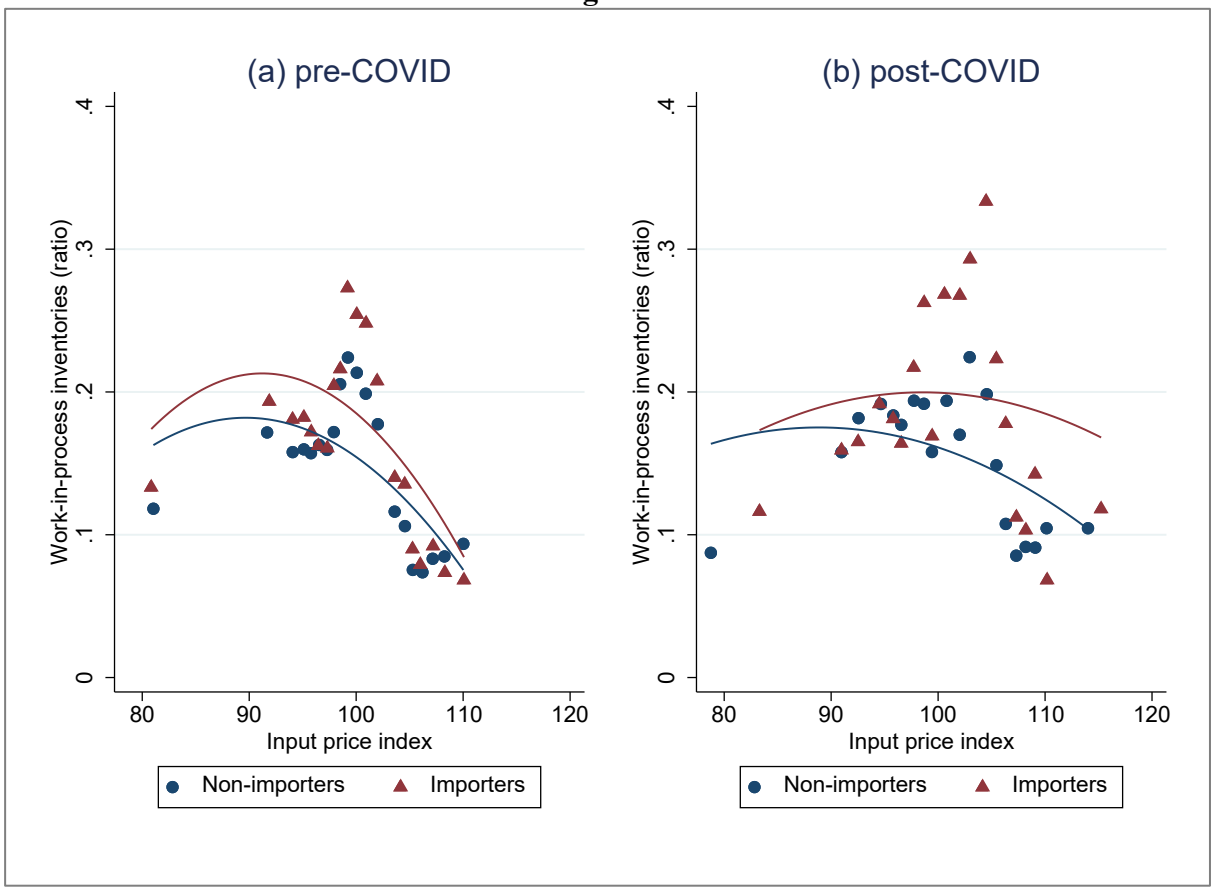
significantly when the input price index reached 100 for both importers and non-importers in the pre-COVID-19 period. However, this was not the case during the post-COVID-19 period. The inventories of intermediate goods held by importers do not decline significantly with the input price, suggesting the possibility of holding inventories as a buffer against input price risks.

Figure 13: Decrease in Materials Inventories with Higher Input Price During the Pandemic



COVID-19 = coronavirus disease, Q = quarter.
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-19 (Q1 2015–Q4 2019) and post-COVID-19 (Q1 2020–Q2 2021) periods, controlling for firm size, region, and time fixed effects. Each dot indicates a bin of firm observations.
Source: Authors' calculation.

Figure 14: Insignificant Decrease in Intermediate Goods Inventories with Higher Input Price During the Pandemic

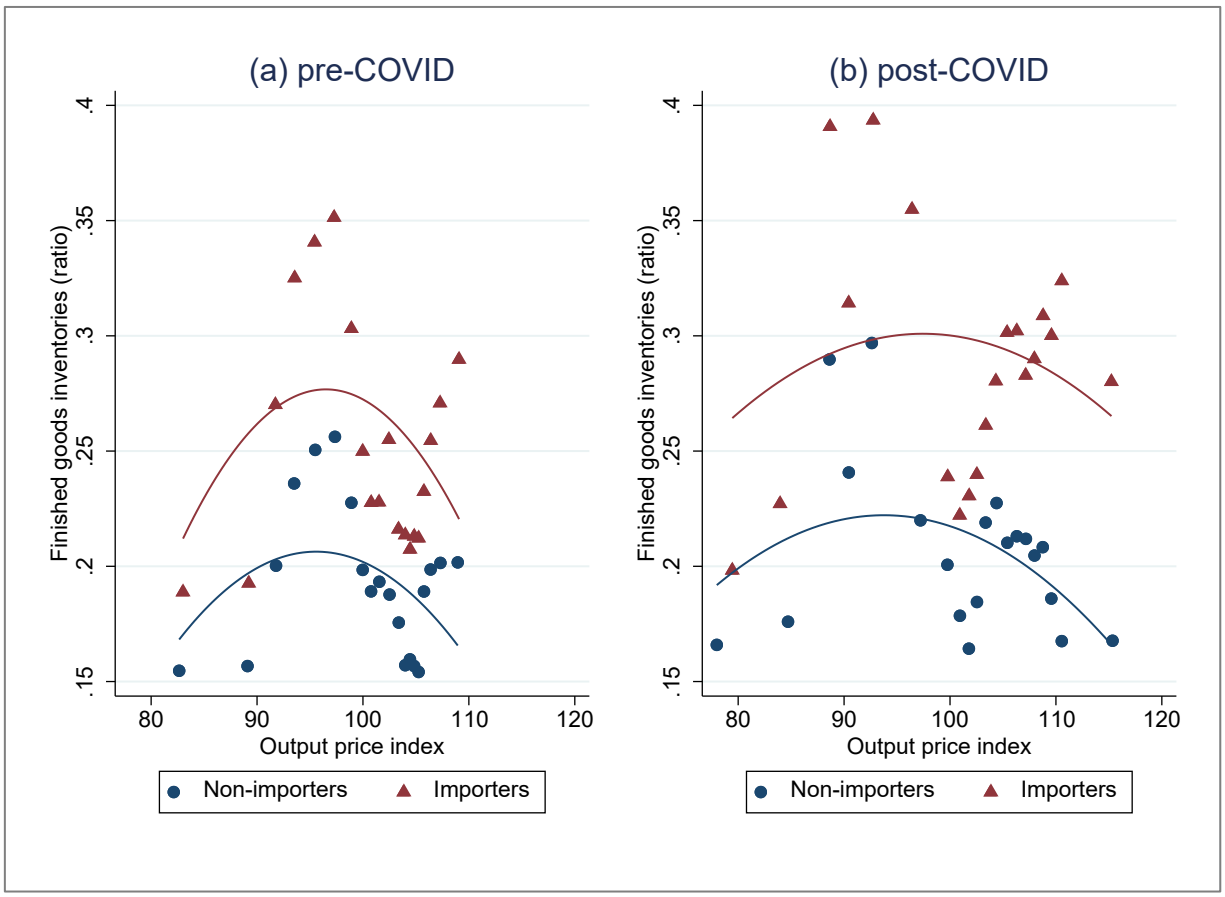


COVID-19 = coronavirus disease, Q = quarter.
Notes: This figure plots the relationship between the industry-level input price index and firm-level inventories in intermediate goods in the pre-COVID-19 (Q1 2015–Q4 2019) and post-COVID-19 (Q1 2020–Q2 2021) periods, controlling for firm size, region, and time fixed effects. Each dot indicates a bin of firm observations.
Source: Authors' calculation.

Finally, Figure 15 indicates that there is a strong non-linear relationship between output price and inventories of finished goods for both importer and non-importers in both the pre-COVID-19 and post-COVID-19 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.[27]

[27] 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 15: Decrease in Finished Goods Inventories with Higher Output Price



COVID-19 = coronavirus disease, Q = quarter.
Notes: This figure plots the relationship between the industry-level output price index and firm-level inventories of finished goods in the pre-COVID-19 (Q1 2015–Q4 2019) and post-COVID-19 (Q1 2020–Q2 2021) periods, controlling for firm size, region, and time fixed effects. Each dot indicates a bin of firm observations.
Source: Authors' calculation.

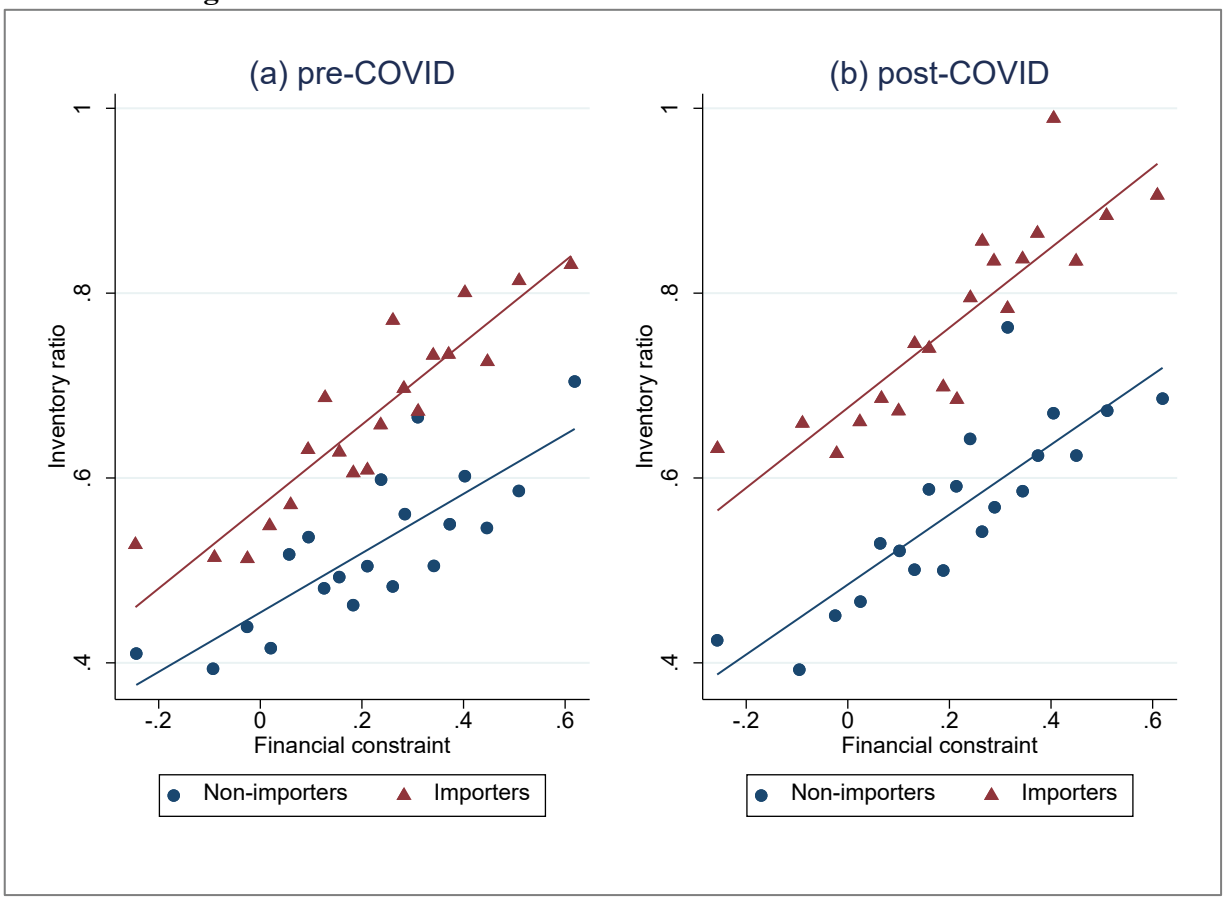
5.5. Financial Constraints and Inventory Holdings

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.

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-19 period than in the pre-COVID-19 period.

Figure 16: Decrease in Inventories due to Financial Constraints



COVID-19 = coronavirus disease, Q = quarter.
Notes: This figure plots the relationship between financial constraints and inventory ratio in the pre-COVID-19 (Q1 2015–Q4 2019) and post-COVID-19 (Q1 2020–Q2 2021) periods, controlling for firm size, region, and time fixed effects. Each dot indicates a bin of firm observations.
Source: Authors' calculation.

5.6. 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 (US real GDP) (Baker et al., 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 have also shown that firm-level uncertainty and economic policy uncertainty are positively correlated with current assets, such as cash holdings and inventory holdings.[28] Dbouk, Moussawi-Haidar,

[28] Khan and Senga (2019) found that uncertainty faced by firms (sales volatilities) correlated positively with cash holdings of publicly listed firms in Japan.

and Jaber (2020) showed that Economic Policy Uncertainty drives high inventory levels in US manufacturing firms, 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' 'unsure' responses about their business outlook (BO) and domestic economic outlook (EO) as a measure of the uncertainty faced by firms.[29] Figure A11 in the Appendix depicts the movements of the share of firms unsure about their BO and the share of firms unsure about their EO. 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 realised 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 non-importers. 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 EO does not significantly affect importers' inventory holdings. We further estimate the effects of uncertainty across three types of inventories.

[29] As Morikawa (2022) pointed out, the concept of uncertainty can be classified into (i) risk or Bayesian uncertainty when the probability is known and (ii) ambiguity or Knightian uncertainty when the probability is unknown. Thus, our measure reflects Knightian uncertainty.

Table 5: Increase in Inventories due to Uncertainty Faced by Importers

Dep. Var.: Inventory ratio	(1)	(2)	(3)	(4)	(5)	(6)
Unsure BO	0.00461		0.00740	-0.00209		-0.00457
	(0.00510)		(0.00628)	(0.00778)		(0.00933)
Unsure EO		-0.000677	-0.00494		0.000472	0.00313
		(0.00483)	(0.00591)		(0.00649)	(0.00771)
Unsure BO*Importer				0.0136		0.0269**
				(0.0100)		(0.0125)
Unsure EO*Importer					-0.00236	-0.0192
					(0.00938)	(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

BO = business outlook, EO = economic outlook.
Notes: The dependent variable is the inventory ratio one-quarter ahead (t+1) in all estimations. 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 Q1 2015–Q2 2021. Standard errors are clustered at firm level. Significance level: * 0.10, ** 0.05, and *** 0.01.
Source: Authors' calculation.

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: Increase in Work-in-Process Inventories due to Uncertainty Faced by Importers

Dep. Var.: Inventory ratio	(1)	(2)	(3)	(4)	(5)	(6)
Panel A: Materials and supplies						
Unsure BO	0.00244		0.000573	0.00175		-0.000522
	(0.00163)		(0.00190)	(0.00248)		(0.00272)
Unsure EO		0.00312**	0.00279		0.00368	0.00398
		(0.00156)	(0.00183)		(0.00246)	(0.00271)
Unsure BO*Importer				0.00141		0.00254
				(0.00326)		(0.00380)
Unsure EO*Importer					-0.00114	-0.00273
					(0.00311)	(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		0.00445	-0.00312		-0.00219
	(0.00250)		(0.00333)	(0.00344)		(0.00460)
Unsure EO		-0.00144	-0.00401		-0.00342	-0.00213
		(0.00206)	(0.00279)		(0.00262)	(0.00368)
Unsure BO*Importer				0.0111**		0.0145**
				(0.00493)		(0.00659)
Unsure EO*Importer					0.00407	-0.00509
					(0.00406)	(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		0.00419	0.00155		0.00149
	(0.00249)		(0.00321)	(0.00332)		(0.00441)
Unsure EO		0.00225	-0.000163		0.000492	-0.000248
		(0.00233)	(0.00304)		(0.00315)	(0.00419)
Unsure BO*Importer				0.00464		0.00576
				(0.00487)		(0.00633)
Unsure EO*Importer					0.00361	-0.000226
					(0.00461)	(0.00602)
N	57558	54156	54156	57558	54156	54156
R-sq	0.854	0.860	0.860	0.854	0.860	0.860

BO = business outlook, EO = economic outlook.

Notes: The dependent variables are the inventory ratios for all estimations. 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 Q1 2015–Q2 2021. Standard errors are clustered at the firm level. Significance level: * 0.10, ** 0.05, and *** 0.01.

Source: Authors' calculation.

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 utilise a large data set of Japanese manufacturing firms covering both the pre-COVID-19 and post-COVID-19 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, especially for firms relying on international supply chains and imported inputs. 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 behaviours 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.

References

Alessandria, G., J.P. Kaboski and V. Midrigan (2010a), 'Inventories, Lumpy Trade, and Large Devaluations', *American Economic Review*, 100(5), pp.2304–39.

——— (2010b), 'The Great Trade Collapse of 2008–09: An Inventory Adjustment?', *IMF Economic Review*, 58(2), pp.254–94.

Alessandria, G.A., S.Y. Khan, A. Khederlarian, C.B. Mix, and K. Ruhl (2023), 'The Aggregate Effects of Global and Local Supply Chain Disruptions: 2020–2022', *NBER Working Paper Series*, No. 30849. Cambridge, MA: National Bureau of Economic Research.

Antràs, P., D. Chor, T. Fally, and R. Hillberry (2012), 'Measuring the Upstreamness of Production and Trade Flows', *American Economic Review*, 102(3), pp.412–16.

Antràs, P. and S.R. Yeaple (2014), 'Multinational Firms and the Structure of International Trade', in G. Gopinath, E. Helpman, and K. Rogoff (eds.) *Handbook of International Economics*, Volume 4. Amsterdam: North Holland, pp.55–130.

Ara, T. and H. Zhang (2020), 'The Margins of Intermediate Goods Trade: Theory and Evidence', *The International Economy*, 23, pp.105–44.

Baker, S.R., N. Bloom, S.J. Davis, and S.J. Terry (2020), 'COVID-induced Economic Uncertainty', *NBER Working Paper Series*, No. 26983. Cambridge, MA: National Bureau of Economic Research.

Baldwin, R. and R. Freeman (2020), 'Supply Chain Contagion Waves: Thinking Ahead on Manufacturing "Contagion and Reinfection" from the COVID Concussion', VoxEU.org, 1 April.

Barrot, J.-N. and J. Sauvagnat (2016), 'Input Specificity and the Propagation of Idiosyncratic Shocks in Production Networks', *Quarterly Journal of Economics*, 131(3), pp.1543–92.

Blinder, A.S. and L.J. Maccini (1991), 'Taking Stock: A Critical Assessment of Recent Research on Inventories', *Journal of Economic Perspectives*, 5(1), pp.73–96.

Boehm, C.E., A. Flaaen, and N. Pandalai-Nayar (2019), 'Input Linkages and the Transmission of Shocks: Firm-level Evidence from the 2011 Tōhoku Earthquake', *Review of Economics and Statistics*, 101(1), pp.60–75.

Brussevich, M., C. Papageorgiou, and P. Wibaux (2022), 'Trade and the COVID-19 Pandemic: Lessons from French Firms', *IMF Working Paper*, No. WP/22/81. Washington, DC: International Monetary Fund.

Carreras-Valle, M.-J. (2021), 'Increasing Inventories: The Role of Delivery Times', mimeo. https://mjcarrerasv.github.io/website/W6_1022_v9.pdf

Carvalho, V.M., M. Nirei, Y.U. Saito, and A. Tahbaz-Salehi (2021), 'Supply Chain Disruptions: Evidence from the Great East Japan Earthquake', *Quarterly Journal of Economics*, 136(2), pp.1255–321.

Chen, C., T. Senga, and H. Zhang (2021), 'Measuring Business-Level Expectations and Uncertainty: Survey Evidence and the COVID-19 Pandemic', *Japanese Economic Review*, 72(3), pp.509–32.

Davis, S.J. and J.A. Kahn (2008), 'Interpreting the Great Moderation: Changes in the Volatility of Economic Activity at the Macro and Micro Levels', *Journal of Economic Perspectives*, 22(4), pp.155–80.

Dbouk, W., L. Moussawi-Haidar, and M.Y. Jaber (2020), 'The Effect of Economic Uncertainty on Inventory and Working Capital for Manufacturing Firms', *International Journal of Production Economics*, 230, 107888.

Gao, X. (2017), 'Corporate Cash Hoarding: The Role of Just-in-Time Adoption', *Management Science*, 64(10), pp.4471–965.

Hayakawa, K. and H. Mukunoki (2021a), 'Impacts of COVID-19 on Global Value Chains', *The Developing Economies*, 59(2), pp.154–77.

——— (2021b), 'Impacts of Lockdown Policies on International Trade', *Asian Economic Papers*, 20(2), pp.123–41.

Helper, S. and E. Soltas (2021), 'Why the Pandemic Has Disrupted Supply Chains', White House, 17 June. https://www.whitehouse.gov/cea/written-materials/2021/06/17/why-the-pandemic-has-disrupted-supply-chains/

Hummels, D. (2001), 'Time as a Trade Barrier'. http://www.krannert.purdue.edu/faculty/hummelsd/research/time3b.pdf.

Jain, N., K. Girotra, and S. Netessine (2014), 'Managing Global Sourcing: Inventory Performance', *Management Science*, 60(5), pp.1083–350.

Jiang, Y. and H. Zhang (2022), 'How Do Large Epidemics Redistribute Market Power: Evidence from the 2003 SARS Shock in China', http://hongsongzhang.weebly.com/uploads/1/3/4/7/13473383/inventory_jz.pdf

Kasahara, H. and B. Lapham (2013), 'Productivity and the Decision to Import and Export: Theory and Evidence', *Journal of International Economics*, 89(2), pp.297–316.

Kesavan, S., T. Kushwaha, and V. Gaur (2016), 'Do High- and Low-Inventory Turnover Retailers Respond Differently to Demand Shocks?', *Manufacturing & Service Operations Management*, 18(2), pp.177–307.

Khan A. and T. Senga (2019), 'Firm-Level Uncertainty and Cash Holding: Theory and Firm-level Empirical Evidence', *Economic Analysis*, 200, pp.164–85. https://www.esri.cao.go.jp/jp/esri/archive/bun/bun200/bun200g.pdf

Kimura, F. and K. Kiyota (2006), 'Exports, FDI, and Productivity: Dynamic Evidence from Japanese Firms', *Review of World Economics*, 142, pp.695–719.

Lafrogne-Joussier, R., J. Martin, and I. Mejean (2022), 'Supply Shocks in Supply Chains: Evidence from the Early Lockdown in China', *IMF Economic Review*, 71, pp.170–215.

Masters, B. and A. Edgecliffe-Johnston (2021), 'Supply Chains: Companies Shift from "Just in Time" to "Just in Case"', *Financial Times*, 20 December. https://www.ft.com/content/8a7cdc0d-99aa-4ef6-ba9a-fd1a1180dc82

Miroudot, S. (2020), 'Resilience Versus Robustness in Global Value Chains: Some Policy Implications', in R. Baldwin and S. Evenett (eds.) *COVID-19 and Trade Policy: Why Turning Inward Won't Work*. London: CEPR Press, pp.117–30.

Morikawa, M. (2022), 'Firms' Knightian Uncertainty during the COVID-19 Crisis', *RIETI Discussion Paper Series*, No. 22-E-089. Tokyo: Research Institute of Economy, Trade and Industry.

Nikkei (2022),' Car parts inventory increases by 30% compared to pre-coronavirus; companies increase due to supply constraints', 25 February 2022 https://www.nikkei.com/article/DGXZQOUC240800U2A220C2000000/ (in Japanese).

Nilson, J. (2013), 'Delayed Production and Raw Materials Inventory under Uncertainty', *International Journal of Production Economics*, 146(1), pp.337–45.

Ohno, T. (1988), *Toyota Production System: Beyond Large-Scale Production*. New York: Productivity Press.

Ortiz, J. (2022), 'Spread Too Thin: The Impact of Lean Inventories', International Finance Discussion Papers 1342. Washington: Board of Governors of the Federal Reserve System, https://doi.org/10.17016/IFDP.2022.1342

Pisch, F. (2020), 'Managing Global Production: Theory and Evidence from Just-in-Time Supply Chains', *CEP Discussion Paper*, No. 1689. London: Centre for Economic Performance, London School of Economics and Political Science.

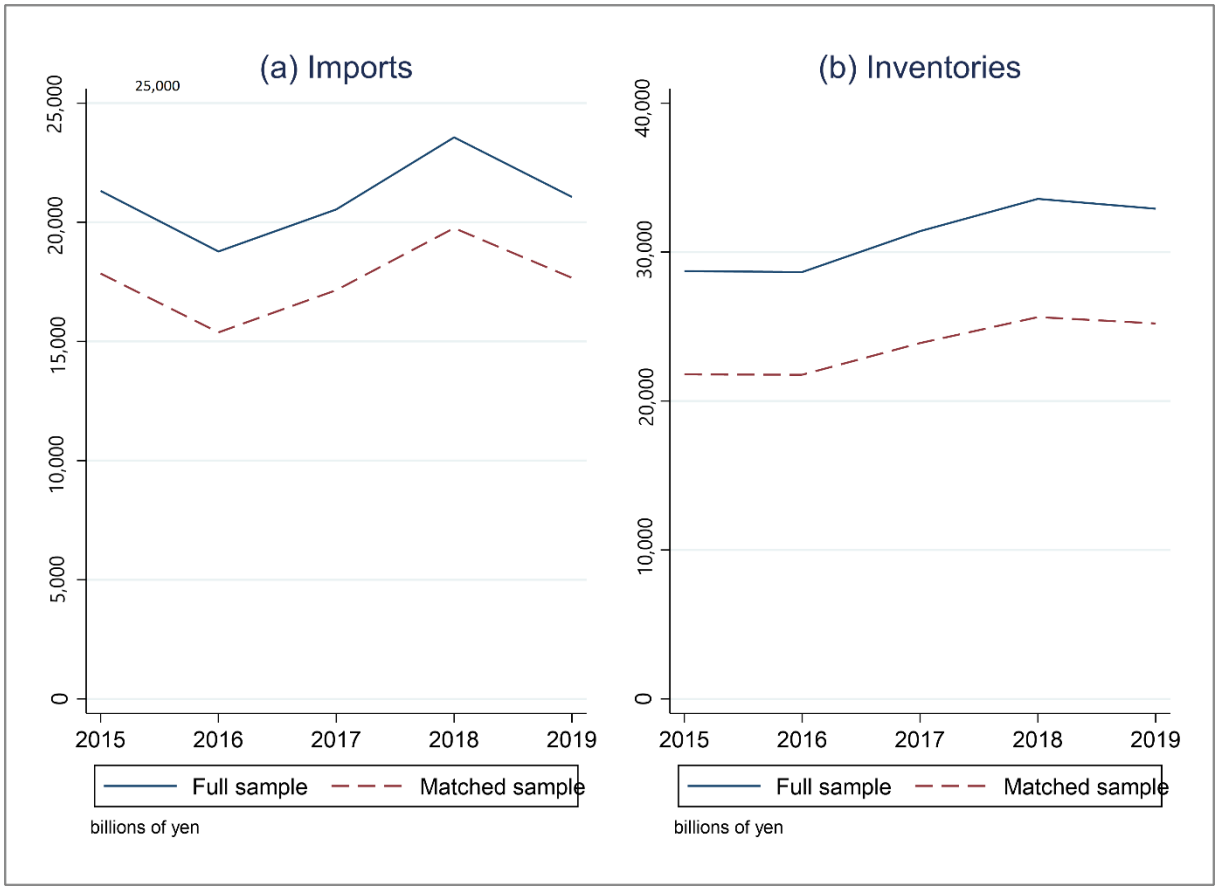
Rauch, J.E. (1999), 'Networks Versus Markets in International Trade', *Journal of International Economics,* 48(1), pp.7–35.

Sato, H., H. Zhang, and R. Wakasugi (2015), 'Imported Intermediates and Firm Performance: An Empirical Analysis Using Micro Data from Japanese Manufacturers', *RIETI Discussion Paper Series*, No. 15-J-015 (in Japanese). Tokyo: Research Institute of Economy, Trade and Industry.

Zhang, H. (2021), 'The Impact of COVID-19 on Global Production: Evidence from Japanese Multinational Firms', *The International Economy*, 24, pp.142–65.

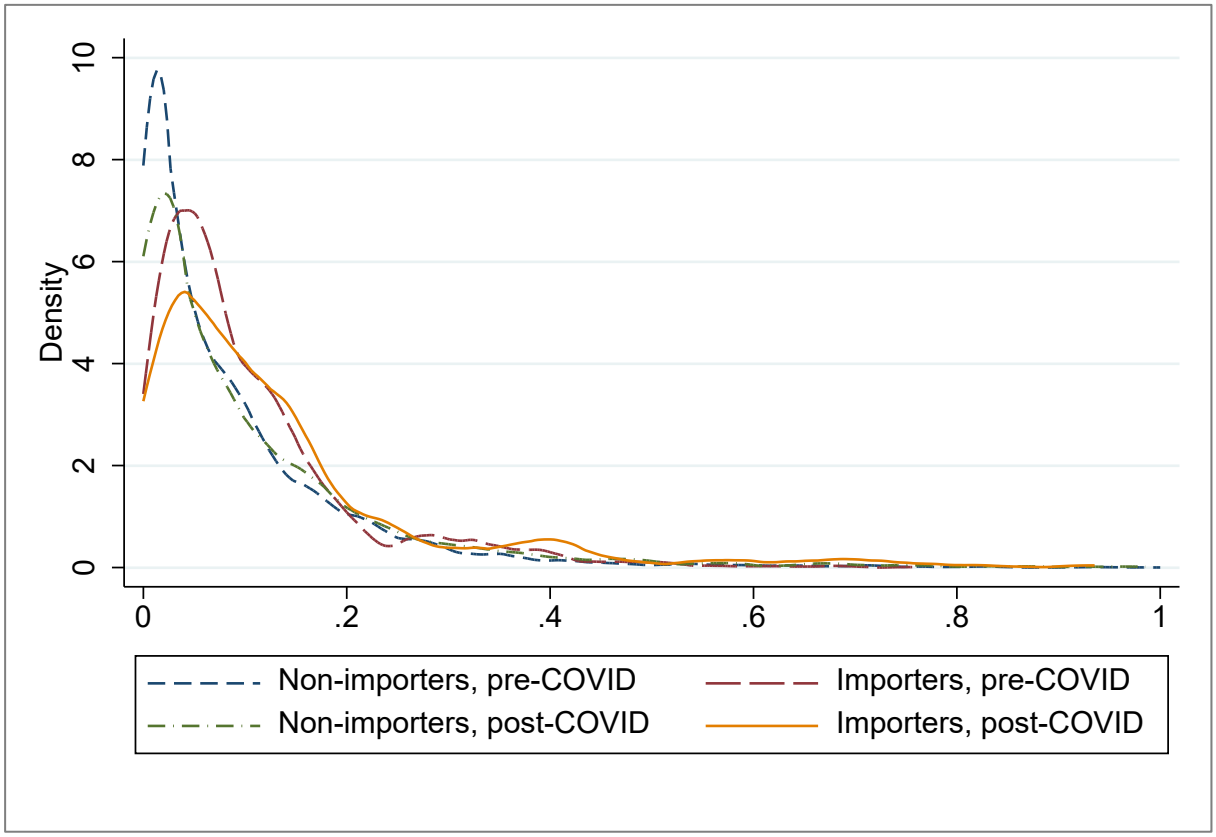
Appendix: Additional Figures and Tables

Figure A1: Data Validation



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

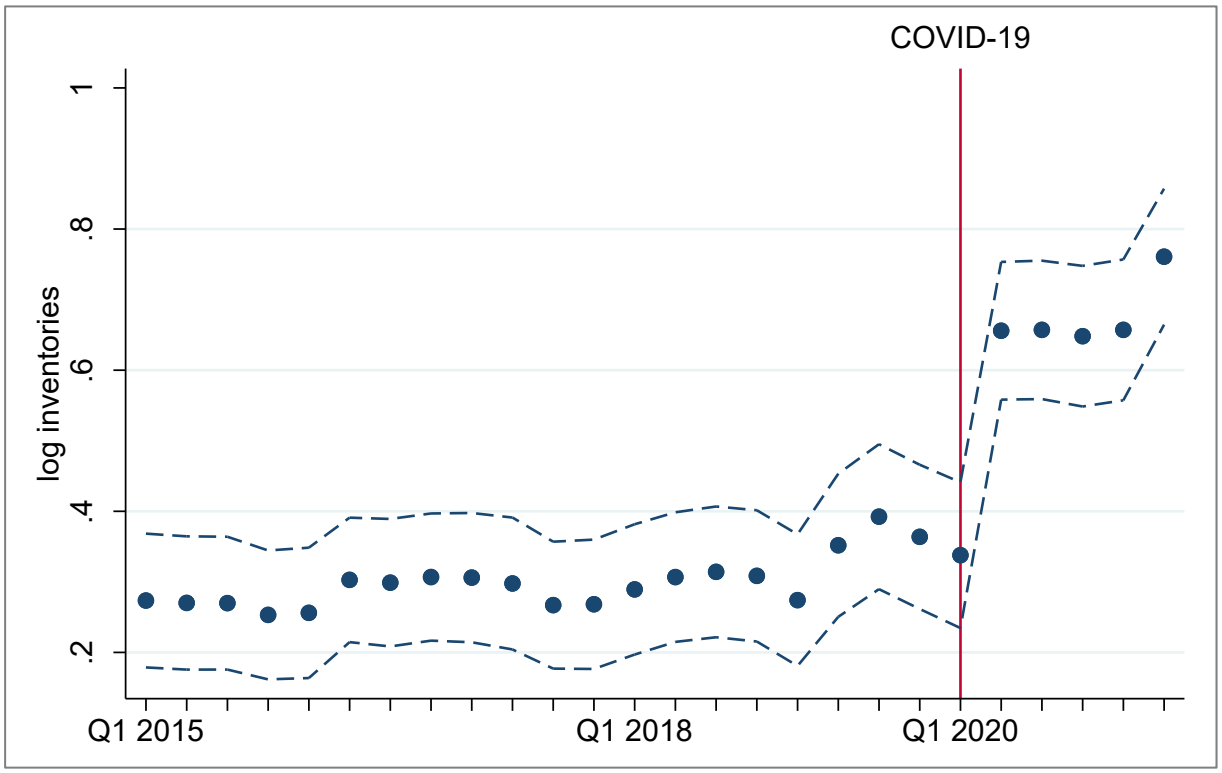


COVID-19 = coronavirus disease, Q = quarter.

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-19 (Q1 2015–Q4 2019) and post-COVID-19 (Q1 2020–Q2 2021) periods.

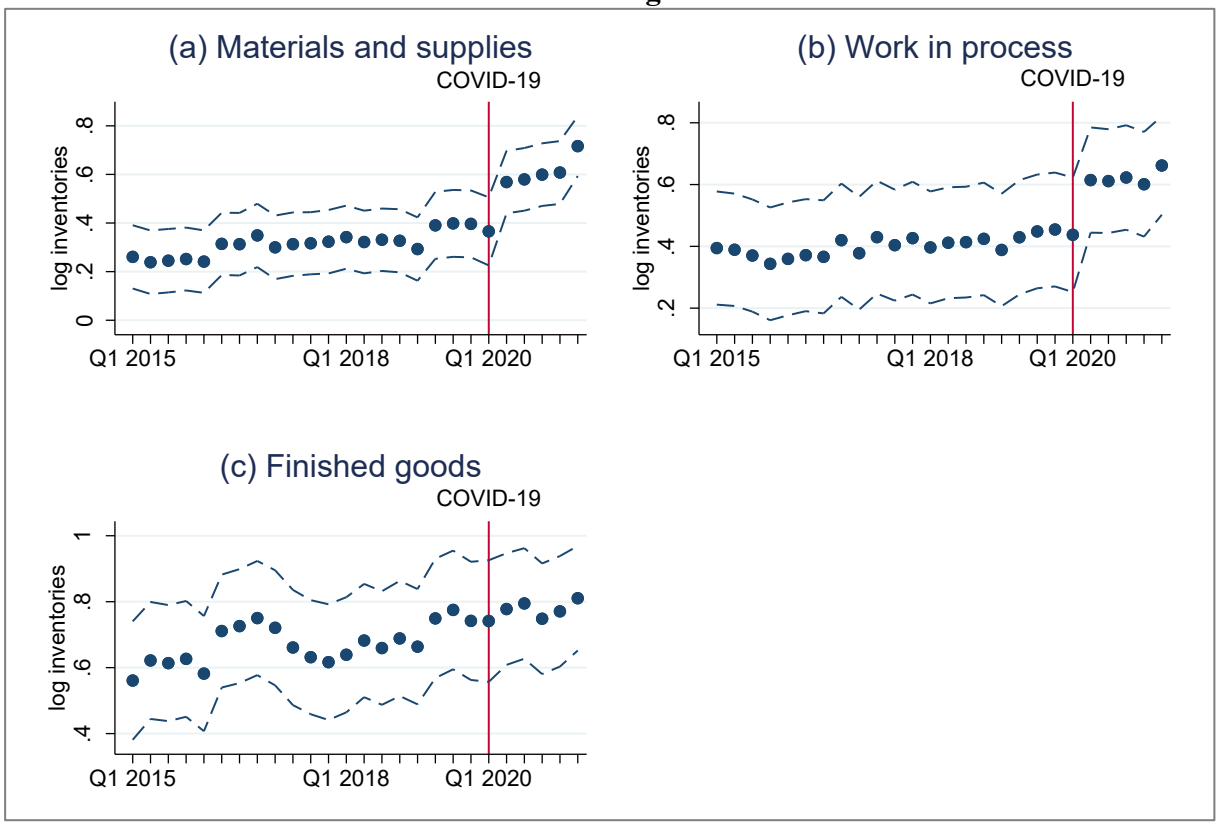
Source: Authors' calculation.

Figure A3: Increase in Importers' Inventories After the Pandemic – Log Inventories



COVID-19 = coronavirus disease, Q = quarter.
Notes: This figure plots the estimates of the importer-time dummy variables for Q1 2015–Q2 2021, controlling for firm size, industry-time, and region-time fixed effects. Dotted lines represent the 95% confidence intervals.
Source: Authors' calculation.

Figure A4: Increase in All Three Types of Inventories by Importers After the Pandemic – Log Inventories

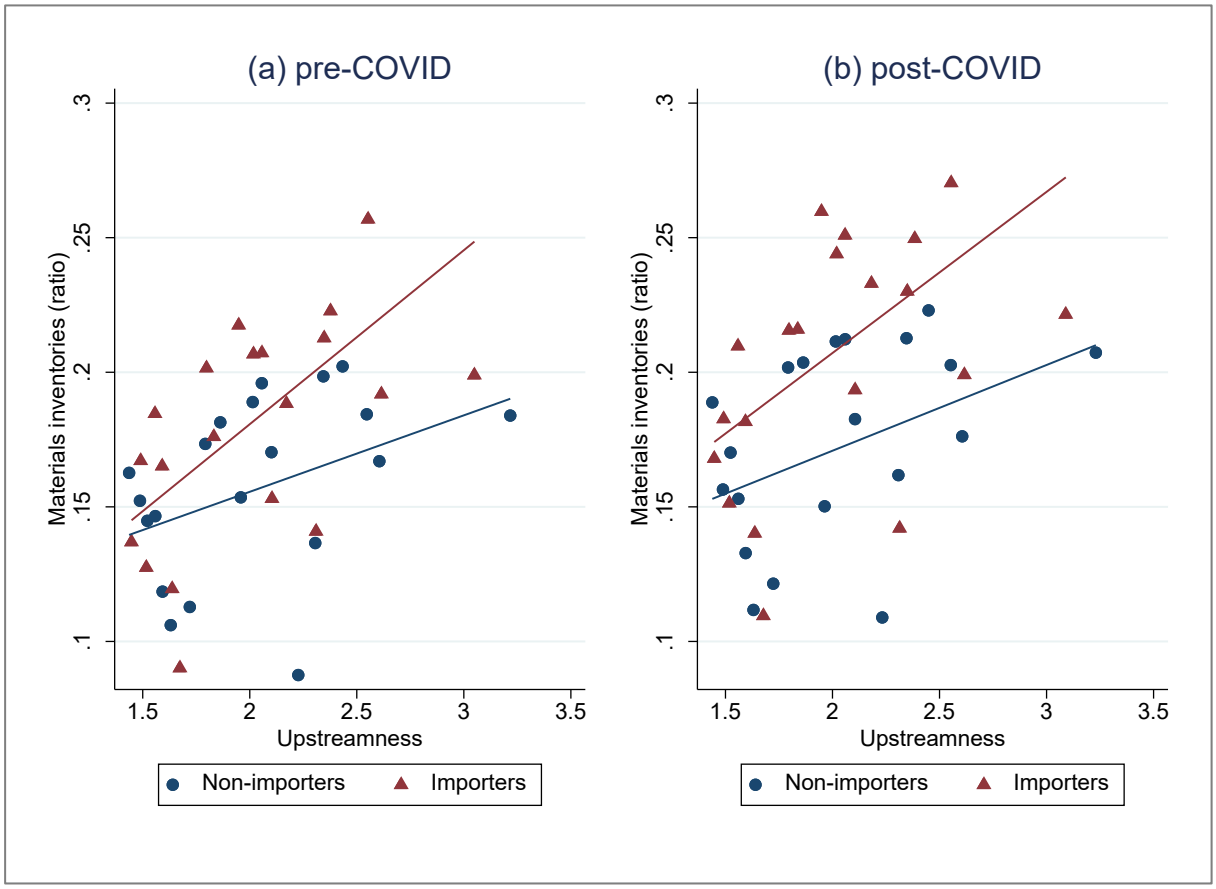


COVID-19 = coronavirus disease, Q = quarter.

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

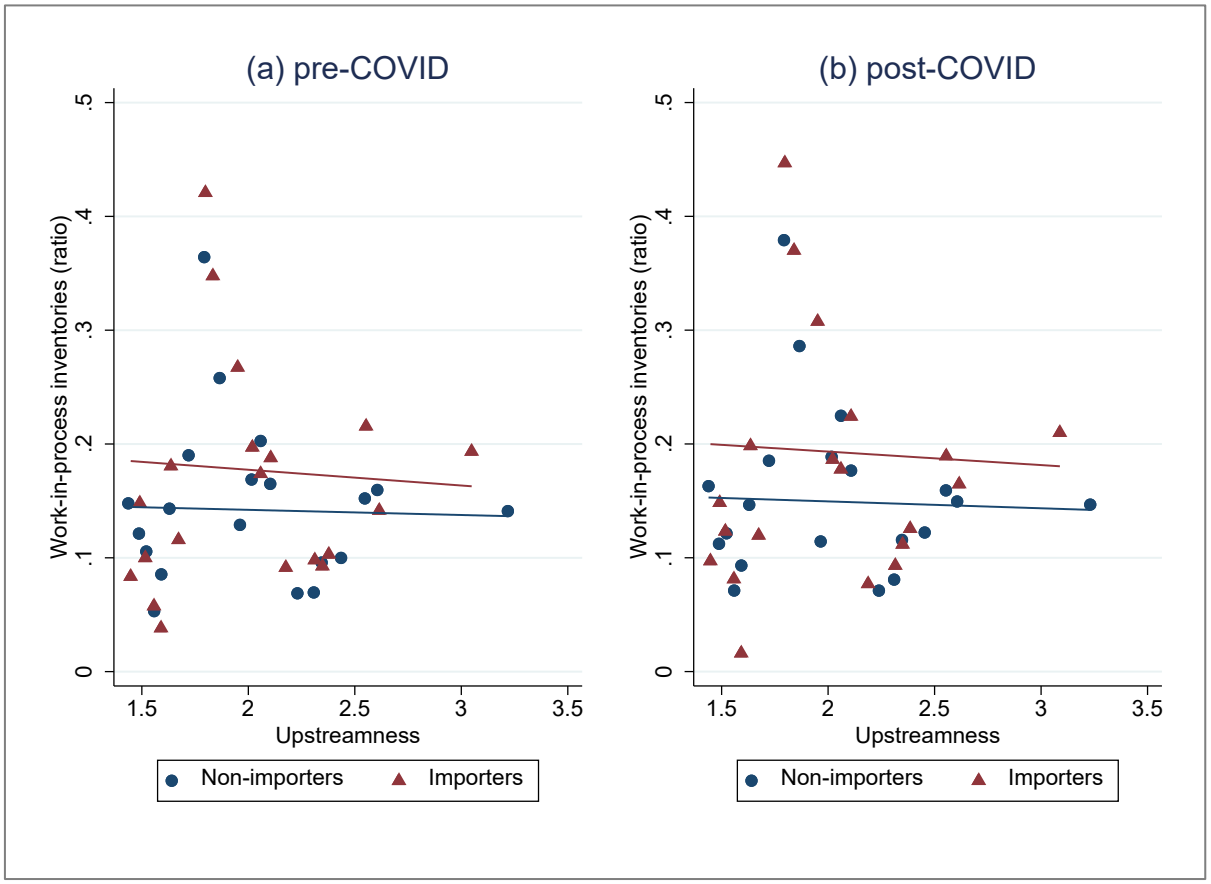
Source: Authors' calculation.

Figure A5: Increase in Materials Inventories in Upstream Industries



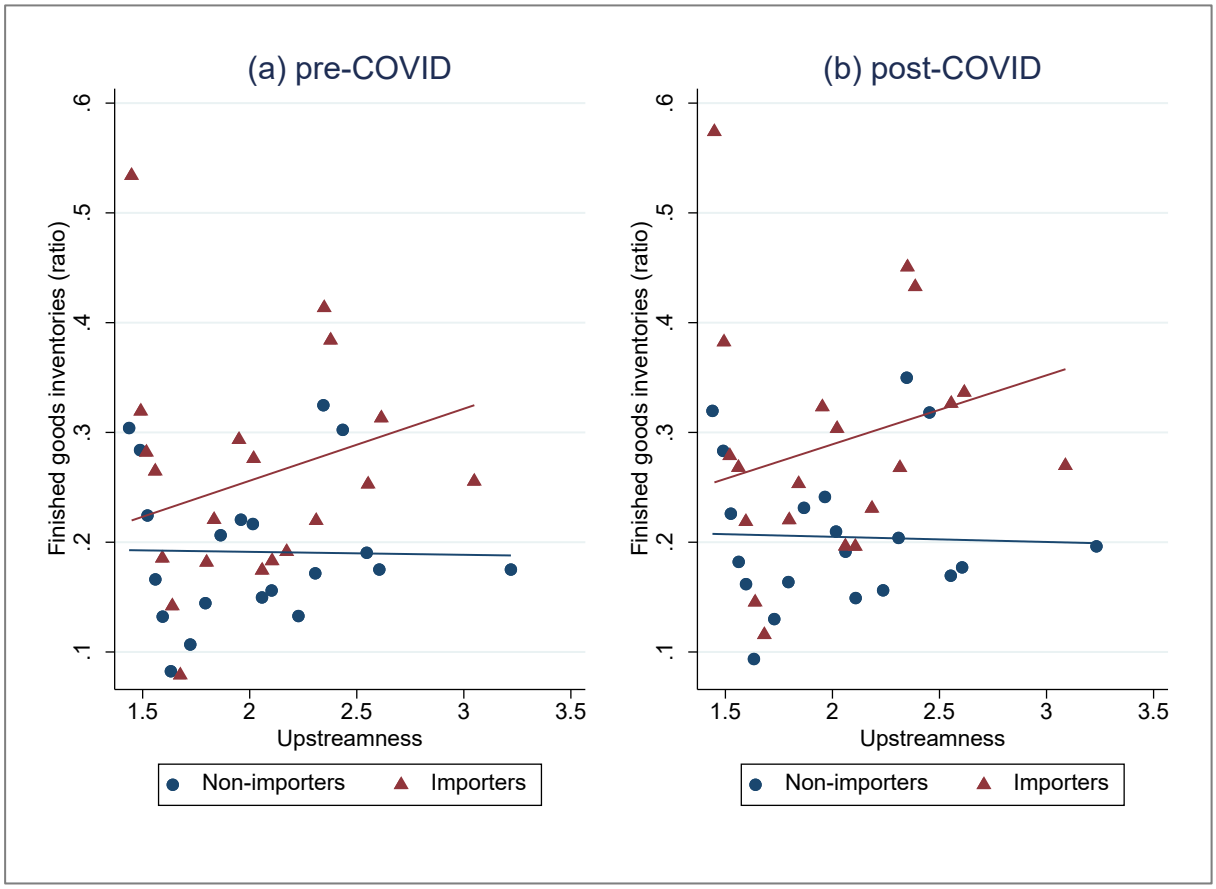
COVID-19 = coronavirus disease, Q = quarter.
Notes: This figure plots the relationship between industry upstreamness and inventory ratio in the pre-COVID-19 (Q1 2015–Q4 2019) and post-COVID-19 (Q1 2020–Q2 2021) periods, controlling for firm size, region, and time fixed effects. Each dot indicates a bin of firm observations. A larger value of upstreamness is associated with a higher level of upstreamness of an industry's output.
Source: Authors' calculation.

Figure A6: No Increase in Work-in-Process Inventories in Upstream Industries



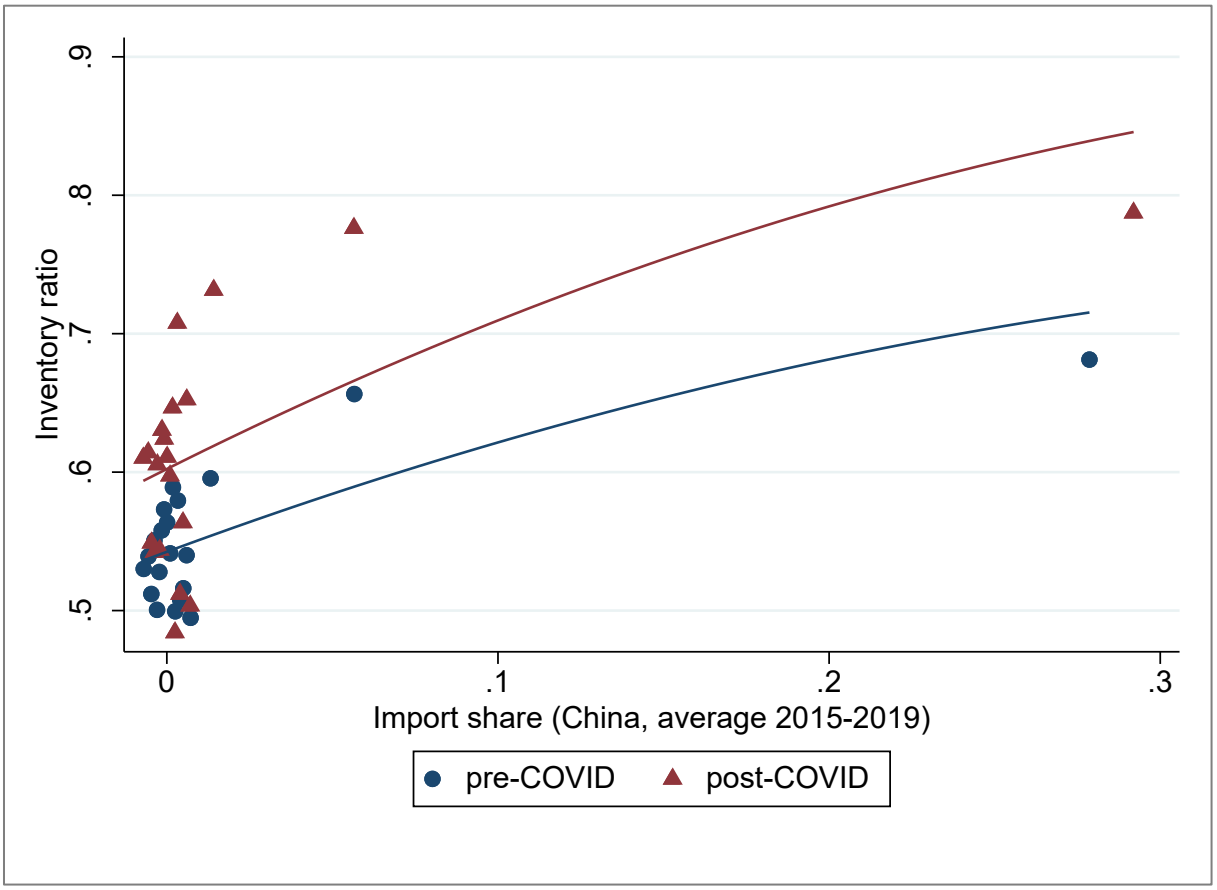
COVID-19 = coronavirus disease, Q = quarter.
Notes: This figure plots the relationship between industry upstreamness and inventory ratio in the pre-COVID-19 (Q1 2015–Q4 2019) and post-COVID-19 (Q1 2020–Q2 2021) periods, controlling for firm size, region, and time fixed effects. Each dot indicates a bin of firm observations. A larger value of upstreamness is associated with a higher level of upstreamness of an industry's output.
Source: Authors' calculation.

Figure A7: Increase in Importers' Final Goods Inventories in Upstream Industries



COVID-19 = coronavirus disease, Q = quarter.
Notes: This figure plots the relationship between industry upstreamness and inventory ratio in the pre-COVID-19 (Q1 2015–Q4 2019) and post-COVID-19 (Q1 2020–Q2 2021) periods, controlling for firm size, region, and time fixed effects. Each dot indicates a bin of firm observations. A larger value of upstreamness is associated with a higher level of upstreamness of an industry's output.
Source: Authors' calculation.

Figure A8: Increase in Inventories with *Ex Ante* Imports from China

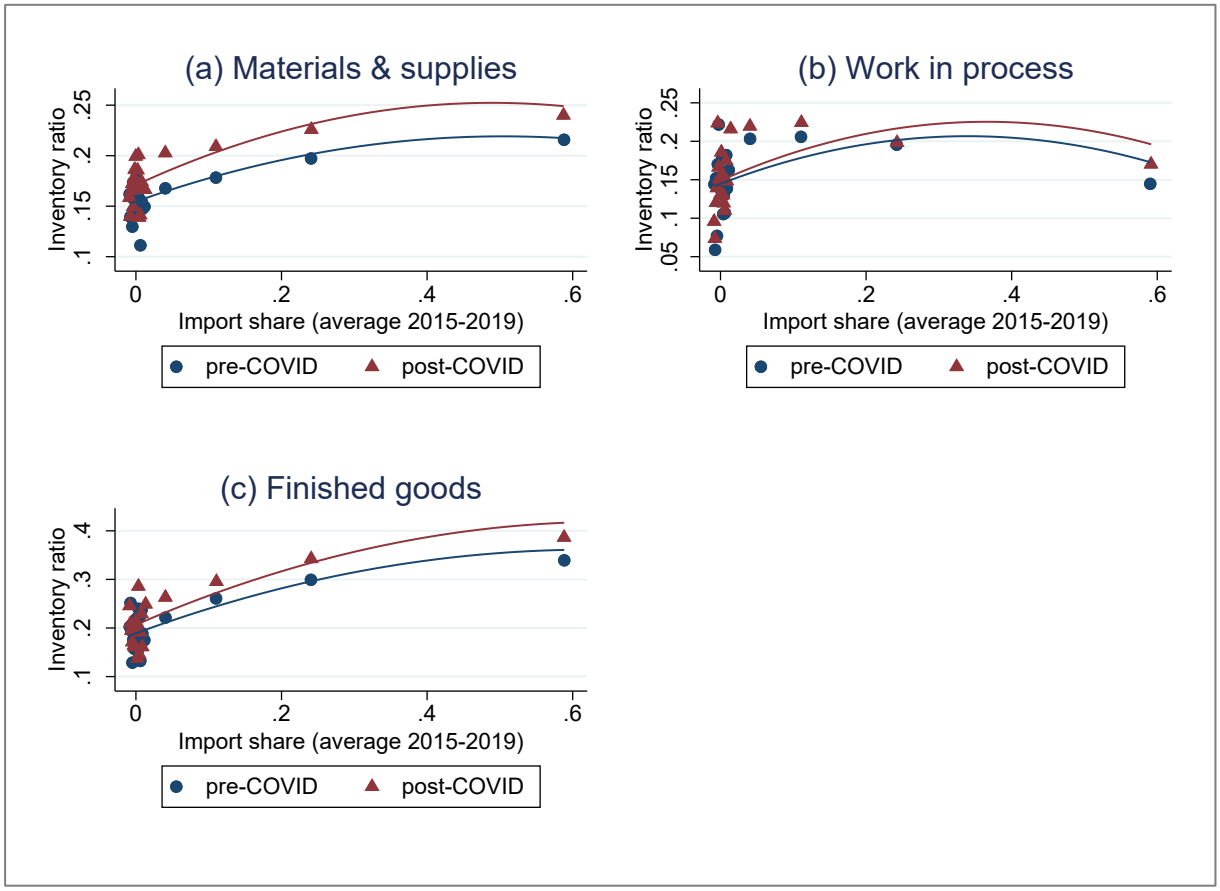


COVID-19 = coronavirus disease, Q = quarter.

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-19 (Q1 2015–Q4 2019) and post-COVID-19 (Q1 2020–Q2 2021) periods, controlling for industry-time and region-time fixed effects. Each dot indicates a bin of firm observations.

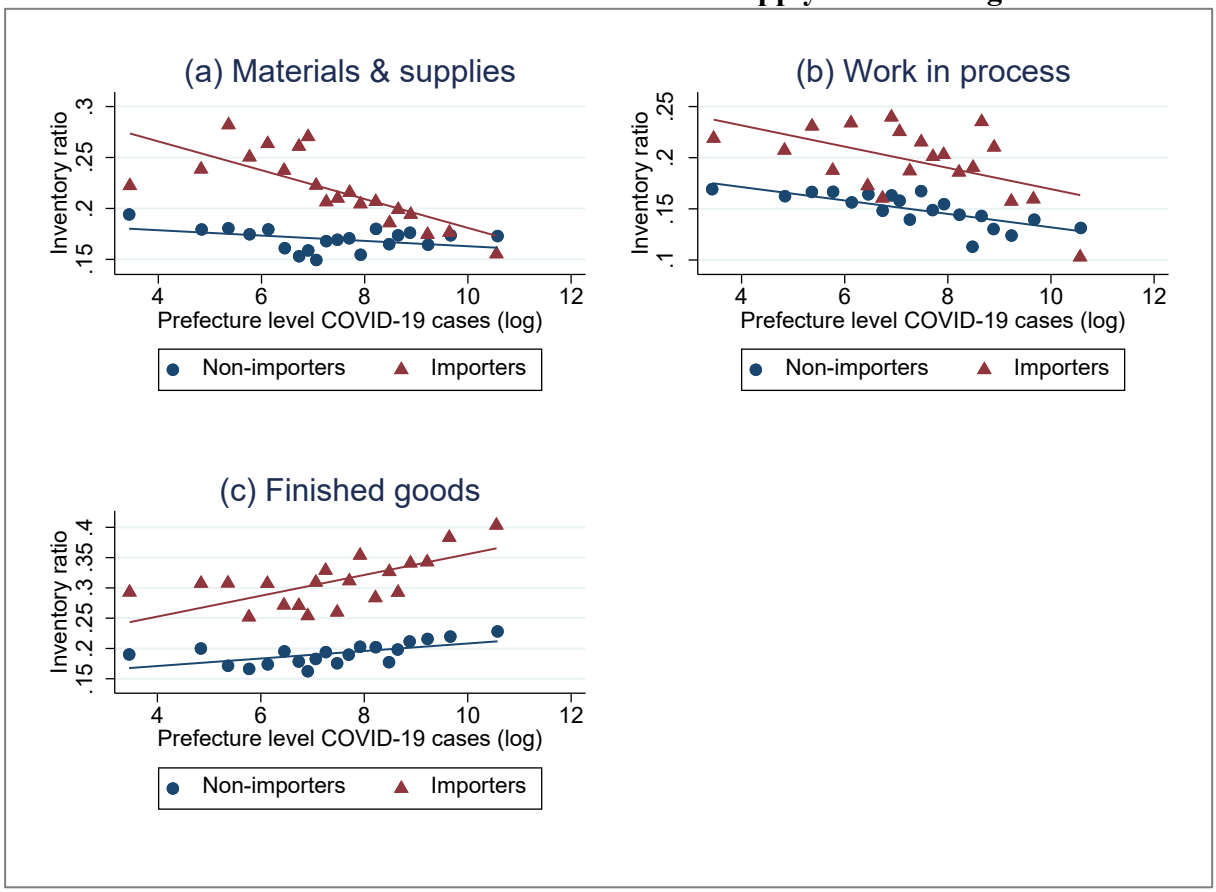
Source: Authors' calculation.

Figure A9: Increase in All Three Types of Inventories with *Ex Ante* Imports After the Pandemic



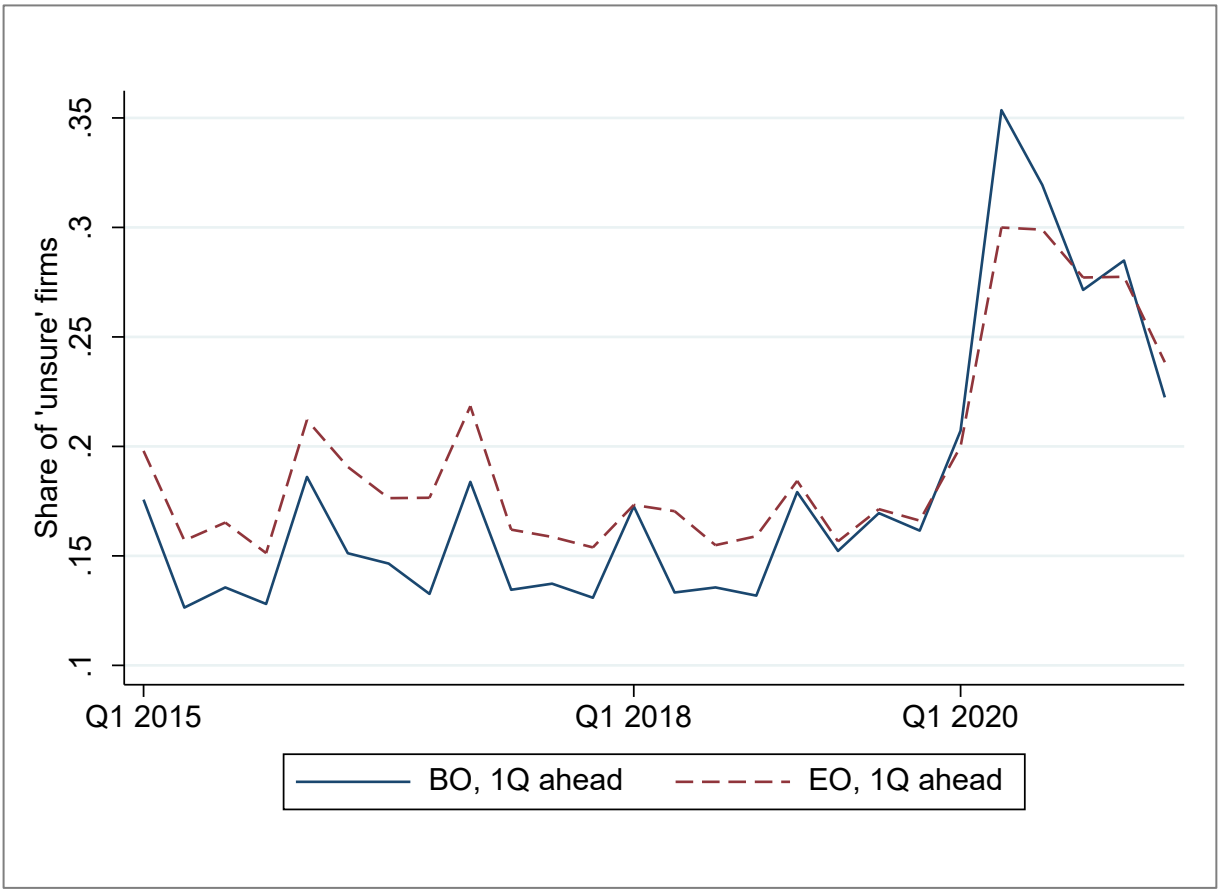
COVID-19 = coronavirus disease, Q = quarter.
Notes: This figure plots the relationship between the *ex ante* firm import share (imported inputs in total sourcing) and inventory ratio in the pre-COVID-19 (Q1 2015–Q4 2019) and post-COVID-19 (Q1 2020–Q2 2021) periods, controlling for industry-time and region-time fixed effects. Each dot indicates a bin of firm observations.
Source: Authors' calculation.

Figure A10: Increase in Finished Goods Inventories due to the Demand Shock and Decrease in Work-in-Process Inventories due to the Supply Shock – Single-Plant Firms



COVID-19 = coronavirus disease, Q = quarter.
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.
Source: Authors' calculation.

Figure A11: Increase in Firm-Level Uncertainty After the Pandemic



BO =business outlook, EO = economic outlook, Q = quarter.
Notes: This figure plots the share of manufacturing firms answering 'unsure' about the business outlook and economic outlook for Q1 2015–Q2 2021.
Source: Authors' compilation based on the BOS.

Table A1: Large Inventories of Importing Firms

	(1)	(2)	(3)	(4)
	log(Inventories)		Inventory ratio	
Importer	1.180***	0.721***	0.0352***	0.0375***
	(0.0318)	(0.0254)	(0.00164)	(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, and *** 0.01.
Source: Authors' calculation based on the BSJBSA.

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