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Resilience of Japanese Multinational Enterprises' Production Networks during the COVID-19 Pandemic

Liang Licheng
(PhD student, Graduate School of Economics, Keio University)

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Institute of Economic Research
Hitotsubashi University
Kunitachi, Tokyo, 186-8603 Japan

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Liang Licheng †

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Abstract

We use COVID-19 as an exogenous shock to analyze the impact of Covid-19 pandemic on Japanese multinational affiliates' performance, determining that the pandemic adversely impacted performance in general, but severe disruptions did not last longer than one year. The COVID-19 shock also affected global transaction networks, and affiliates' total sales were severely affected by procurement challenges. Regarding heterogeneous effects, affiliates actively engaged in trade experienced worse conditions than local-oriented firms. Finally, we explore whether and which local backward linkages could mitigate such shocks, concluding that affiliates' local procurement from companies beyond only Japanese firms could gain resilience.

Keywords: COVID-19; Multinational enterprises (MNEs); Affiliates; International production network; Resilience
JEL Codes: F14; F23

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†PhD student, Graduate School of Economics, Keio University

1 Introduction

To date, the ongoing COVID-19 pandemic still grips the whole world, with a total of more than 670.2 million confirmed cases and 6.8 million deaths as of January 2023 [1]. Since the first outbreak in China in early 2020, the COVID-19 pandemic has hit the global economy heavily. On the demand side, the pandemic and corresponding lockdown policies reduced consumers' buying capabilities and willingness (Brinca et al., 2020) and hampered supply because workplaces were closed, plants slowed production or shut down, and cross-border activities were largely restricted., The pandemic caused unprecedented disruptions to international trade and global production networks as an economic consequence, given existing global value chains (GVCs).

Along with the economic consequences of COVID-19, multinational enterprises (MNEs) faced disrupted supply chains, declining revenue, and falling production (Saurav et al., 2021). Considerable anecdotal evidence demonstrates GVCs' consequential damage, as well as many real-world examples of the ripple effect of COVID-19 on multinational firms' value chains. One among many is the case of Nissan Motor. When the operation of the joint ventures in Hubei, China (the pandemic's epicenter) was affected by lockdowns, Nissan's plant in Kyushu, Japan suspended production. According to a survey conducted by the Shanghai Japanese Commerce and Industry Club in early 2020, the supply chains of 54% of the Japanese companies operating in China interviewed were affected, while only 23% had alternative procurement channels (Xing, 2021).

In this context, this crisis revived policy debates regarding the benefits and costs of the expanding and deepening fragmentation of production in GVCs. Some argue that the pandemic uncovered the underlying vulnerability of existing GVCs, predicting overall reconfiguration in the aftermath of the pandemic (Silverthorne, 2020). Evolving geographical GVC configurations could result in the rise of regionalization (Enderwick and Buckley, 2020).

[1] Refer to the Coronavirus Research Center, Johns Hopkins University. The data is available here: https://coronavirus.jhu.edu/map.html

Restructuring value chains, including localization of critical goods, diversification of suppliers, and reshoring, has become the new strategic approach for firms and government policy intervention (Javorcik, 2020). In a real-world example from the pandemic, multi-sourcing and supply chain diversification are now common sense among many Japanese manufacturing companies [2]. In contrast to the predictions of the large-scale reengineering of GVCs, some others note that supply chains were more robust and resilient than originally assumed (Ando et al., 2021), and supply chain fragility does not solely explain the decline in trade, but only had a modest role when compared with the demand shock during the pandemic period (Ahsan and Iqbal, 2021). Although the transmission of COVID-19 shock through GVCs caused global GDP decline, re-nationalization of value chains could deteriorate the situation rather than improve it, given that international trade can save troubled economies by providing critical foreign inputs (Bonadio et al., 2021). In addition, localization of current regimes is estimated to decrease global real GDP by more than 5% and lower the stability of the world economy (Arriola et al., 2020). Rather than localization, the role of supplier and customer diversification in mitigating the COVID-19 shock is widely studied (Todo et al., 2022; Gereffi, 2020; Lafrogne-Joussier et al., 2022).

The pandemic also generated further debate regarding firms' inventory philosophy, such as the strategic choice between just-in-time and just-in-case manufacturing (Brakman et al., 2020). The relationship between these two approaches can be analogized as a tradeoff between efficiency and robustness; thus, finding a balancing point is crucial for firms' resilience. Some argue that multinational firms should follow the "probability matching" rule[3] to consider "the worst case scenario" in response to a systemic shock like COVID-19 (Jiang et al., 2022). Some highlight the positive effect of high inventories on firm resilience (Lafrogne-Joussier et al., 2022).

Although previous studies have documented the adverse impacts of COVID-19 on in-

[2]Refer to the FJCCIA Business Survey (2020), see https://jjc.or.id/hojin/wp-content/uploads/rijikai/01-4-Annex-to-position-paper-FJCCIA-Survey-Report.pdf

[3]A psychological phenomenon indicating that the propensity for an agent to choose among alternatives reflects the probability associated with the outcome of such choice.

ternational trade and GVCs (Hayakawa and Mukunoki, 2021a; Hayakawa and Mukunoki, 2021b; Baldwin and Freeman, 2020), investigations regarding COVID-19 impacts on within-MNEs' international production networks are lacking; therefore, this study aims to fill this gap. Zhang (2021) examines the impacts of COVID-19 on MNEs' global production activities using country- and industry-level aggregate data on Japanese manufacturing affiliates, revealing significant adverse impacts on production and performance in general. However, given that COVID-19 is a systemic shock, the overall impacts must not be limited to direct impacts alone. In other words, supply–customer linkages across firms in different locations also affect targeted affiliates' production activities. In this case, studies might overlook the impacts transmitted through affiliates' transaction networks if they solely focus on the direct pandemic shock. To avoid this issue, we assess the extent to which the impacts of COVID-19 are propagated through transaction linkages within MNE global production networks.

To quantify the disruptions of COVID-19 on MNEs' overseas production networks, we use detailed quarterly affiliate-level data from Japanese MNEs from 2019 Q1 to 2020 Q4. Since our focus is MNEs' production networks, supply shock generated by governments' response policies had substantial influence; thus, in addition to the number of confirmed new COVID-19 cases, we also employ the stringency index gauging governments' response to COVID-19 as another measure of the pandemic for some of our tests. Taking advantage of the detailed affiliate-level data, we further explore the heterogeneous impacts of COVID-19 across affiliates' different exposure circumstances. For instance, although the COVID-19 pandemic was a systemic shock for affiliates worldwide overall, each affiliate was exposed to the shock differently. Regarding the stylized fact that Japanese foreign direct investment (FDI) is networked (Okubo and Watabe, 2023), to precisely identify the heterogeneous impacts, we classify affiliates into trading and local-oriented affiliates. Trading affiliates are export/import-intensive affiliates with a higher international trade share, while local-oriented affiliates are inactive in exports or imports. We expect that affiliates that are highly dependent on trade were more susceptible to shocks as they experienced more severe

shocks from demand and supply. We compare the performance differences between local-oriented affiliates and those engaged in international trade and demonstrate the positive effect of localization in resilience to COVID-19. Moreover, we also examine the heterogeneous reactions of affiliates depending on different local backward linkages to the COVID-19 shock. Our empirical results show that overseas affiliates that were strongly reliant on inputs from the home country pre-COVID-19 tended to experience worse conditions during the pandemic. This finding has policy implications regarding the application of local procurement strategy in the post-pandemic era.

The remainder of the paper is organized as follows. The next section reviews the relevant previous literature. In Section 3, we present an overview of the study's empirical framework and hypotheses. Section 4 describes the data and empirical strategies, and section 5 presents the results. Finally, section 6 discusses our findings and proposed policy implications.

2 Literature review

This study is related to several strands of literature. First, the study supplements the nascent literature regarding the impacts of COVID-19 on international trade and the resilience of GVCs. Baldwin and Freeman (2020) point out that the manufacturing supply chain contagion that originated from China reinfected Chinese industries. The industrial disruption of the pandemic outbreak in China also hit other economies that relied strongly on Chinese imports. This is considered the first round of the contagion. When the US and Germany implemented COVID-19 measures, the contagion changed course, resulting in difficulties in Chinese manufacturing production. Such studies assert that international coordination is a solution to these cyclical contagion effects. Comparing the January–August 2019 with the same period in 2020, Hayakawa and Mukunoki (2021a) verify the significant negative impacts of the pandemic on trade for both exporting and importing countries, regardless of which measure is applied to demonstrate COVID-19 damage. The authors extend the study to ma-

chinery trade in the GVC context, revealing evidence of propagated supply-chain disruptions that decreased exports of final goods from an exporting country that sources inputs from a country experiencing a difficult COVID-19 situation (Hayakawa and Mukunoki, 2021b). Considering three types of shocks (negative supply shocks, negative demand shocks, and positive demand shocks), Ando et al.(2021) investigate the resilience of trade in parts and components by examining decomposed HS nine-digit Japanese machinery trade data in the early wave of pandemic. Their findings confirm the dramatic drop in components and final goods trade during the first wave of the pandemic from January to May 2020; however, after reaching a low in May 2020, trade began to recover and returned to normal around October 2020. Because existing shocks can affect production differently, the authors also reveal heterogeneous effects across sectors and products in the same sector.

Similarly, Ahsan and Iqbal (2021) analyze firm-level trade data for apparel manufacturers in Bangladesh and find that the demand shocks from COVID-19 in exporting destination countries accounted for the highest decline in exports from hypothetical firms. The empirical analysis includes both the supply and demand shocks, but the impacts induced by the former are negligible compared with those from the latter channel. The authors also suggest that firms that were more dependent on Chinese inputs did not suffer sharp declines in comparison with those that were less dependent on Chinese inputs, concluding that supply chains may not be as fragile as initially considered. Kiyota (2022) examines how global trade networks have changed since COVID-19, with a focus on ASEAN economies. The network analysis results imply that the relative importance of ASEAN countries in the international trade network remained unchanged throughout the pandemic.

This paper is also related to previous studies examining the spatial propagation of natural disaster shocks through production chains. Barrot and Sauvagnat (2016) identify transmission of shocks via supplier–customer linkages between firms, determining that shocks to upstream suppliers lead to decreased sales growth and stock returns for downstream customers. Boehm et al. (2019) demonstrate the spatial propagation of disasters through

between-firm supply chain linkages using firm-level data. Focusing on the US affiliates of Japanese multinational companies, the research suggests that the output produced by these firms dropped significantly in the aftermath of the 2011 Tohoku earthquake, along with a decline in imports. Todo et al. (2015) demonstrate that border and more diversified supply-chain networks may delay a firm's recovery from shocks because of the spatial propagation effect; however, since a more diversified supply chain network allows firms to replace disrupted suppliers more efficiently, such benefits can offset the negative effect. Todo et al. (2019) also simulate the impact of the 2011 earthquake on production dynamics across Japan through supply chains, showing that indirect effects are far more significant. In contrast to inter-firm propagation, studies on within-firm dimensions are limited. Seetharam (2018) examines the spatial propagation of the impact of hurricanes by examining linkages between disrupted and non-disrupted areas via plant ties within firms. The author determines that additional jobs are lost in non-disrupted or non-directly exposed areas due to spatial propagation within multi-plant firms.

Another related strand of literature investigates the impacts of COVID-19 on MNEs' investment decisions and overseas operations. Hayakawa et al. (2022) find that severity of COVID-19 conditions in home and host countries lowered the propensity of greenfield FDI. However, this is not the case for cross-border mergers and acquisitions. Zhang (2021) examines the impacts of COVID-19 cases and lockdown policies using aggregate-level data from Japanese overseas affiliates, finding generally negative impacts on production and performance, also determining that lockdown policies to be negatively related with sales and employment. Borino et al. (2021) further confirm the resilience of international firms, finding that despite international firms being more exposed to COVID-19 shocks, they still exhibited greater resilience than domestic-only firms due to more extensive availability of alternative solutions; namely, sourcing from new suppliers, developing new products, and other approaches.

Additionally, we join the discussion regarding the strategies for firms to gain resilience.

Using a unique firm-level data set, Todo et al. (2022) seek to identify the firm characteristics or linkages between firms that advanced resilience in response to COVID-19, and the results suggest that diversification of input sources may mitigate the shock. This finding aligns with Ando and Hayakawa (2022), which also emphasize the positive effects of input import diversity for generating value chain resilience. Another study about the impacts of Chinese lockdowns on French firms (Lafrogne-Joussier et al., 2022) demonstrates that inventories mattered more than ex-ante diversification since inventories acted as a buffer against input shortages in the early period of the pandemic. There is also an association between localization and resilience. Experienced Japanese MNE affiliates have been engaged in enhancing local backward linkages for years (Kiyota et al., 2008). For affiliates in particular, an increased local procurement ratio may contribute to better performance in host countries with low wages (Ito and Fukao, 2010). Furthermore, investigating the impacts of the 2011 Thailand flood on Japanese affiliates, Hayakawa et al. (2015) find that damaged small Japanese affiliates tended to reduce local procurement shares, particularly from other Japanese firms located in the same host country. Whether localization matters for firms in navigating the COVID-19 shock remains an unanswered question.

3 Empirical Framework and hypotheses

We first conduct an examination of the adverse impacts of Covid-19 on affiliates' performance to demonstrate the disruptions in overseas production activities during the pandemic. Then, based on previous literature, we establish the following hypotheses to be tested.

Hypothesis 1: Affiliates operating in industries that rely heavily on international production and supply chains may experience a relatively slow recovery.

Some industrial sectors are more exposed to the shock because of high value-chain intensity, such as automotives, electronics, machinery and equipment (UNCTAD, 2022). Thus, we expect that the cluster of industries with higher exposure may take more time for recovery.

Hypothesis 2: Effects are propagated through transaction networks across regions, and affiliates' production is affected by the COVID-19 circumstances in the host country as well as procurement origins and sales destinations. Also, such propagation occurs within the MNE's international production networks.

Considering the transmission of the shock, firms with higher international exposure are expected to be more likely to encounter difficulties compared to domestic-only firms (Borino et al., 2021). Therefore, we expect local-oriented affiliates that are concentrated in the domestic market to suffer less from the shock relative to exporting or importing-intensive affiliates. Bearing in mind the relationship between procurement localization and performance (Ito and Fukao, 2010), we expect local procurement to have an influence in this case, arguing that affiliates with higher reliance on local inputs are less affected by international trade disruptions, leading to our third hypothesis below.

Hypothesis 3: Firms engaged in international trade are more likely to face worse conditions due to COVID-19. Localization of procurement may help solve the input shortage issue and partially mitigate the shock.

High reliance on specific inputs may result in substitution difficulties (Barrot and Sauvagnat, 2016). In this case, we expect that Japanese affiliates that are highly dependent on made-in-Japan inputs may encounter more difficulties due to input shortages during the pandemic leading to inferior performance.

Hypothesis 4: Since input specificity creates difficulties in resilience, high dependence on specific home-country linkages could negatively affect overseas affiliates' performance.

4 Data and methodology

4.1 Data

In the empirical analysis, we examine the impacts of COVID-19 on overseas affiliates' of Japanese MNEs. Affiliate-level data for Japanese MNEs are obtained from the Japanese

governmental surveys, using the Quarterly Survey of Overseas Subsidiaries (QSOS) compiled by the Ministry of Economy, Trade, and Industry (METI). This survey contains rich information on sales, capital investment, and regular employees of overseas affiliates in the Japanese manufacturing sector with more than 50 employees. One merit of using this data source is that affiliate-level sales are decomposed into local sales, sales to Japan, and sales to third countries (excluding Japan). The sample period of our study is from the first quarter of 2019 (2019q1) to the last quarter of 2020 (2020q4).

To identify the heterogeneous impacts of COVID-19 shock across affiliates, we also use information on affiliates' pre-COVID characteristics. For this information, we refer to another data source, the Basic Survey on Overseas Business Activities compiled by the METI, which provides annual information on affiliates' profiles and financial details. In this data set, sales and procurement are decomposed in terms of shipment destinations and procurement origins, including local sales, sales to North America (NA), sales to Asia (exports to Asia), sales to Europe (exports to Europe), and sales to the rest of the world (exports to RoW), local procurement, procurement from Japan (imports from Japan), procurement from NA (imports from NA). Similarly, the data are further decomposed for local procurement, including local procurement from Japanese corporations, local procurement from regional corporations, and local procurement from other corporations. This information facilitates our identification of affiliates' procurement purchases from different local sources using annual data from 2017 to 2019.

To measure the damage of COVID-19, we use the number of confirmed new cases at the end of each quarter. The data are obtained from the Data Repository of the Johns Hopkins University Center for Systems Science and Engineering, which covers daily COVID-19 cases since January 2020. We also use the number of deaths, the number of new cases per million, and the number of deaths per million as alternative measures of COVID-19 damage. Other than COVID-19 infection cases, to comprehensively assess the shock, we employ an index that captures the stringency of governmental response policies to COVID-19 to measure the

strictness of lockdown policies, which is constructed by the Oxford Blavatnik School of Government Coronavirus Government Response Tracker. The Government Response Tracker (GRT) systematically records government responses to COVID-19 worldwide, examining 17 indicators such as workplace closures and economic support. The stringency index ranges from 0 to 100, in which a larger number indicates a more stringent level of government action. We aggregate the daily data at quarterly level. As supplementary information, there are also subcategory indicators of lockdown policies, such as workplace closing indicators [4] and economic support index [5].

Table 1 summarizes the data. Based on total sales, affiliates in Asia were smaller than those in other regions. Dividing the average local sales by the total sales per region, the ratio between local sales and total sales had the highest value for affiliates in NA, indicating that most affiliates in NA are market-seeking affiliates. In comparison, European affiliates were more prone to exports. Heterogeneity is evident between regions in terms of COVID-19 damage measured by the number of cases per million people. The pandemic was less severe in Asia during our sample period than in other regions. In contrast, NA and Europe were more likely to implement gentle lockdown policies and strong economic support programs.

As shown in Figure 1, changes in Japanese affiliates' total sales of were heterogeneous across regions. While, other than affiliates in China, all other regions experienced sharp declines in total sales around the first quarter of 2020, when the pandemic began to spread worldwide. As the epicenter of the pandemic, a substantial decline in total sales took place much earlier in China, with a quick recovery around and after 2020q1, while total sales in most non-China regions saw a recovery by 2020q3. Although the disruption in total sales was quite severe during in 2020q1, this quick recovery implies the resilience of Japanese MNEs'

[4]Workplace closures have ordinal indicators representing different levels of the restrictions: 0- no restrictions; 1- recommend closing or recommend work from home; 2- require closing or work from home for some sectors or categories of workers; and 3- require closing or work from home for all-but-essential workplaces (e.g., grocery stores, doctors). In our analysis, the workplace closure variable is defined as the share of time length in each quarter when a country ordered and implemented a workplace closing policy above a certain level—1, 2, or 3 .

[5]The economic support index measures policies such as income support and debt relief.

production networks.

4.2 Methodology

In this subsection, we introduce the empirical strategies for our examination of COVID-19 impacts and tests our hypotheses.

To estimate the impact of COVID-19 and corresponding lockdown policies on production activities by affiliates, we run the following specification:

$$y_{a,c,t} = \beta_1 COVID_{c,t} + \alpha_a + \delta_{c,q} + \epsilon_{a,c,t} \tag{1}$$

where $y_{a,c,t}$ denotes the response variables that proxy affiliate performance, including total sales, local sales, exports, investment, and total employees of affiliate a operating in country c in year-quarter t. $Covid_{c,t}$ represents COVID-19 damage (i.e., number of cases, number of deaths, number of cases per million, and number of deaths per million) and lockdown policies (stringency index, workplace closing, and economic support index) in host country c in year-quarter t. α_a controls for affiliate fixed effects. $\delta_{c,q}$ captures the country-quarter fixed effects to control for seasonality, and $\epsilon_{a,c,t}$ denotes the error term.

To test Hypothesis 1, we group the sample by industry and estimate the above specification for the sub-samples.

Regarding Hypothesis 2, we further include the spillover effects of COVID-19 in trading partner regions by considering the transmission of the shock through GVCs. The following equations are used for the test:

$$\begin{aligned} y_{a,c,t} =& \theta_1 \cdot COVID_{a,c,t} + \theta_2 \cdot COVID_{Asia,t} \cdot \overline{ImpShare}^{Asia}_{a,c,2017-2019} + \\ & \theta_3 \cdot COVID_{NA,t} \cdot \overline{ImpShare}^{NA}_{a,c,2017-2019} + \theta_4 \cdot COVID_{EU,t} \cdot \overline{ImpShare}^{EU}_{a,c,2017-2019} + \\ & \alpha_a + \delta_{c,q} + \epsilon_{a,c,t} \end{aligned} \tag{2}$$

$$
\begin{aligned}
y_{a,c,t} =& \gamma_1 \cdot COVID_{a,c,t} + \gamma_2 \cdot COVID_{Asia,t} \cdot \overline{ExpShare}^{Asia}_{a,c,2017-2019} + \\
& \gamma_3 \cdot COVID_{NA,t} \cdot \overline{ExpShare}^{NA}_{a,c,2017-2019} + \gamma_4 \cdot COVID_{EU,t} \cdot \overline{ExpShare}^{EU}_{a,c,2017-2019} + \\
& \alpha_a + \delta_{c,q} + \epsilon_{a,c,t}
\end{aligned} \tag{3}
$$

where $Covid_{Asia,t}$, $Covid_{NA,t}$, and $Covid_{EU,t}$ respectively represent the number of new confirmed COVID-19 cases in Asia, NA, and Europe. $\overline{ImpShare}_{a,c,2017-2019}$ denotes the average share of imports from respective regions in total procurement for affiliate a in country c during 2017–2019. $\overline{ExpShare}_{a,c,2017-2019}$ represents the average share of exports in respective regions in total sales for affiliate a in country c during 2017–2019.

Also, to capture the propagation of the COVID-19 shock through within-MNE networks, we test that whether having a large number of siblings affect the target affiliate's performance by running the equation below:

$$
y_{a,c,t} = \mu_1 COVID_{c,t} + \mu_2 COVID_{c,t} \cdot Num\_Siblings_{a,2019} + \alpha_a + \delta_{c,q} + \epsilon_{a,c,t} \tag{4}
$$

where we include the interaction term between the number of main manufacturing sibling affiliates of the target affiliate in the year of 2019 and COVID-19 cases, the coefficient on which captures the aggravation or mitigation effects by the number of sibling affiliates.

According to Hypothesis 3, we focus on the performance difference between local-oriented and trade-intensive affiliates, running the following regression:

$$
\begin{aligned}
y_{a,c,t} =& \phi_1 \cdot COVID_{a,c,t} + \phi_2 \cdot COVID_{a,c,t} \cdot \overline{LS\_Share}_{a,c,2017-2019} + \\
& \phi_3 \cdot COVID_{a,c,t} \cdot \overline{LP\_Share}_{a,c,2017-2019} + \\
& \alpha_a + \delta_{c,q} + \epsilon_{a,c,t}
\end{aligned} \tag{5}
$$

In the regression, we include the interaction terms between COVID-19 cases and local sales or local procurement share. $\overline{LS\_Share}_{a,c,2017-2019}$ denotes the average value of local sales share in total sales during 2017–2019, and $\overline{LP\_Share}_{a,c,2017-2019}$ denotes the average value

of the share of local procurement in total procurement during 2017–2019. We expect that local-oriented firms performed better than international affiliates, and if this is the case, ϕ_2 and ϕ_3 will have positive signs.

To test Hypothesis 4, we further decompose local procurement into categories of local procurement from Japanese corporations and local procurement from regional (domestic) corporations, to determine which procurement channel enhanced resilience.

$$\begin{aligned} y_{a,c,t} =& \pi_1 \cdot COVID_{a,c,t} + \pi_2 \cdot COVID_{a,c,t} \cdot \overline{LP\_Share}^{JPN}_{a,c,2017-2019} + \\ & \pi_3 \cdot COVID_{a,c,t} \cdot \overline{LP\_Share}^{Domestic}_{a,c,2017-2019} + \\ & \alpha_a + \delta_{c,q} + \epsilon_{a,c,t} \end{aligned} \tag{6}$$

where $\overline{LP\_Share}^{JPN}_{a,c,2017-2019}$ denotes the three-year average of the ratio between procurement from Japanese firms in the host country and total procurement (procurement from Japanese firms in the host country a/ total procurement). Similarly, $\overline{LP\_Share}^{Domestic}_{a,c,2017-2019}$ captures the average value of the ratio of procurement from domestic firms in the host country and total procurement (procurement from domestic firms in the host country a/ total procurement).

5 Results

5.1 Impacts on global production networks by COVID-19

Table 2 presents the results for equation (1). Regardless of the variables we use to measure COVID-19 damage, the results reveal a consistent negative sign. Columns (1)–(4) demonstrate the significant negative impacts of COVID-19 on total sales. Taking the first column as the baseline results, a 100% increase in the number of new confirmed COVID-19 cases leads to a 0.6% decline in total sales. If we consider the rapid spread of infections[6], the mag-

[6]The number of cumulative COVID-19 cases worldwide increased from 3.37 million at the end of 2020q1 to 82.21 million at the end of 2020q4, representing a relative change of about 2,439%.

nitude is much larger than we perceive (Zhang, 2021). Columns (5)–(6) show the negative impacts of lockdown policies. Comparing the results of the quarterly average stringency and quarterly max stringency indices, it is clearly evident that more stringent lockdown policies led to a more severe declines in total sales.

Table 3 presents the estimation results regarding the impacts of workplace closures on affiliates' performance. The strictest workplace closing orders heavily harmed total sales; however, regardless of the strictness of workplace closures, affiliates tended to experience decreased exports, capital investment, and employment when such orders occurred. Table 4 provides the results regarding the impacts of economic support policies on performance. In general, economic support programs (e.g., income support, debt relief) partially mitigated the adverse impacts of COVID-19 on total sales, local sales, and exports.

To investigate the disruption and recovery patterns across regions, we run the subsample regressions by region with interactions between the number of COVID-19 cases and quarter dummy variables. The corresponding results are presented in Table 5. The variety of coefficients on the number of COVID-19 cases across regions implies that the disruptions were heterogeneous geographically. Compared to other areas, the production networks of MNEs in Asia showed less disruption when COVID-19 hit in 2020q1. Given the significant positive coefficients on the interaction terms between cases and the 2020q2 dummy, it is notable that affiliates in all regions began to recover quite soon after the second quarter of 2020. However, in terms of the timing until a full recovery of total sales (the summation of the coefficient of cases and interaction term becomes positive), affiliates in Europe and Asia fully recovered around 2020q3. In contrast, NA affiliates and the RoW recovered in 2020q4. Although COVID-19 generated challenging conditions for the global production networks operated by Japanese MNEs, the negative impacts only lasted for a short time, and regional production chains exhibit varying levels of resilience.

5.2 Heterogeneous effects by industry

This subsection examines the results of our test of Hypothesis 1, arguing that the impacts of COVID-19 are heterogeneous across industrial sectors. We group the data set by industry and rerun equation (1) with interaction terms between the number of COVID-19 cases and quarter dummies. Table 6 presents the regression results. The corresponding dummy variables with highlighted coefficients in red indicate the timing of complete recovery from the COVID-19 shock. The total number of red underlines beneath coefficients in each row indicates the time spent on the recovery by industry. For example, there are three red underlines for the textiles sector, indicating that it took three quarters for affiliates operating in textiles to recover sales to pre-COVID-19 levels. Confirming with our expectations, affiliates from various of industries experienced vastly different paces of recovery. More importantly, due to widely pandemic-induced disruptions on supply chains and international trade, value-chain-intensive industries were more likely to face difficulties (UNCTAD, 2022). Affiliates operating in value-chain-intensive industries were more exposed and hit more heavily by the COVID-19 shock because of the lower reliance of international production networks and supply chains, resulting in more diminished performance and slower recovery (Zhang, 2021). As a result, some industries took relatively longer to recover, such as machinery and equipment and textiles, validating Hypothesis 1.

5.3 Propagation of COVID-19 shock along transaction networks

We run the equations (2) and (3) by region to test Hypothesis 2 and illustrate the geographical propagation of the COVID-19 shock. In Table 7, the first column represents the results for affiliates in Europe, indicating that sourcing channels with surroundings and other continents may have transmitted the negative shock and aggravated total sales; however, the transmission effects are not significant in this case. For NA-located affiliates, sourcing linkages with Asia exacerbated the adverse impact of the pandemic, which is mirrored in Asia. Sourcing linkages with surrounding areas in Asia propagated the negative shock and made

conditions more severe for Asia-located affiliates' sales. However, we do not find a significant propagation effect through the linkages between RoW affiliates and other regions.

To construct a complete image of the propagation along transaction networks, we also examine the impacts from the demand side. Table 8 presents the relevant results. In the case of Europe, NA, and the RoW, there was no significant propagation of the COVID-19 shock from shipment destination regions. In contrast, Asia-located exporting affiliates were affected by pandemic-induced demand shocks in the same region. In addition to local pandemic, total sales of exporters concentrated in the Asian market were negatively affected by the pandemic condition in surrounding area.

In summary, we demonstrate the propagation effect along transaction networks. Both local pandemic and COVID-19 conditions in the regional procurement origin may affect affiliates' performance. Especially, NA-located affiliates and Asia-located those with higher reliance on imports from Asia experienced more severe effects. From the demand side perspective, exporting affiliates in Asia that concentrated on Asian market experienced worse circumstances during the pandemic.

Regarding the within-MNE propagation of the COVID-19 shock, the corresponding results are presented by Table 9. Affiliates with a larger number of manufacturing siblings in different locations met more difficulties during the pandemic with declining sales and employment. It implies that the propagation of the COVID-19 shock via global production networks aggravate the condition.

5.4 Localized affiliates vs. trading affiliates

The role of localization in navigating the COVID-19 shock is another concern of this study. To this end, we test Hypothesis 3 using equation (4). The results are summarized in Table 9. Given the positive and significant estimated coefficients on total sales, local sales, exports, and capital investment, it is evident that pre-pandemic reliance on local procurement had a positive role in mitigating the negative shock. On average, a higher local procurement share

led to a lower level of performance damage. In contrast, the coefficients on the interaction variable between COVID-19 cases and local sales share are insignificant for all the cases, implying that dependence on local sales neither mitigated nor aggravated the negative shock.

In this analysis, since the control group includes trading affiliates (exporters and importers), our finding also implies that higher international exposure may aggravate the effects of shock and lead to worse performance. During the pandemic, localized affiliates demonstrated higher resilience than trading affiliates.

5.5 Heterogeneous effects of local backward linkages

To assess whether local backward linkage led to resilience and the role of diversification of local sourcing, we further test Hypothesis 4. Table 10 presents the results. Columns (1) and (5) indicate that Japanese corporations' pre-pandemic reliance on local procurement negatively impacted total sales and employment. Higher reliance on local Japanese intermediate inputs worsened performance. A possible reason is that critical inputs purchased from Japanese firms are generally characterized by input specificity, so substitution difficulties were faced for such inputs. Due to COVID-19, the effects of disrupted supply chains and trade on Japanese inputs became problematic for production by affiliates relying on local inputs, resulting in total sales decline. In contrast, local procurement with domestic corporations does not present a significant aggravation effect on total sales. There is only one exception in which local linkage with domestic firms may aggravate exports in column (3). These results document supportive evidence for the hypothesis that input specificity may cause difficulties and result in further vulnerability.

Running the test by region indicates that the aggravation effects of local procurement from Japanese firms were more pronounced for affiliates in Europe and NA (Table 11). These results imply that distant affiliates that were highly dependent on Japanese inputs and components faced more difficulties when the pandemic disrupted this channel.

6 Discussion and conclusion

Using data from overseas affiliates of Japanese MNEs, this study reveals empirical evidence regarding the disruption of global production generated by the COVID-19 pandemic. Both the pandemic itself and related lockdown policies negatively affected Japanese MNEs' multinational production. Total sales recovery began in the second quarter of 2020 following the initial disruptions, and the recovery pattern differed across regions. By around 2020q3, production activities in Europe and Asia had almost fully recovered, and one quarter later, total sales of affiliates in NA and RoW returned to pre-pandemic levels. From the view of industry heterogeneity, affiliates operating in most industries were fully recovered by 2020q4. Recovery also followed various patterns across industries. Specifically, industries more reliant on international production networks and supply chains experienced relatively slower recovery. Regardless, the overall large-scale recovery by 2020q4 demonstrates the resilience of the current global production networks established by Japanese MNEs.

Our study also documents the propagation of COVID-19 shock along affiliates' transaction networks and within-MNE production networks. Considering the propagation, affiliates' production resilience was also affected by COVID-19 circumstances in trading partner regions. For example, affiliates located in NA may have suffered from the pandemic conditions in Asia due to input linkages. Trade linkages with trading partner regions caused affiliates' international exposure affecting resilience. As a result, localized or local-oriented affiliates tended to have higher resilience. We determine that localization of procurement may mitigate the negative shock. This finding is consistent with previous studies that emphasize the importance of local backward linkages (Kiyota et al.,2008; Ito and Fukao,2010).

Furthermore, this study provides partial evidence regarding negative effect of input specificity. Examining the role of different local backward linkages reveals that high pre-pandemic reliance on local inputs from Japanese corporations aggravated affiliates' circumstances. Echoing previous studies revealing the advantages of localization and diversification of supplier networks (Todo et al.,2022; Ito and Fukao,2010), our findings also highlight the

strategic significance of enhancing and diversifying local backward linkages.

Our findings also have some policy implications. First, Japanese affiliates should enhance local backward linkages and expand local procurement following COVID-19. Facing a future systemic shock like COVID-19, procurement localization could mitigate the severe input shortages caused by dependence on non-local networks. Therefore, Japanese affiliates should more actively establish local input networks and actively gain footholds in local markets. Second, as suggested by previous studies (Barrot and Sauvagnat,2016; Todo et al.,2022) and our findings, Japanese affiliates that still depend on specific inputs from other Japanese firms in the host country should actively seek to diversify local supply chains by expanding local procurement sources, which could contribute to the resilience of supply chain networks. Deepening procurement localization, reducing input specificity, and diversifying local backward linkages are potential strategic approaches for firms endeavoring to gain more resilience in the short run. In reality, many Japanese companies have already taken these practices into consideration or actively practice them. According to the 2021 Questionnaire Survey on Overseas Business Expansion of Japanese Companies by the Japan External Trade Organization (JETRO)[7], more than 60% of surveyed Japanese companies planned to adjust supply chains, and 59.6% planned to adjust procurement sources. Compared to 2020, the number of companies planning to switch procurement sources increased by 5.6%. We expect that firms with multi-sourcing and diversified local supplier networks will have greater resilience to any future shocks.

If intra-affiliate transaction/trade data becomes available, the propagation of COVID-19 shock among affiliates within the same MNE network could be more clearly captured. Also, some other characteristics of affiliates may advance resilience, but we did not explore those in this study. For example, the degree of servitization relates to organizational resilience (Li et al., 2022). We leave these issues for future research.

[7]More details are available at https://www.jetro.go.jp/biz/areareports/special/2022/0301/992fdac73a1ceb67.html

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Tables

Table 1: Descriptive statistics

	Europe			North America			Asia			RoW		
	N	Mean	SD	N	Mean	SD	N	Mean	SD	N	Mean	SD
log (Total sales)	4042	7.2	2.4	5666	7.8	2.2	31180	6.6	2.2	2592	7.1	1.9
log (Local sales)	4042	5.4	3.1	5666	7.5	2.4	31180	5.3	2.9	2592	5.9	2.9
log (Exports)	4042	4.9	3.4	5666	3.3	3.3	31180	2.8	3.0	2592	3.4	3.3
log (Investment)	4042	2.6	2.5	5666	2.8	2.7	31180	2.0	2.2	2592	2.5	2.3
log (Labor)	4042	5.4	1.8	5666	5.6	1.6	31180	5.6	1.7	2592	5.8	1.6
log (COVID-19 cases)	4042	5.9	6.0	5666	7.2	7.3	31180	4.4	4.6	2592	5.7	6.1
Stringency index (quarterly mean)	4038	28.8	30.5	5666	28.7	32.1	31180	30.9	33.2	2592	30.2	34.4
Stringency index (quarterly max)	4042	38.0	38.3	5666	36.3	36.3	31180	37.6	38.9	2592	39.1	39.4
log (cases per million)	4042	4.1	4.2	5666	4.4	4.5	31180	1.6	2.2	2592	3.5	3.9
log (deaths)	4042	4.0	4.2	5666	5.3	5.4	31180	1.7	2.8	2592	4.0	4.7
log (deaths per million)	4042	2.2	2.5	5666	2.5	2.7	31180	0.3	0.9	2592	2.0	2.6
workplace closure 1	3894	0.4	0.5	5666	0.4	0.5	31180	0.4	0.5	2592	0.4	0.5
workplace closure 2	3894	0.3	0.4	5666	0.4	0.5	31180	0.3	0.4	2592	0.4	0.5
workplace closure 3	3894	0.1	0.2	5666	0.1	0.3	31180	0.2	0.3	2592	0.2	0.3
Economic support	3894	28.4	37.3	5666	24.0	29.9	31180	19.5	29.2	2592	17.2	28.2

Note: Author's compilation based on the Quarterly Survey of Overseas Subsidiaries compiled by the Ministry of Economy, Trade and Industry (METI), Johns Hopkins University Center for Systems Science and Engineering and Oxford Coronavirus Government Response Tracker.

Table 2: Impacts of COVID-19 and policy stringency on firm performance

Dependent var: log (total sales)	(1)	(2)	(3)	(4)	(5)	(6)
log (COVID-19 cases)	-0.00641***					
	(0.000581)					
log (deaths)		-0.0143***				
		(0.000917)				
log (cases per million)			-0.0120***			
			(0.00106)			
log (deaths per million)				-0.0165***		
				(0.00203)		
stringency (quarterly mean)					-0.000470***	
					(9.17e-05)	
stringency (quarterly max)						-0.00100***
						(8.05e-05)
Observations	43,417	43,417	43,417	43,417	43,409	43,417
R-squared	0.921	0.921	0.921	0.921	0.921	0.921
Firm FE	YES	YES	YES	YES	YES	YES
Country-quarter FE	YES	YES	YES	YES	YES	YES

Note: Clustered robust standard errors at the affiliate level in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 3: Impacts of workplace closing policy on firm performance

Dependent Var:	(1) log (Total sales)	(2) log (Local sales)	(3) log (Exports)	(4) log (Investment)	(5) log (Labor)
workplace closure 1	0.00428	0.00514	-0.0199*	-0.278***	-0.0294***
	(0.00653)	(0.00913)	(0.0104)	(0.0154)	(0.00346)
R-squared	0.921	0.937	0.940	0.833	0.986
workplace closure 2	0.00780	0.0156	-0.0228**	-0.276***	-0.0298***
	(0.00706)	(0.00989)	(0.0110)	(0.0166)	(0.00373)
R-squared	0.921	0.937	0.940	0.832	0.986
workplace closure 3	-0.0741***	-0.0380**	-0.0822***	-0.436***	-0.0552***
	(0.0112)	(0.0160)	(0.0194)	(0.0287)	(0.00603)
R-squared	0.921	0.937	0.940	0.832	0.986
Observations	43,265	43,265	43,265	43,265	43,265
Firm FE	YES	YES	YES	YES	YES
Country-quarter FE	YES	YES	YES	YES	YES

Note: Clustered robust standard errors at the affiliate level in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 4: Impacts of economic support policy on firm performance

Dependent Var:	(1) log (Total sales)	(2) log (Local sales)	(3) log (Exports)	(4) log (Investment)	(5) log (Labor)
log (COVID-19 cases)	-0.0212***	-0.0199***	-0.0108***	-0.0238***	-0.00319***
	(0.000918)	(0.00122)	(0.00129)	(0.00198)	(0.000493)
Economic support	0.00374***	0.00337***	0.00159***	-0.000576	0.000105
	(0.000164)	(0.000220)	(0.000242)	(0.000363)	(8.37e-05)
Observations	43,265	43,265	43,265	43,265	43,265
R-squared	0.922	0.937	0.940	0.833	0.986
Firm FE	YES	YES	YES	YES	YES
Country-quarter FE	YES	YES	YES	YES	YES

Note: Clustered robust standard errors at the affiliate level in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 5: Recovery from disruptions by region and quarter

	log (Total sales)			
	Europe	North America	Asia	RoW
log (COVID-19 cases)	-0.0458***	-0.0454***	-0.0302***	-0.111***
	(0.00373)	(0.00239)	(0.00126)	(0.00686)
*Dummy(2020q2=1)	0.0403***	0.0376***	0.0160***	0.0896***
	(0.00420)	(0.00256)	(0.00133)	(0.00656)
*Dummy(2020q3=1)	0.0516***	0.0435***	0.0303***	0.103***
	(0.00472)	(0.00235)	(0.00157)	(0.00632)
*Dummy(2020q4=1)	0.0593***	0.0488***	0.0558***	0.117***
	(0.00429)	(0.00251)	(0.00165)	(0.00707)
Observations	4,030	5,657	31,140	2,590
R-squared	0.942	0.913	0.920	0.918
Firm FE	YES	YES	YES	YES
Country-quarter FE	YES	YES	YES	YES

Note: Clustered robust standard errors at the affiliate level in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 6: Recovery from disruptions by industry and quarter (H1)

Dependent Var: log (Total sales)	log (COVID-19 cases)	*Dummy(2020q2=1)	*Dummy(2020q3=1)	*Dummy(2020q4=1)
Food and Tobacco	-0.0134*	0.0189***	0.0208***	0.0312***
Textiles	-0.0407***	0.0209***	0.0283***	0.0429***
Paper Product	-0.0152**	0.00667	0.0130	0.0245**
Chemicals	-0.0237***	0.0172***	0.0266***	0.0368***
Oil product	-0.0200*	0.0148	0.0200*	0.0422***
Ceramic	-0.0234***	0.0143***	0.0209**	0.0419***
Iron and steel	-0.0473***	0.0324***	0.0483***	0.0761***
Non-ferrous metal	-0.0377***	0.0236***	0.0378***	0.0567***
Fabricated metal	-0.0350***	0.0205***	0.0225***	0.0547***
General-purpose machinery	-0.00922	-0.00127	0.00488	0.0421***
Production-oriented machinery	-0.0258***	0.0128***	0.0251***	0.0492***
Business-oriented machinery	-0.0224***	0.0111***	0.0202***	0.0302***
Electrical machinery	-0.0247***	0.0124***	0.0250***	0.0357***
ICT product	-0.0248***	0.0127***	0.0268***	0.0355***
Transportation equipment	-0.0691***	0.0521***	0.0684***	0.0858***
Miscellaneous manufacturing	-0.0363***	0.0260***	0.0345***	0.0514***

Note: Clustered robust standard errors at the affiliate level in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 7: COVID-19 and imports by region (H2)

	log (Total sales)			
	Europe	NA	Asia	RoW
log (COVID-19 cases)	-0.00526**	-0.0103***	-0.00531***	-0.0189***
	(0.00228)	(0.00115)	(0.000977)	(0.00213)
$\overline{ImpShare}^{EU} \#Covid_{EU}$	-0.00687	0.0115	-0.00316	-0.0142
	(0.00436)	(0.0122)	(0.00972)	(0.0170)
$\overline{ImpShare}^{NA} \#Covid_{NA}$	-0.0204	-0.0120	0.0111	-0.0107
	(0.0176)	(0.0131)	(0.00714)	(0.0166)
$\overline{ImpShare}^{Asia} \#Covid_{Asia}$	-0.00375	-0.0138**	-0.00583**	-0.0245
	(0.00999)	(0.00659)	(0.00266)	(0.0559)
Observations	2,608	3,775	21,751	1,724
R-squared	0.953	0.936	0.922	0.906
Firm FE	YES	YES	YES	YES
Country-quarter FE	YES	YES	YES	YES

Note: Clustered robust standard errors at the affiliate level in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 8: COVID-19 and exports by region (H2)

	log (Total sales)			
	Europe	NA	Asia	RoW
log (COVID-19 cases)	-0.00632**	-0.0109***	-0.00521***	-0.0215***
	(0.00254)	(0.00114)	(0.00102)	(0.00411)
$\overline{ExpShare}^{EU} \#Covid_{EU}$	-0.00148	0.00426	0.00269	0.00302
	(0.00405)	(0.0185)	(0.00887)	(0.0123)
$\overline{ExpShare}^{NA} \#Covid_{NA}$	-0.0157	0.000782	-0.00919	0.00202
	(0.0132)	(0.00250)	(0.00747)	(0.00732)
$\overline{ExpShare}^{Asia} \#Covid_{Asia}$	0.0320	0.00285	-0.00399*	0.00630
	(0.0305)	(0.0205)	(0.00216)	(0.0380)
Observations	2,608	3,775	21,751	1,724
R-squared	0.953	0.936	0.922	0.906
Firm FE	YES	YES	YES	YES
Country-quarter FE	YES	YES	YES	YES

Note: Clustered robust standard errors at the affiliate level in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 9: COVID-19 and number of siblings (H2)

Dependent Var:	(1) log (Total sales)	(2) log (Local sales)	(3) log (Exports)	(4) log (Investment)	(5) log (Labor)
log (COVID-19 cases)	-0.00488***	-0.00445***	-0.00307**	-0.0247***	-0.00169***
	(0.000820)	(0.00115)	(0.00119)	(0.00168)	(0.000513)
log (COVID-19 cases)#Num_Siblings	-0.000124**	-0.000171**	-0.000121*	-9.56e-05	-8.63e-05**
	(5.61e-05)	(7.26e-05)	(6.54e-05)	(8.66e-05)	(4.06e-05)
Observations	42,908	42,908	42,908	42,908	42,908
R-squared	0.922	0.937	0.941	0.833	0.986
Firm FE	YES	YES	YES	YES	YES
Country-quarter FE	YES	YES	YES	YES	YES

Note: Clustered robust standard errors at the affiliate level in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 10: COVID-19 and local-oriented affiliates (H3)

Dependent Var:	(1) log (Total sales)	(2) log (Local sales)	(3) log (Exports)	(4) log (Investment)	(5) log (Labor)
log (COVID-19 cases)	-0.0122***	-0.0143***	-0.0134***	-0.0472***	-0.00572***
	(0.00223)	(0.00362)	(0.00382)	(0.00505)	(0.00169)
log (COVID-19 cases)#$\overline{LP\_Share}$	0.00485*	0.0102***	0.0105***	0.0230***	0.00254
	(0.00258)	(0.00369)	(0.00364)	(0.00575)	(0.00175)
log (COVID-19 cases)#$\overline{LS\_Share}$	-1.25e-05	-0.00302	0.000284	0.000901	0.000677
	(0.00193)	(0.00317)	(0.00342)	(0.00460)	(0.00101)
Observations	29,858	29,858	29,858	29,858	29,858
R-squared	0.929	0.941	0.945	0.831	0.991
Firm FE	YES	YES	YES	YES	YES
Country-quarter FE	YES	YES	YES	YES	YES

Note: Clustered robust standard errors at the affiliate level in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 11: Local procurement from JP firms vs. local procurement from domestic firms (H4)

Dependent Var:	(1) log (Total sales)	(2) log (Local sales)	(3) log (Exports)	(4) log (Investment)	(5) log (Labor)
log (COVID-19 cases)	-0.00802***	-0.00911***	-0.00347**	-0.0263***	-0.00285***
	(0.000765)	(0.00127)	(0.00139)	(0.00196)	(0.000455)
log (COVID-19 cases)#$\overline{LP\_Share}^{JPN}$	-0.00483*	-0.00268	-0.00321	-0.0119	-0.00417***
	(0.00271)	(0.00367)	(0.00601)	(0.00796)	(0.00120)
log (COVID-19 cases)#$\overline{LP\_Share}^{Domestic}$	0.000256	0.00423	-0.00603*	-0.00503	-8.64e-06
	(0.00224)	(0.00292)	(0.00311)	(0.00504)	(0.00102)
Observations	29,597	29,597	29,597	29,597	29,597
R-squared	0.929	0.941	0.945	0.831	0.991
Firm FE	YES	YES	YES	YES	YES
Country-quarter FE	YES	YES	YES	YES	YES

Note: Clustered robust standard errors at the affiliate level in parentheses
*** p<0.01, ** p<0.05, * p<0.1

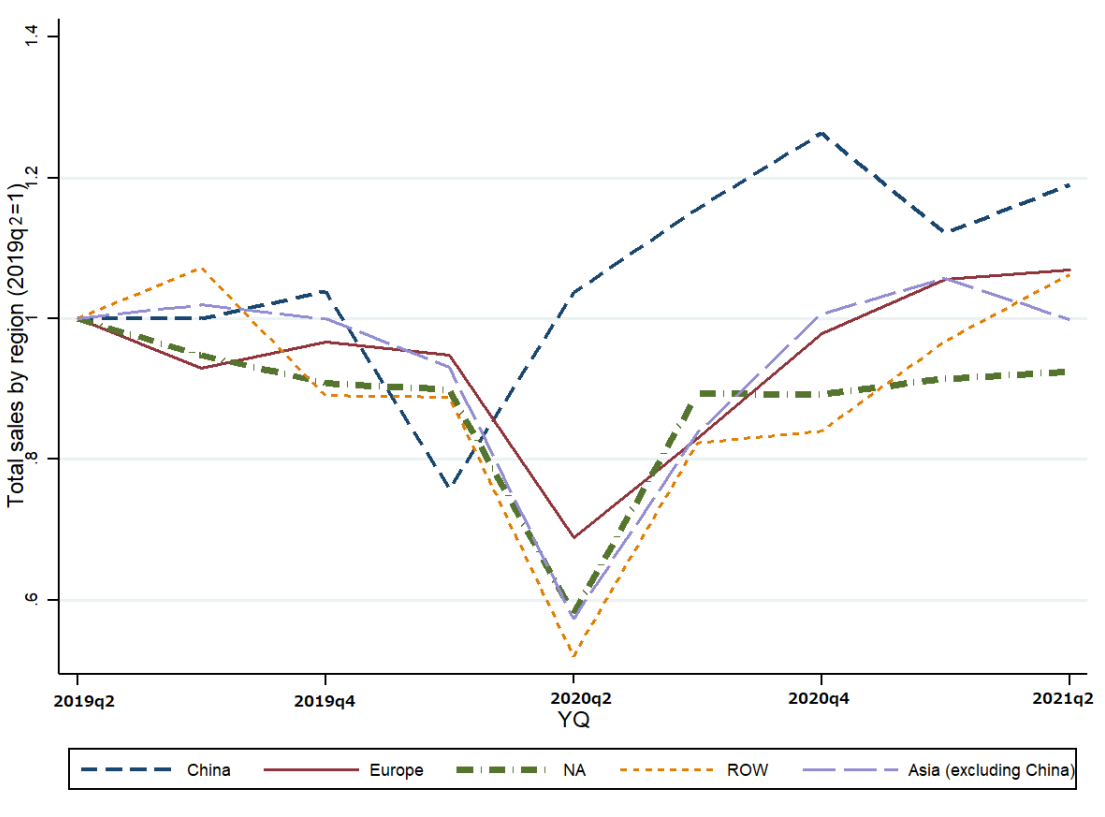
Table 12: Local procurement from JP firms vs. local procurement from domestic firms by region

	log (Total sales)			
	Europe	NA	Asia	RoW
log (COVID-19 cases)	-0.00518**	-0.00973***	-0.00589***	-0.0204***
	(0.00229)	(0.000965)	(0.000962)	(0.00496)
log (COVID-19 cases)#$\overline{LP\_Share}^{JPN}$	-0.0262***	-0.00854***	-0.00405	-0.00368
	(0.00582)	(0.00289)	(0.00369)	(0.0111)
log (COVID-19 cases)#$\overline{LP\_Share}^{Domestic}$	-0.00549	-0.00210	0.00211	-0.00548
	(0.00435)	(0.00344)	(0.00312)	(0.00800)
Observations	2,577	3,727	21,601	1,692
R-squared	0.954	0.936	0.923	0.905
Firm FE	YES	YES	YES	YES
Country-quarter FE	YES	YES	YES	YES

Note: Clustered robust standard errors at the affiliate level in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Figures

Figure 1: Total sales by region before and after the outburst of COVID-19



Note: Author's plotting based on the Quarterly Survey of Overseas Subsidiaries compiled by the Ministry of Economy, Trade and Industry (METI)

Appendix I: Classification of regions

Europe: Ireland, the United Kingdom, Italy, Ukraine, Austria, the Netherlands, Greece, Swiss, Sweden, Spain, Slovakia, Slovenija, the Czech Republic, Denmark, Germany, Turkey, Hungary, Finland, France, Bulgaria, Belgium, Poland, Portugal, Montenegro, Luxembourg, Romania, and Russia
NA: the United States and Canada
Asia: Indonesia, Thailand, the Philippines, Malaysia, Cambodia, Singapore, Brunei, Vietnam, Myanmar, Laos, Singapore, Taiwan, Korea, China, Hong Kong, India, Sri Lanka, Pakistan, Bangladesh
RoW : Argentina, Israel, Uruguay, Egypt, Eswatini, El Salvador, Australia, Guatemala, Kenya, Costa Rica, Columbia, Saudi Arabia, Tanzania, Tunisia, Chile, Nigeria, New Zealand, Brazil, Venezuela, Peru, South Africa, Mexico, and Morocco

Appendix II: Recovery from disruptions measured by additional performance indicators

Table 13: Recovery from disruptions by region and quarter (Local sales)

	log (Local sales)			
	Europe	NA	Asia	RoW
log (COVID-19 cases)	-0.0459***	-0.0473***	-0.0285***	-0.104***
	(0.00475)	(0.00264)	(0.00159)	(0.00980)
*Dummy(2020q2=1)	0.0392***	0.0379***	0.0162***	0.0804***
	(0.00469)	(0.00279)	(0.00171)	(0.00868)
*Dummy(2020q3=1)	0.0507***	0.0435***	0.0289***	0.105***
	(0.00547)	(0.00275)	(0.00196)	(0.00921)
*Dummy(2020q4=1)	0.0571***	0.0458***	0.0526***	0.115***
	(0.00542)	(0.00303)	(0.00207)	(0.0105)
Observations	4,030	5,657	31,140	2,590
R-squared	0.951	0.904	0.936	0.929
Firm FE	YES	YES	YES	YES
Country-quarter FE	YES	YES	YES	YES

Note: Clustered robust standard errors at the affiliate level in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 14: Recovery from disruptions by region and quarter (Exports)

	log (Exports)			
	Europe	NA	Asia	RoW
log (COVID-19 cases)	-0.0233***	-0.0235***	-0.0152***	-0.0470***
	(0.00553)	(0.00329)	(0.00192)	(0.00926)
*Dummy(2020q2=1)	0.0171***	0.0190***	0.00341*	0.0352***
	(0.00525)	(0.00325)	(0.00198)	(0.00841)
*Dummy(2020q3=1)	0.0290***	0.0233***	0.0150***	0.0303***
	(0.00608)	(0.00346)	(0.00237)	(0.00969)
*Dummy(2020q4=1)	0.0310***	0.0262***	0.0243***	0.0495***
	(0.00619)	(0.00383)	(0.00254)	(0.0104)
Observations	4,030	5,657	31,140	2,590
R-squared	0.945	0.942	0.937	0.934
Firm FE	YES	YES	YES	YES
Country-quarter FE	YES	YES	YES	YES

Note: Clustered robust standard errors at the affiliate level in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Appendix III: Recovery from disruptions measured by additional performance indicators

Table 15: Recovery from disruptions by region and quarter (Investment)

	log (Investment)			
	Europe	NA	Asia	RoW
log (COVID-19 cases)	-0.0456***	-0.0286***	-0.0273***	-0.0500***
	(0.00653)	(0.00534)	(0.00270)	(0.0113)
*Dummy(2020q2=1)	0.0231***	0.00441	-0.00781**	0.0146
	(0.00631)	(0.00531)	(0.00310)	(0.0116)
*Dummy(2020q3=1)	0.0292***	0.00115	-0.00944***	0.0224*
	(0.00797)	(0.00579)	(0.00341)	(0.0124)
*Dummy(2020q4=1)	0.0358***	0.0108	0.0133***	0.0361***
	(0.00852)	(0.00658)	(0.00367)	(0.0134)
Observations	4,030	5,657	31,140	2,590
R-squared	0.863	0.847	0.823	0.819
Firm FE	YES	YES	YES	YES
Country-quarter FE	YES	YES	YES	YES

Note: Clustered robust standard errors at the affiliate level in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 16: Recovery from disruptions by region and quarter (Labor)

	log (Iabor)			
	Europe	NA	Asia	RoW
log (COVID-19 cases)	-0.00349*	-0.00382***	-0.00330***	-0.00658**
	(0.00211)	(0.00105)	(0.000578)	(0.00303)
*Dummy(2020q2=1)	0.00155	0.000561	-0.00194***	0.00159
	(0.00243)	(0.000779)	(0.000544)	(0.00130)
*Dummy(2020q3=1)	0.00390	0.00205**	-0.000326	0.00292*
	(0.00281)	(0.00103)	(0.000714)	(0.00170)
*Dummy(2020q4=1)	0.00454*	0.00216**	0.00180**	0.00606**
	(0.00263)	(0.00105)	(0.000822)	(0.00290)
Observations	4,030	5,657	31,140	2,590
R-squared	0.982	0.990	0.987	0.974
Firm FE	YES	YES	YES	YES
Country-quarter FE	YES	YES	YES	YES

Note: Clustered robust standard errors at the affiliate level in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Appendix IV: Recovery from disruptions and strictness of lockdown

Table 17: Recovery from disruptions by region and quarter (Labor)

	log (Total sales)			
	Europe	NA	Asia	RoW
stringency(quarterly mean)	-0.0119***	-0.0245***	-0.00400***	-0.0230***
	(0.00119)	(0.00128)	(0.000202)	(0.00177)
*Dummy(2020q2)	0.0109***	0.0229***	0.00237***	0.0198***
	(0.00112)	(0.00129)	(0.000202)	(0.00177)
*Dummy(2020q3)	0.0132***	0.0240***	0.00419***	0.0216***
	(0.00130)	(0.00125)	(0.000238)	(0.00177)
*Dummy(2020q4)	0.0144***	0.0253***	0.00828***	0.0244***
	(0.00127)	(0.00121)	(0.000259)	(0.00188)
Observations	4,022	5,657	31,140	2,590
R-squared	0.951	0.913	0.919	0.914
Firm FE	YES	YES	YES	YES
Country-quarter FE	YES	YES	YES	YES

Note: Clustered robust standard errors at the affiliate level in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Appendix V: COVID-19 and transaction networks

Table 18: COVID-19 and imports by region (Based on 2019 trade shares)

	log (Total sales)			
	Europe	NA	Asia	RoW
log(COVID-19 cases)	-0.00531**	-0.0104***	-0.00545***	-0.0185***
	(0.00230)	(0.00123)	(0.00101)	(0.00210)
$ImpShare^{EU}_{2019}\#Covid_{EU}$	-0.00849**	0.0146***	-0.0135**	-0.00878
	(0.00416)	(0.00453)	(0.00525)	(0.0206)
$ImpShare^{NA}_{2019}\#Covid_{NA}$	-0.0145	-0.0112	0.0104	-0.0109
	(0.0155)	(0.0128)	(0.00655)	(0.0160)
$ImpShare^{Asia}_{2019}\#Covid_{Asia}$	0.000132	-0.0171**	-0.00443*	-0.0326
	(0.00918)	(0.00669)	(0.00241)	(0.0574)
Observations	2,500	3,495	20,729	1,680
R-squared	0.954	0.944	0.926	0.906
Firm FE	YES	YES	YES	YES
Country-quarter FE	YES	YES	YES	YES

Note: Clustered robust standard errors at the affiliate level in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Table 19: COVID-19 and imports by region (Based on 2019 trade shares)

	log (Total sales)			
	Europe	NA	Asia	RoW
log(COVID-19 cases)	-0.00653**	-0.0113***	-0.00517***	-0.0214***
	(0.00262)	(0.00116)	(0.00104)	(0.00425)
$ExpShare^{EU}_{2019}\#Covid_{EU}$	-0.00113	0.00904	0.00510	0.00348
	(0.00353)	(0.0140)	(0.00911)	(0.0125)
$ExpShare^{NA}_{2019}\#Covid_{NA}$	-0.0148	0.00297	-0.0124	0.00329
	(0.0130)	(0.00325)	(0.00756)	(0.00756)
$ExpShare^{Asia}_{2019}\#Covid_{Asia}$	0.0353	0.00634	-0.00486**	-0.0177
	(0.0318)	(0.0125)	(0.00211)	(0.0140)
Observations	2,500	3,495	20,729	1,680
R-squared	0.954	0.944	0.926	0.906
Firm FE	YES	YES	YES	YES
Country-quarter FE	YES	YES	YES	YES

Note: Clustered robust standard errors at the affiliate level in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Appendix VI: Lockdown stringency and localized affiliates

Table 20: COVID-19 and local-oriented affiliates

Dependent Var:	(1) log(Total sales)	(2) log(Local sales)k	(3) log(Exports)	(4) log(Investment)	(5) log(Labor)
stringency (quarterly max)	-0.00191***	-0.00196***	-0.00217***	-0.00602***	-0.000707***
	(0.000304)	(0.000475)	(0.000512)	(0.000663)	(0.000212)
stringency#$\overline{LP\_Share}$	0.000898**	0.00155***	0.00165***	0.00286***	0.000347
	(0.000366)	(0.000510)	(0.000507)	(0.000774)	(0.000233)
stringency#$\overline{LS\_Share}$	-6.92e-05	-0.000634	0.000139	-0.000103	1.60e-06
	(0.000273)	(0.000426)	(0.000443)	(0.000629)	(0.000127)
Observations	29,858	29,858	29,858	29,858	29,858
R-squared	0.929	0.941	0.945	0.831	0.991
Firm FE	YES	YES	YES	YES	YES
Country-quarter FE	YES	YES	YES	YES	YES

Note: Clustered robust standard errors at the affiliate level in parentheses
*** p<0.01, ** p<0.05, * p<0.1

Appendix VII: Upstream vs. downstream

Table 21: Disruption and recovery of upstream affiliates

Dependent Var:	(1) log(Total sales)	(2) log(Local sales)	(3) log(Exports)	(4) log(Investment)	(5) log(Labor)
log (COVID-19 cases)	-0.0279***	-0.0278***	-0.0147***	-0.0339***	-0.00243***
	(0.00130)	(0.00181)	(0.00222)	(0.00362)	(0.000644)
*Dummy(2020q2=1)	0.0178***	0.0164***	0.00420*	-0.00111	-0.00120**
	(0.00127)	(0.00213)	(0.00233)	(0.00375)	(0.000536)
*Dummy(2020q3=1)	0.0287***	0.0286***	0.0142***	0.00223	-0.000339
	(0.00165)	(0.00242)	(0.00275)	(0.00421)	(0.000758)
*Dummy(2020q4=1)	0.0449***	0.0395***	0.0235***	0.0213***	0.00137*
	(0.00174)	(0.00246)	(0.00310)	(0.00455)	(0.000828)
Observations	17,394	17,394	17,394	17,394	17,394
R-squared	0.930	0.936	0.938	0.827	0.989
Firm FE	YES	YES	YES	YES	YES
Country-quarter FE	YES	YES	YES	YES	YES

Note: Based on the classification of industries by Ito and Vézina (2016), we split affiliates into two subgroups: upstream and downstream. This results test for the impacts of COVID-19 shock on performance of affiliates operating in uptream sectors, including , etc. *** p<0.01, ** p<0.05, * p<0.1

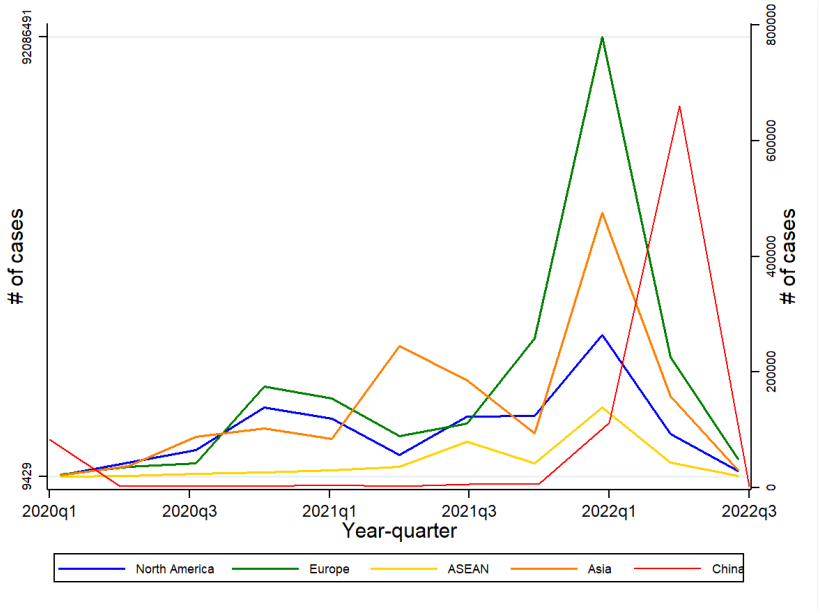
Table 22: Disruption and recovery of downstream affiliates

Dependent Var:	(1) log(Total sales)	(2) log(Local sales)	(3) log(Exports)	(4) log(Investment)	(5) log(Labor)
log (COVID-19 cases)	-0.0446***	-0.0429***	-0.0218***	-0.0279***	-0.00428***
	(0.00159)	(0.00188)	(0.00217)	(0.00282)	(0.000707)
*Dummy(2020q2=1)	0.0313***	0.0309***	0.0134***	-0.000188	-0.000400
	(0.00168)	(0.00182)	(0.00213)	(0.00314)	(0.000666)
*Dummy(2020q3=1)	0.0431***	0.0423***	0.0204***	-0.00265	0.00170**
	(0.00173)	(0.00202)	(0.00242)	(0.00346)	(0.000802)
*Dummy(2020q4=1)	0.0603***	0.0586***	0.0272***	0.0124***	0.00318***
	(0.00180)	(0.00219)	(0.00251)	(0.00379)	(0.000885)
Observations	26,023	26,023	26,023	26,023	26,023
R-squared	0.919	0.939	0.944	0.837	0.985
Firm FE	YES	YES	YES	YES	YES
Country-quarter FE	YES	YES	YES	YES	YES

Note: This results test for the impacts of COVID-19 shock on performance of affiliates operating in downstream sectors, including Food and tobacco, Transportation equipment, miscellaneous manufacturing, etc. *** p<0.01, ** p<0.05, * p<0.1

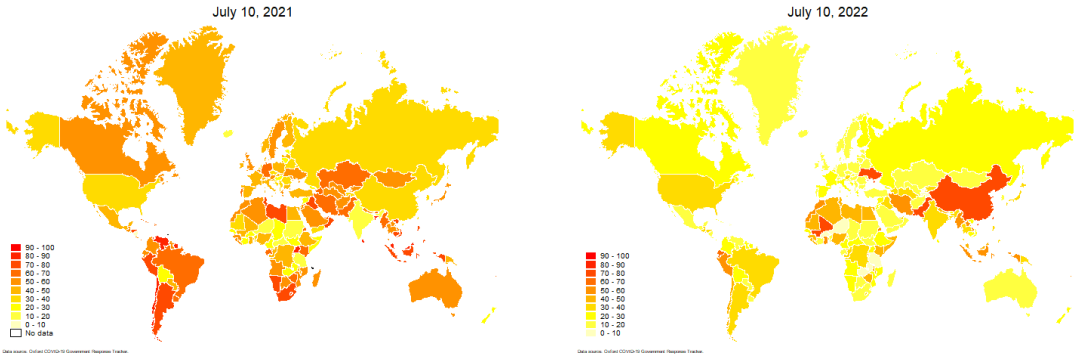
Appendix VII: Visualization of COVID-19 cases and lockdown stringency

Figure 2: Number of new COVID-19 cases by region



Note: Author's plotting based on the Johns Hopkins University Center for Systems Science and Engineering and Oxford Coronavirus Government Response Tracker

Figure 3: COVID-19 Policy Stringency Index by country



Note: Author's plotting based on the Johns Hopkins University Center for Systems Science and Engineering and Oxford Coronavirus Government Response Tracker