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

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Introduction

Research question: Are the multinational production networks resilient to the COVID-19 disruptions?

In this paper:

1. Analyze the impacts of the COVID-19 on oversea affiliates' performance of Japanese MNEs
2. Propagation effect through production/transaction networks
3. Heterogeneous effects across affiliates (e.g., localized affiliates vs.trading affiliates)

Outline

Previous literature

1. Spatial propagation of disasters:
   Barrot and Sauvagnat (2016); Boehm, C. E., Flaaen, A., & Pandalai-Nayar (2015); Seetharam, I. (2018)

2. Trade and global value chains (GVCs) disruptions by COVID-19:
   Hayakawa and Mukunoki (2021a); Hayakawa and Mukunoki (2021b); Ando et al.(2021)

3. The negative impacts of the COVID-19 crisis on foreign investment:
   Zhang (2021); Hayakawa, K., Lee, H. H., & Park, C. Y. (2022)

4. The effect of geographic diversification and localization on resilience:
   Todo et al. (2022); Lafrogne-Joussier et al. (2022); Ito and Fukao(2010)

What we do

Our paper

- use detailed Japanese affiliate-level quarterly data (worldwide)
- find heterogeneous impacts and geographic prorogation of COVID-19 across affiliates
- find the positive effect of localization in response to COVID-19

Zhang (2021)

- use country-level and industry-level aggregate data on Japanese manufacturing affiliates
- find general negative impacts of COVID-19 on production and performance
- find lockdown policies negatively related with sales and employment

Outline

Data

- Quarterly data of overseas affiliates (*the Quarterly Survey of Overseas Subsidiaries compiled by the Ministry of Economy, Trade and Industry (METI)*)
  - Variables: decomposed sales (total sales, local sales, sales (exports) to Japan and sales (exports) to third countries), capital investment and number of regular employees
  - Data available 2018q4-2021q1
- Annual data of overseas affiliates (*the Basic Survey on Overseas Business Activities compiled by METI*)
  - Variables: decomposed sales and procurement in terms of shipment destinations and procurement origins (e.g., local sales, sales (exports) to North America, sales (exports) to Europe, local procurement, procurement (imports) from Japan, procurement (imports) from North America).
  - Data available 2017-2019 to this project

Data

- The COVID-19 shock:
  - Variables: number of COVID-19 cases (e.g., # of new confirmed cases, # of deaths, total population) (*the COVID-19 Data Repository by the Center for Systems Science and Engineering at Johns Hopkins University*)
  - Variables: the stringency index of government policies (*the Oxford Coronavirus Government Response Tracker project*) [1]
  - Data available Jan. 22, 2020-now to this project.

[1] which is a composite measure based on nine response indicators (e.g., workplace closure) ranging from 0 to 100. The higher the value, the stricter the measure.

Data

- The subcategory indicators of lockdown policies:
  - Workplace closures: orders to close workplaces [2]
  - Defined as the share of days when a country orders a policy above a certain level 1, 2, or 3.
  - Economic support index: measures policies such as income support and debt relief

[2] 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; 3- require closing or work from home for all-but-essential workplaces (e.g., grocery stores, doctors)

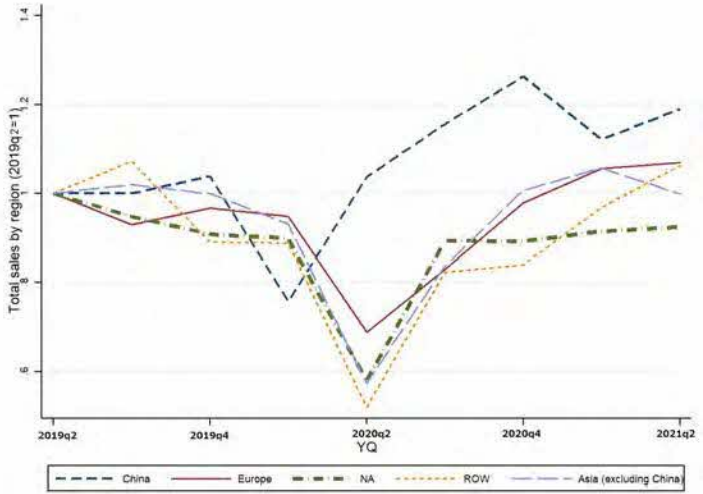
Summary of statistics

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

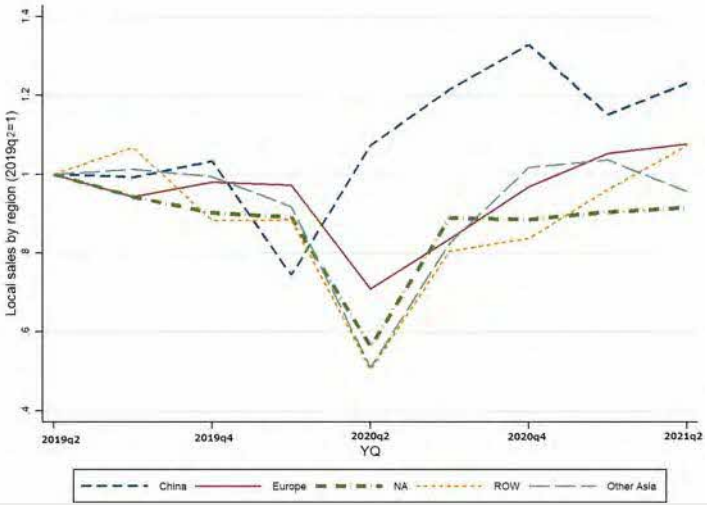
Visualization of COVID-19 disruption and recovery: total sales

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



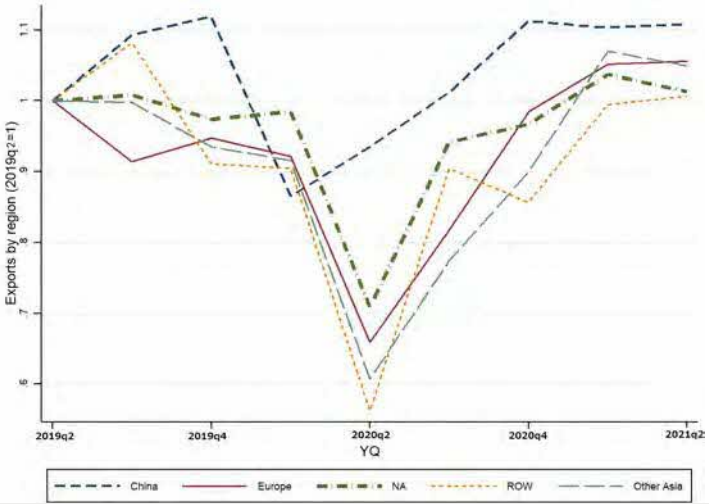
Visualization of COVID-19 disruption and recovery: local sales

Figure 2: Local sales by region before and after the outburst of COVID-19



Visualization of COVID-19 disruption and recovery: exports

Figure 3: Exports by region before and after the outburst of COVID-19



Outline

Overview of empirical framework and hypotheses

O: The adverse impact of Covid 19 on MNEs activities

H1: Industries which rely heavily on international production and supply chains may experience a relatively slow recovery. ▸ H1

H2: The COVID-19 shock propagated through MNEs' internal networks. ▸ H2

H3: Given the propagation through transaction networks, the production of affiliates is affected by the COVID-19 circumstances in procurement origin and sales destinations. ▸ H3

H4: Firms engaging in international trade are more likely to face worse condition during pandemic (Saurav et al., 2021; Borino et al., 2021). Localization helps mitigate the shock. ▸ H4

H5: Input specificity creates difficulties in gaining resilience, high dependence on specific home-country linkages could negatively affect overseas affiliates' performance. ▸ H5

Empirical Strategy: COVID-19 and production disruption

To estimate the impact of the COVID-19 and corresponding lockdown policies:

$$y_{a,c,t} = \beta_0 + \beta_1 COVID_{c,t} + \alpha_a + \delta_{c,q} + \epsilon_{a,c,t} \quad (1)$$

Variables

- $y_{a,c,t}$: total sales, local sales, exports, investment, employment of firm a operating in country c at year-quarter t.
- $Covid_{c,t}$: the COVID-19 damage (# of cases, # of deaths, # of case per million people, # of deaths per million people); lockdown policies (stringency index, workplace closing, economic support index) in host country c at year-quarter t
- α_a: affiliate fixed effects
- $\delta_{c,q}$: country-quarter fixed effects
- $\epsilon_{a,c,t}$: error term

Results: production disruption

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

Dependent var: log (total sales)	(1)	(2)	(3)	(4)	(5)	(6)
log (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)		
strigency (quarterly mean)					-0.000470***	
					(9.17e-05)	
strigency (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

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

Results: workplace closing policies

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

Results: economic support policies

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)
Eonomic 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

Results: production disruption and recovery by region

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: coefficient is highlighted in red when the summation of the coefficient of cases in corresponding column and interaction term itself becomes positive

Results: production disruption and recovery by region

Table 6: Recovery from disruptions by region and quarter

	log (Local sales)				log (Exports)			
	Europe	North Aermica	Asia	RoW	Europe	North Aermica	Asia	RoW
log (COVID-19 cases)	-0.0459***	-0.0473***	-0.0285***	-0.104***	-0.0233***	-0.0235***	-0.0152***	-0.0470***
	(0.00475)	(0.00264)	(0.00159)	(0.00980)	(0.00553)	(0.00329)	(0.00192)	(0.00926)
*Dummy(2020q2=1)	0.0392***	0.0379***	0.0162***	0.0804***	0.0171***	0.0190***	0.00341*	0.0352***
	(0.00469)	(0.00279)	(0.00171)	(0.00868)	(0.00525)	(0.00325)	(0.00198)	(0.00841)
*Dummy(2020q3=1)	0.0507***	0.0435***	0.0289***	0.105***	0.0290***	0.0233***	0.0150***	0.0303***
	(0.00547)	(0.00275)	(0.00196)	(0.00921)	(0.00608)	(0.00346)	(0.00237)	(0.00969)
*Dummy(2020q4=1)	0.0571***	0.0458***	0.0526***	0.115***	0.0310***	0.0262***	0.0243***	0.0495***
	(0.00542)	(0.00303)	(0.00207)	(0.0105)	(0.00619)	(0.00383)	(0.00254)	(0.0104)
Observations	4,030	5,657	31,140	2,590	4,030	5,657	31,140	2,590
R-squared	0.951	0.904	0.936	0.929	0.945	0.942	0.937	0.934
Firm FE	YES	YES	YES	YES	YES	YES	YES	YES
Country-quarter FE	YES	YES	YES	YES	YES	YES	YES	YES

- The disruptions were heterogeneous geographically, but all regions began to recover quite soon after 2020q2.

Results: production disruption and recovery by industry

H1

Table 7: Recovery from disruptions by industry and quarter (H1)

Dependent Var: log (Total sales)	log (COVID-19 cases)	*(2020q2=1)	*(2020q3=1)	*(2020q4=1)
Food and Tabacco	-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***

- Value-chain-intensive industries were more likely to face difficulties

Empirical Strategy: within-MNE propagation

◂ H2 Regarding the spillovers between affiliates and within-MNE propagation, we add the spillover index into equation:

$$COVID\_Spillover_{a,t} = \sum_{c'=1}^{c'} Num\_Siblings_{a,c'} \times COVID_{c',t} \tag{2}$$

$$y_{a,c,t} = u_0 + u_1 COVID_{c,t} + u_2 COVID\_Spillover_{a,t} + \alpha_a + \delta_{c,q} + \epsilon_{a,c,t} \tag{3}$$

Variables

- $y_{a,c,t}$: total sales, local sales, exports, investment, employment of firm a operating in country c at year-quarter t.
- $Covid_{c,t}$: the number of COVID-19 cases in c at year-quarter t
- $Num\_Siblings_{a,c}$: number of sibling affiliates of a that locate in country c'
- $COVID\_Spillover_{a,t}$: spillover of COVID-19 shock from sibling affiliates' locations
- α_a: affiliate fixed effects
- $\delta_{c,q}$: country-quarter fixed effects
- $\epsilon_{a,c,t}$: error term

Results: within-MNE propagation

Table 8: COVID-19 spillovers (H2)

Dependent Var:	(1) log (Total sales)	(2) log (Local sales)	(3) log (Exports)	(4) log (Investment)	(5) log (Labor)
log (COVID-19 cases)	-0.00504***	-0.00470***	-0.00306***	-0.0241***	-0.00179***
	(0.000743)	(0.00108)	(0.00112)	(0.00163)	(0.000438)
COVID_Spillover	-0.000119**	-0.000162**	-0.000129**	-0.000154*	-8.50e-05**
	(5.09e-05)	(6.78e-05)	(6.01e-05)	(8.43e-05)	(3.49e-05)
Observations	43,417	43,417	43,417	43,417	43,417
R-squared	0.921	0.937	0.941	0.833	0.987
Firm FE	YES	YES	YES	YES	YES
Country-quarter FE	YES	YES	YES	YES	YES

- Find spillover effects of the COVID-19 shock among affiliates, suggesting the within-MNE propagation

Empirical Strategy: number of siblings

H2 To examine whether firm size matters:

$$y_{a,c,t} = \nu_0 + \nu_1 COVID_{c,t} + \nu_2 COVID_{c,t} \cdot Num\_Siblings_a + \alpha_a + \delta_{c,q} + \epsilon_{a,c,t} \quad (4)$$

Variables

- $y_{a,c,t}$: total sales, local sales, exports, investment, employment of firm a operating in country c at year-quarter t.
- $Covid_{c,t}$: the number of COVID-19 cases in c at year-quarter t
- $Num\_Siblings_a$: total number of sibling affiliates of a
- α_a: affiliate fixed effects
- $\delta_{c,q}$: country-quarter fixed effects
- $\epsilon_{a,c,t}$: error term

Results: number of siblings

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

- More siblings worsened performance
- Partial evidence on the internal propagation of the shock

Empirical Strategy: propagation along transaction network

H3 Including the spillovers of COVID-19 in trading partner regions:

$$y_{a,c,t} = \theta_1 \cdot COVID_{a,c,t} + \theta_2 \cdot COVID_{Asia,t} \cdot \overline{ImpShare}^{Asia}_{a,c,2017-2019} + \theta_3 \cdot COVID_{NA,t} \cdot \overline{ImpShare}^{NA}_{a,c,2017-2019} + \theta_4 \cdot COVID_{EU,t} \cdot \overline{ImpShare}^{EU}_{a,c,2017-2019} + \alpha_a + \delta_{c,q} + \epsilon_{a,c,t} \quad (5)$$

$$y_{a,c,t} = \gamma_1 \cdot COVID_{a,c,t} + \gamma_2 \cdot COVID_{Asia,t} \cdot \overline{ExpShare}^{Asia}_{a,c,2017-2019} + \gamma_3 \cdot COVID_{NA,t} \cdot \overline{ExpShare}^{NA}_{a,c,2017-2019} + \gamma_4 \cdot COVID_{EU,t} \cdot \overline{ExpShare}^{EU}_{a,c,2017-2019} + \alpha_a + \delta_{c,q} + \epsilon_{a,c,t} \quad (6)$$

Variables

- $Covid_{Asia,t}$, $Covid_{NA,t}$ and $Covid_{EU,t}$ respectively represents the number of COVID-19 cases in Asia, North America and Europe.
- $\overline{ImpShare}^{region}_{a,c,2017-2019}$: average share of imports from respective regions in total procurement during 2017-2019.
- $\overline{ExpShare}^{region}_{a,c,2017-2019}$: average regional export share in total sales

Results: COVID-19 and imports by region

Table 10: COVID-19 and imports by region (H3)

	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

Results: COVID-19 and exports by region

Table 11: COVID-19 and exports by region (H3)

	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

Interpretation: propagation along transaction network

1. Both local pandemic and COVID-19 condition in procurement origin region affect the performance.
   – NA-located affiliates sourcing from Asia; Asia-located affiliates sourcing from surrounding areas
2. Asian exporters affected by the shock in the same region
3. Not find significant effects on other regions

Empirical Strategy: localized affiliates vs. trading affiliates

H4 We expect the heterogeneous effects between local-oriented firms and international ones:

$$y_{a,c,t} = \phi_1 \cdot COVID_{a,c,t} + \phi_2 \cdot COVID_{a,c,t} \cdot \overline{LS\_Share}_{a,c,2017-2019} + \phi_3 \cdot COVID_{a,c,t} \cdot \overline{LP\_Share}_{a,c,2017-2019} + \alpha_a + \delta_{c,q} + \epsilon_{a,c,t} \quad (7)$$

Variables

- $\overline{LS\_Share}_{a,c,2017-2019}$: average value of local sales share (in total sales) during 2017-2019 .
- $\overline{LP\_Share}_{a,c,2017-2019}$: average value of local procurement share (in total procurement) during 2017-2019 .

Results: COVID-19 and localized affiliates

Table 12: COVID-19 and local-oriented affiliates (H4)

Dependent Var:	(1) log (Total sales)	(2) log (Local sales)	(3) log (Exports)	(4) log (Investment)	(5) log (Labor)
log (COVID-19 cases)	-0.0122***	-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

Interpretation: COVID-19 and local-oriented affiliates

1. Aggravation effects by higher international exposure
   – trading firms experienced more serious problems
2. Shortage of inputs is still a primary concern (Saurav et al., 2021).
3. Local backward linkages helped mitigate the adverse shock

Empirical Strategy: further decomposition of local linkages

◂ H5 A question rises: Local procurement from whom contributes to resilience?

$$y_{a,c,t} = \pi_1 \cdot COVID_{a,c,t} + \pi_2 \cdot COVID_{a,c,t} \cdot \overline{LP\_Share}^{JPN}_{a,c,2017-2019} + \pi_3 \cdot COVID_{a,c,t} \cdot \overline{LP\_Share}^{Domestic}_{a,c,2017-2019} + \alpha_a + \delta_{c,q} + \epsilon_{a,c,t} \quad (8)$$

Variables

- $\overline{LP\_Share}^{JPN}_{a,c,2017-2019}$: procurement from Japanese firms in the host country / total procurement
- $\overline{LP\_Share}^{Domestic}_{a,c,2017-2019}$: procurement from domestic firms in the host country / total procurement

Results: Further decomposition of local linkages

Table 13: Local procurement from JP firms vs. local procurement from domestic firms (H5)

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

Results: Further decomposition of local linkages

Table 14: Local procurement from JP firms vs. local procurement from domestic firms by region (H5)

	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

Interpretation: Further decomposition of local linkages

1. Higher reliance on local Japanese inputs worsened performance.
2. Negative but not significant on the coeff. of the Procurement share from domestic firms
   → dependence on domestic linkages may not cause a worse condition.
3. Disrupted supply chains on Japanese inputs may further deteriorate business
   → heavily reliance on Japanese inputs leads to specificity (e.g., *keiretsu* transactions)
   → input specificity may cause difficulties and further result in vulnerability
4. More pronounced for affiliates in Europe and NA

Outline

Discussion

1. Find evidence on the pandemic-induced disruption of global production
2. Resilience of the global production network and supply chains
   - large-scale recovery by 2020q4
3. Linkages with trading partner regions affect resilience
   - the propagation along transaction networks
4. Localized affiliates shows higher resilience to the global shock.
5. Negative effect of input specificity

Policy implications

1. Restructuring of the global production network.
   - more than 60% of surveyed companies plan to adjust supply chains[3]
2. Localization of procurement and enhancement of backward linkages
   - more actively establish local input networks and actively gain local footholds
3. Diversification of local procurement sources
   - 59.6% planned to adjust procurement sources[4]

[3] According to the 2021 Questionnaire Survey on Overseas Business Expansion of Japanese Companies by JETRO

[4] According to the 2021 Questionnaire Survey on Overseas Business Expansion of Japanese Companies by JETRO

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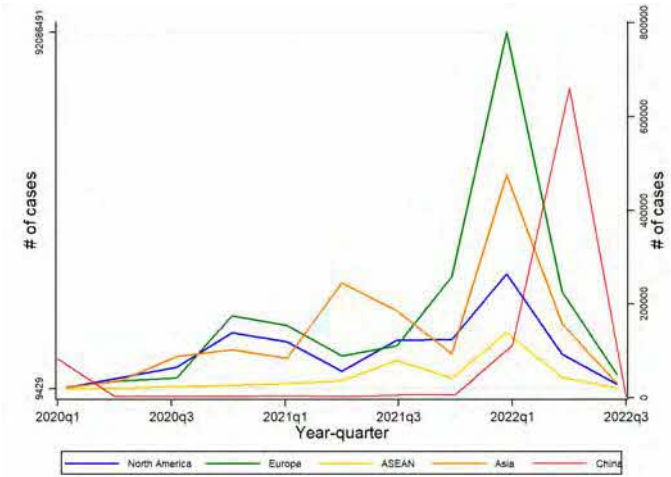
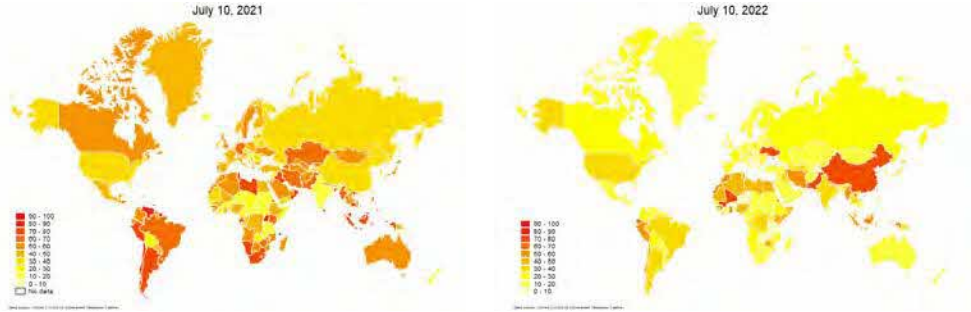
Appendix: Visualization of COVID-19 cases

Figure 4: Number of new COVID-19 cases by region



Appendix: Visualization of lockdown stringency

Figure 5: COVID-19 Policy Stringency Index by country



Appendix: 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: 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

Appendix: Recovery from disruptions measured by additional performance indicators

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

	log (labor)			
	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

Appendix: Lockdown stringency and recovery

Table 17: Recovery from disruptions by region and quarter (Lockdown as the shock)

	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

Appendix: COVID-19 and transaction networks

Table 18: COVID-19 and imports by region (Based on 2019 import 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

Appendix: COVID-19 and transaction networks

Table 19: COVID-19 and imports by region (Based on 2019 export 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

Appendix: Lockdown stringency and localized affiliates

Table 20: Lockdown stringency 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

Appendix: Local procurement from JP firms and total local procurement

Table 21: Local procurement from JP firms and total local procurement

Dependent Var:	(1) log (Total sales)	(2) log (Local sales)	(3) log (Exports)	(4) log (Investment)	(5) log (Labor)
log (COVID-19 cases)	-0.0117***	-0.0157***	-0.0129***	-0.0457***	-0.00496***
	(0.00218)	(0.00317)	(0.00320)	(0.00483)	(0.00159)
log (COVID-19 cases)#$\overline{LP\_Share}^{JPN}$	-0.00480*	-0.00304	-0.00241	-0.0111	-0.00414***
	(0.00272)	(0.00365)	(0.00599)	(0.00791)	(0.00121)
log (COVID-19 cases)#$\overline{LP\_Share}$	0.00471*	0.00944***	0.0105***	0.0233***	0.00267
	(0.00244)	(0.00356)	(0.00363)	(0.00545)	(0.00174)
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

Robust standard errors in parentheses
*** p<0.01, ** p<0.05, * p<0.1