Global supply chain interdependence and shock amplification – evidence from Covid lockdowns

By SALLY CHEN, ERIC TSANG AND LEANNE (SI YING) ZHANG[1,2]

[1] Chen: Regional Advisor, Monetary and Economics Department, Bank for International Settlements (e-mail: Sally.Chen@bis.org);
Tsang: Senior Economist, Research Department, Hong Kong Monetary Authority (email: ethtsang@hkma.gov.hk);
Zhang: Advisor, Bank for International Settlements Innovation Hub – Hong Kong Centre (email: Leanne.Zhang@bisih.org)

[2] This paper is based on the work conducted for the BIS Quarter Review (BIS March 2023). The authors thank Ryan Banerjee, Claudio Borio, Stijn Claessens, Jon Frost, Hyun Song Shin, Nikola Tarashev and Egon Zakrajšek for helpful comments and discussions, and Jimmy Shek and Ronald Yip for excellent research assistance. The views expressed are those of the authors and do not necessarily reflect those of the Bank for International Settlements or the Hong Kong Monetary Authority. All errors or omissions are the authors.

Abstract

Supply disruptions from the Covid-19 pandemic raised questions about the benefits and costs of global value chain (GVC) participation. We use granular data to document the evolution of GVC firm-level linkages in the aftermath of the Covid-19 outbreak and study how they might have affected equity investors' reaction to pandemic-related disruptions. We find that the number of GVC linkages generally declined and was slow to recover for some sectors after the Covid-19 shock but that the volume of the resilient linkages helped to cushion production disruptions. Firms with GVC links to countries undergoing Covid-related lockdowns suffered larger stock price losses than those without such links.

JEL classification: F10, G12, G14, O24.

Keywords: supply chain, supply networks, amplification, equity prices

I. Introduction

A rich literature has analysed the trade-offs from participation in global value chains (GVCs), the organisation of production processes, trade and investment across different locations to optimise production. The findings suggest that GVC participation propagates and amplifies risks (Zhang (2021), Huang et al (2022), Mohommad et al (2022)), but could reduce production costs and improve economies' resilience (Ando and Hayakawa (2022), Barrot and Sauvgnat (2016), Kashiwagi et al (2021)). Less frequently discussed is GVC participation at the firm level, and in particular how stock market investors assess GVC linkages in the face of global shocks.

We draw insights from firm-level data to study the evolution of GVCs over several quarters after the Covid-19 outbreak and the role of GVC participation in firms' stock market performance at the time of the outbreak. We find that declines in the number of cross-border linkages were still evident two years after the onset of the pandemic but a rise in the volume of the remaining linkages helped cushion the fallout. Furthermore, our empirical analysis suggests that firms' GVC participation played a role in stock market investors' trading decisions at the start of Covid-induced disruptions. The cumulative returns on firms linked to two major GVC countries in lockdown – China and Germany – declined by 1.5 percentage points more over a week than the returns on other firms, a magnitude comparable to the typical annual volatility of returns in normal times.

Our analysis builds on two strands of work – the empirical body of research studying the transmission of shocks via supply chain linkages at the firm level, and the corporate finance literature that studies the effects of supply chain linkages on asset pricing. We show that GVC participation amplifies spillovers from pandemic-related production disruptions. Moreover, firm-level data on supply chain interconnections can provide valuable insight on globalisation trends, both at the intensive (ie, value of trade) and extensive margins (ie, number of linkages).

This paper seeks to tap into insights from granular data to better understand the state of GVCs post Covid and the impact of GVC participation on firms' stock market performance. We first construct network visualisations of global firm-level supply-chain interconnections for an overview of GVCs following the onset of the Covid pandemic. Drilling further to better understand

suppliers' flexibility in responding to Covid-related disruptions, we analyse quantitative measures of suppliers' shipments and associated quantities. Lastly, we empirically assess whether stock market investors took into account firms' GVC participation when responding to news of Covid-related lockdowns.

Our analysis uncovered several insights. Network maps of global GVC networks reveal complex and extensive network structures, with firms in Asia, the US, and Europe all exerting significant influence, likely acting as an important propagation mechanism of the Covid-19 shock from initially-affected economies. Comparing these network structures over time shows that, on net, GVC networks had been slow to recover to their pre-pandemic levels with notable declines in the number of cross-border linkages still evident two years following the onset of the pandemic. The contraction of GVC networks is particularly evident in the IT industry, consistent with its more geographically dispersed and decentralised network structure.

Meanwhile, our empirical analysis suggests that GVC participation amplified the impact of Covid-induced supply disruptions, with the share prices of firms linked to two major manufacturing countries in lockdown (China and Germany) exhibiting greater declines compared to those without such linkages. Moreover, the equity return underperformance for those linked firms is found to be persistent. Specifically, stock prices of firms with ties to China and Germany significantly underperformed other firms in a week-long window following news of the lockdowns, highlighting the economic significance of global production network linkages as a mechanism for propagating the coronavirus shock. The extent of underperformance, in turn, depends on the relative positioning in the supply chain (as upstream suppliers or downstream consumers vis-à-vis lockdown-affected firms in China or Germany), as well as the closeness of connections to these economies (network distance). As expected, the impact of lockdown announcements on the equity prices of China- and Germany-linked firms fades with increasing network distance. The impact of supply chain positions on equity returns, however, is more nuanced and sector-specific.

Diving further into the industry breakdowns reveals that China and Germany-linked firms in cyclical industries (e.g. consumer discretionary, industrials), and those with prominent global

segmentation of production (e.g. information technology), exhibited significantly greater equity price declines. And speaking to the public health nature of the COVID-19 shock, in the healthcare sector, firms upstream to China and Germany outperformed the downstream players.

Examining specific periods in the aftermath of the Covid-19 outbreak, the rest of this article is organised as follows. The first section examines granular data on customer-supplier interlinkages from a sample of global firms as well as data on maritime shipments to the United States. The second section assesses equity investors' sensitivities to firms' GVC linkages. The last section concludes.

II. Literature Review

Our work combines several strands of research at the intersection of trade and finance and adds to the current discussion on the costs and benefits of GVC participation. Recent work has found that exports of goods that are more dependent on global value chains are more volatile than other goods (Mohommad et al (2022)), and GVC networks acted as an important propagation mechanism of China's early lockdowns in 2020 to the rest of the world (Zhang (2021), Huang et al (2022)). Our research draws on this work and adds to the literature on firm-level responses to shocks. Using unexpected events that exogenously affect firms, we show that GVC participation amplifies the negative impact from supply disruptions on firms' share prices. In doing so, our finding contributes to studies on the financial implications of supply chain linkages.

III. Data and sample construction

3.1 Data

To gauge potential shifts in GVCs following the outbreak of the pandemic, we employ two granular supply chain datasets: i) firm-level interlinkages from S&P's Capital IQ (CIQ), which provides cross-sectional snapshots of customer-supplier linkages declared within the past two years; and ii) shipping manifests from government public records compiled by Datamyne (eg, bills of lading, country of origin, consignee and product description) for all ocean freight entering and

exiting from the US.[3] The CIQ dataset provides balance sheet and interfirm business linkage information for a global sample of firms. Each CIQ supply-chain linkage represents whether a firm has declared another firm as its customer or supplier over a two-year period. The Datamyne dataset consists of US maritime shipment information (also known as bills of lading, or BoL) from the US Census Bureau. BoL data often comes with company names for both the shipper (ie, supplier, exporter, or freighter forwarder) and consignee (the importer, or firm receiving the final merchandise delivery) and the volume of shipments, thus allowing detailed mapping of companies' customer-supplier relationships. Together, these two datasets offer information on both the existence of supply chain linkages (eg, whether a firm has a supplier or customer) and the intensity of supply chain connections (eg, the number of shippers and volume of shipments to a firm).

From the CIQ database, we obtain a data sample comprising of tens of thousands of publicly-listed and private companies covering eight of the eleven Global Industry Classification Standard (GICS) sectors[4] in over 150 economies[5] – see Chart 1. Following Zhang (2021), we only look at firms in the "Manufacturing", "Mining", and "Agriculture, Forestry and Fishing" SIC industry classifications for the network visualisations and mapping to capture supply-chain-related activities (excluding Services and Wholesale and Retail trade, for example).[6] Later for the regression analysis, we take a subset of these firms that are publicly listed and further add back firms in the other remaining sectors to provide an empirical benchmark for our estimates.

[3] We focus on the US case given the quality and high coverage of data.

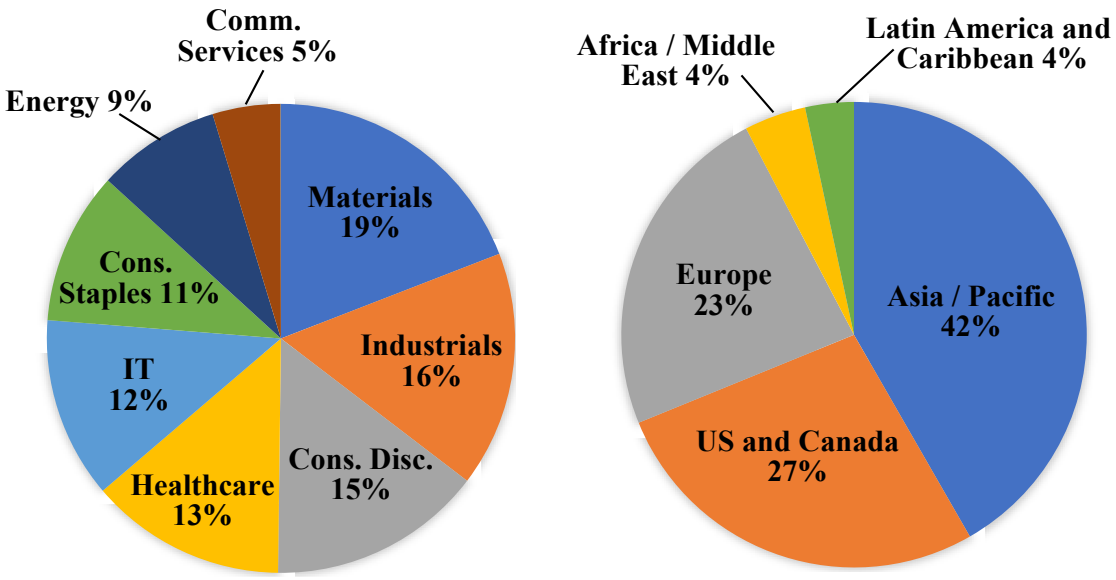
[4] Firms in the Financials, Utilities, and Real Estate GICS sectors are excluded; the GICS-SIC mapping process captures some Communication Services firms as manufacturing firms-for example, firms in movies and entertainment that produce entertainment equipment. For a detailed sector breakdown, see: https://www.spglobal.com/marketintelligence/en/documents/112727-gics-mapbook_2018_v3_letter_digitalspreads.pdf.

[5] Represents the economy / country in which the firm's headquarters / primary offices are located. Headquarters can be the subsidiary of a firm in another country (e.g. Mainland China-headquartered firms may include US multinational subsidiary firms in the Mainland). We use this specification instead of the country of the ultimate parent company as our purpose is to illustrate foreign supply chain exposures on a locational basis.

[6] While the default industry classification used by CIQ is GICS, it provides a mapping system to SIC primary industry categorization which allows a simpler identification of "supply-chain-related" industries; we exclude other SIC industry classifications to avoid capturing firms performing non-supply-chain-related activities. For other purposes, however, we use the CIQ default industry classification -GICS.

Chart 1: Breakdown of firms by GICS sector and region

A: GICS sector breakdown **B: Region breakdown**



Notes: "Cons. Staples" = Consumer Staples; "Cons. Disc." = Consumer Discretionary, "Comm. Services" = "Communication Services".

Sources: CIQ and staff calculations.

Firm's reported connections may represent only a portion of their total customers and suppliers, as companies are typically not obligated to disclose them all (the SEC mandates that issuers disclose all customers representing 10% or more of their revenue, for example). To account for this, we follow Carvalho et al. (2016) and Zhang (2021) by augmenting each firm's list of suppliers (customers) with the reports of other companies that declare the firm as their customer (supplier), although this may not be able to capture all the unreported suppliers and customers. Another limitation of the CIQ supply chain data is that it is a binary variable representing the existence of a relationship, but does not provide the intensity of each linkage.

To address potential concerns that could arise due to the self-reported nature of the interfirm linkages in CIQ and for granular information on the intensity of the customer-supplier transactions such as the estimated volume of import shipments, we make use of the US firms' bills of lading, compiled by Datamyne. Shipping manifests from the US consisted of 456,453 shipment-level

details associated with unique consignees headquartered in the US for 2020. We are able to verify that, for US-based firms, only about 20% of those that declared supplier relationships with China and / or Germany in CIQ could not be matched. Because not all firms receive shipments every month, BoL would not be able to confirm all of CIQ's linkages.

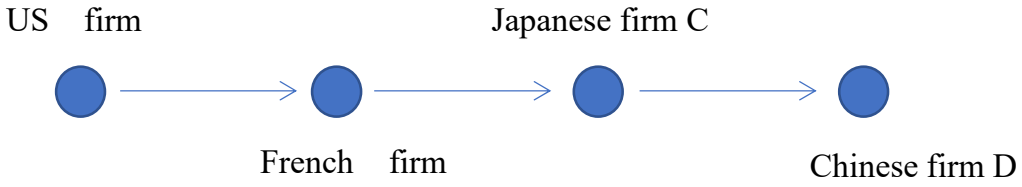
3.2 Mapping supply chain exposures to China and Germany

To construct global firm measures of China and Germany's supply chain exposure, we use the CIQ data and first exclude from our sample firms headquartered in China and Germany. We then form dummy variables representing network distances of the remaining firms to Chinese or German companies using those firms' declared business relationships, differentiating between upstream (supplier) and downstream (customer) positions. For instance, a firm that declares a customer (supplier) in China or Germany is deemed an upstream (downstream) supplier (customer) to China or Germany with one degree of separation, ie, this firm is directly upstream (downstream) to a Chinese or German firm. For indirect linkages with higher degrees of separation, we connect firms to customers and suppliers in China through multiple layers of bilateral relationships. See Chart 2 below for an illustrative example. It is important to note that we are neither trying to measure a firm's position in, nor the length of, the overall value chain of a product or sector; rather, we are measuring a firm's position, and the length of the supply chain, relative to a firm in China or Germany in the same production network.

Chart 2: Illustrative example - direct and indirect upstream exposure of a US firm to a Chinese firm

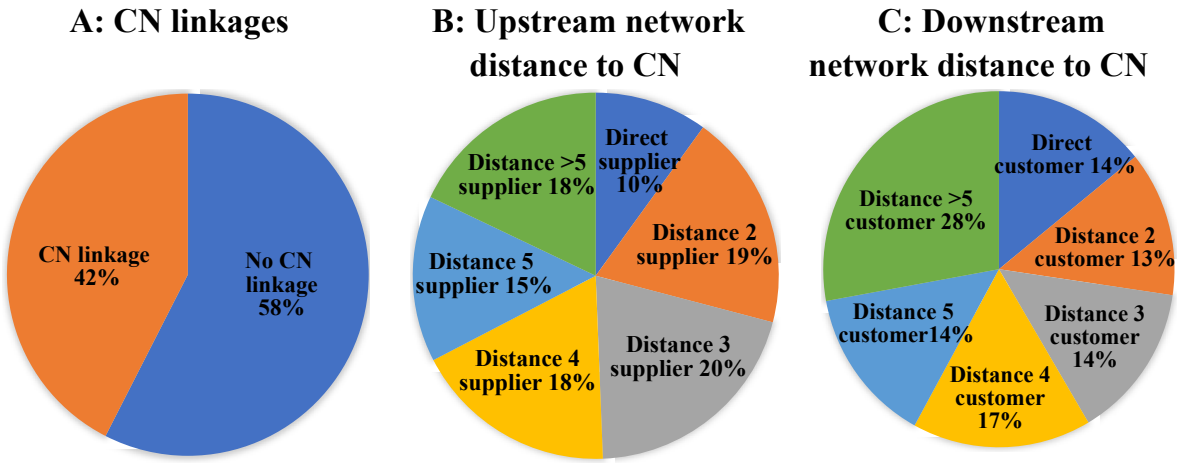
Direct upstream linkage:

Indirect upstream linkage:



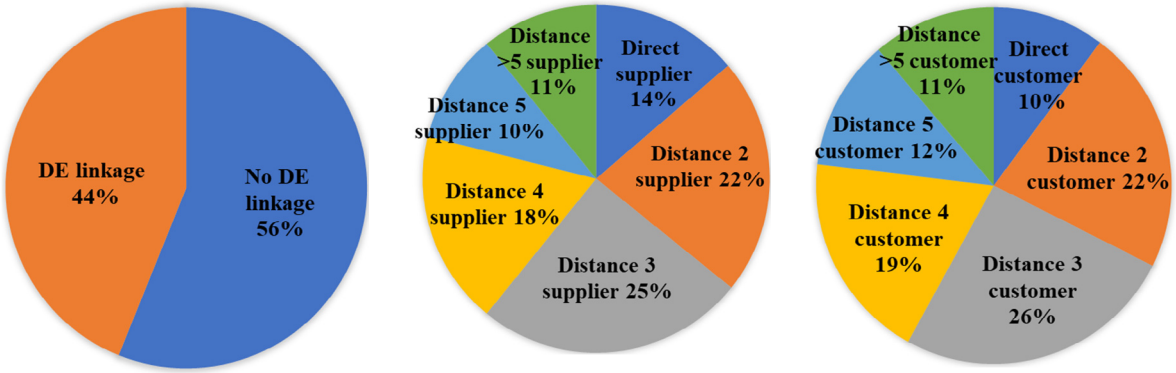
This mapping exercise reveals that nearly half of the non-Chinese and non-German manufacturing firms in our sample have direct or indirect supply chain linkages to China and Germany, respectively (Charts 3A and 4A), underscoring the geographical interconnectedness of production networks and China and Germany's outsized role in global manufacturing. Furthermore, the majority of China- and German-linked firms are exposed to both countries through indirect linkages, often with multiple degrees of separation (Charts 3B and 3C, and 4B and 4C), demonstrating the complexity of GVCs and the importance of looking beyond the immediate inter-firm business ties when assessing production network exposures.

Chart 3: Supply chain linkages with China ('CN'), among non-CN firms



Sources: CIQ and staff calculations.

Chart 4: Supply chain linkages with Germany ('DE'), among non-DE firms



Sources: CIQ and staff calculations.

IV. GVC trends during the Covid pandemic – stylised facts

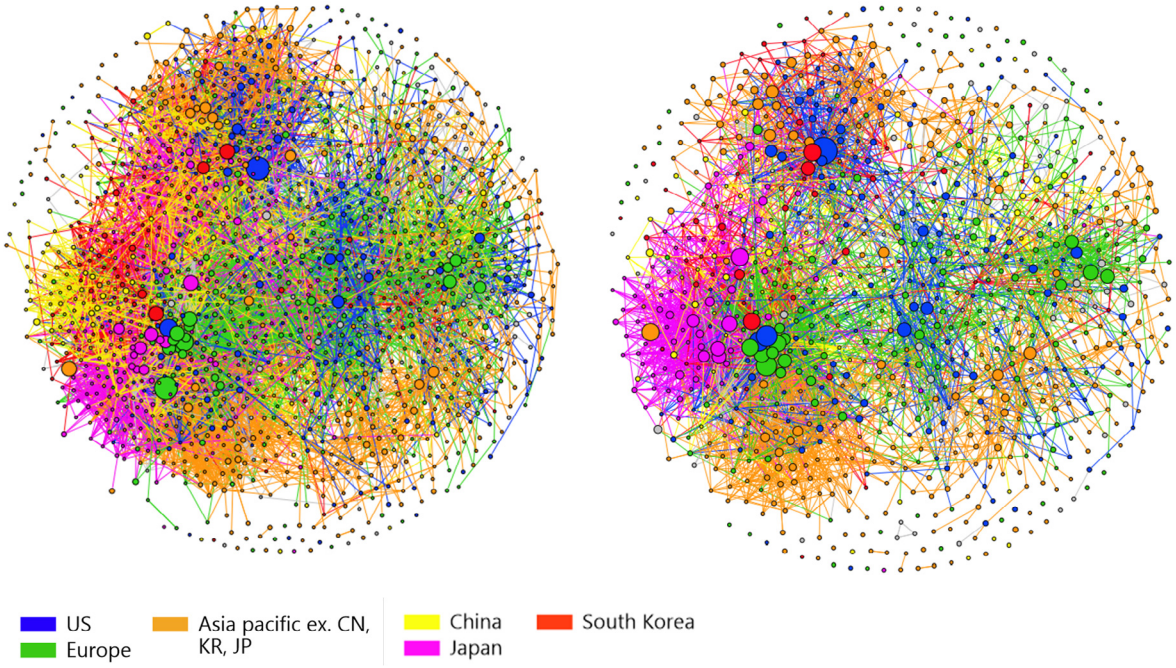
To shed light on granular GVC interlinkages and how GVCs might have evolved during the pandemic, we create detailed graphical depictions of firm interlinkages using information from CIQ and study bills of lading data from Datamyne.

Leveraging the global nature of the CIQ data sample, we first create cross-sectional snapshots of global firm supply chain linkages from pre- and post-pandemic periods, building on the work in Zhang (2021) (who only looks at the pre-pandemic state of GVCs). In these network diagrams, firms are depicted by nodes, the sizes of which are proportional to a firm's importance in the overall network. A firm's importance in the network is defined by eigenvector centrality, which measures a node's influence by taking into consideration not only the number of connections a node has, but also the centrality of the nodes it is connected to. All nodes start off equal, but as the computation progresses (and after several iterations), nodes with more edges start to gain importance, and their importance propagates out to the nodes to which they are connected. Customer-supplier relationships are represented by the edges – ie, connecting lines – between two nodes. Edge color aligns with the colour of the supplier, hence identifying the source of the connection. The network maps are structured so that nodes sharing more connections are placed closed together. Denser (thinner) patches featuring a greater (smaller) number of edges and/or nodes therefore suggest more (less) integrated networks.

Chart 5 provides a birds-eye view of the pre- and post-pandemic global supply chain networks, using data on global firm customer-supplier interlinkages in February 2020 and December 2021, respectively. As pointed out in Zhang (2021), the network visualisations highlight the complexity and interconnectedness of global manufacturing production networks, with firms in Asia, the US, and Europe all exerting significant influence, that likely acted as an important transmission mechanism of the Covid-19 shock from initially affected economies. When looking across two different periods of time, the network map from late 2021 (Graph 5, right-hand panel), compared to early 2020 (left-hand panel), suggests that GVC networks had yet to fully recover two years into the pandemic. Customer-supplier networks appeared less interconnected at the end of 2021 compared to early 2020, as shown by the less dense patches and the presence of more empty space in 2021. Indeed, the number of linkages in the sample fell by 30% on a net basis (after accounting for new relationships formed) over the two-year period.

Chart 5: Global supply chain networks

A: February 2020 **B: December 2021**



Notes: data were taken from CIQ, where firms' customer and supplier relationships are sourced from company filings, news aggregators, press releases etc.
Sources: CIQ and authors' calculations.

Zhang (2021)'s analysis dove into the (pre-pandemic) network structures of a few industries, finding that two industries in particular – auto and IT – demonstrated globally interconnected, unique and contrasting network structures. The author found that the auto industry's unique regional and country "subnetworks" nested within the global auto supply chain suggests it could be more resilient to GVC shifts compared to that of the IT industry, which displays a more decentralised and globally-dispersed network. Notably, Zhang (2021) noted that:

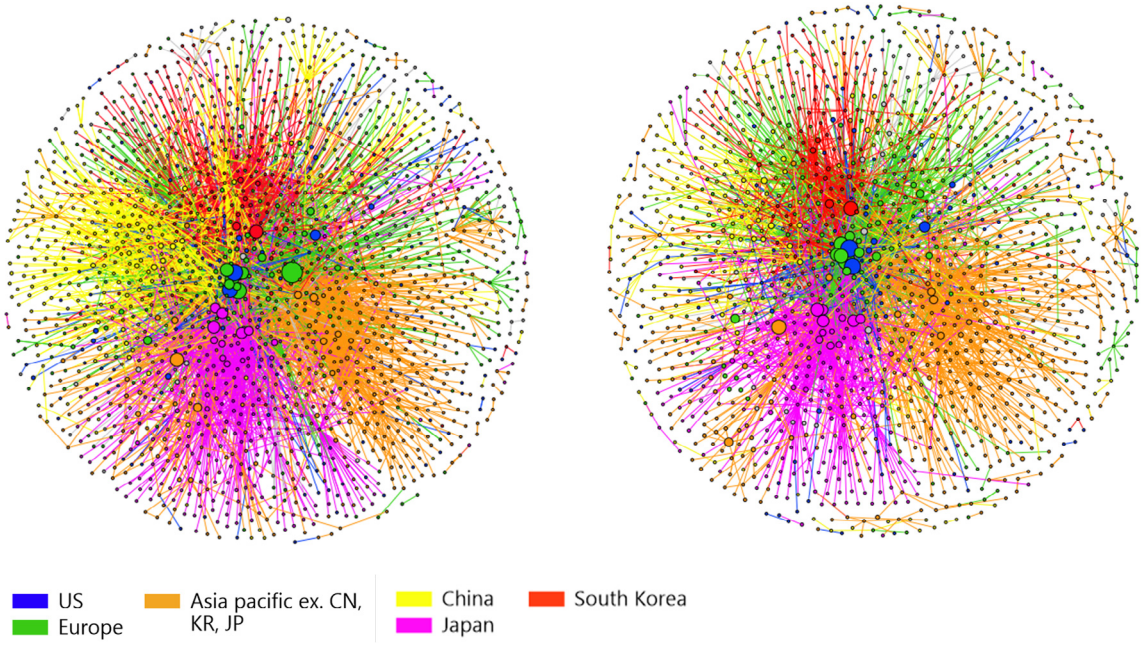
"[the] auto industry may be more resilient to the resulting disruptions due to its unique organizational structure…Auto firms from the same country / region tend to gather in bunches, implying extensive intra-country and intra-regional linkages…[when faced with disruptions,] automakers may continue to capitalize upon the well-established regional supply chain clusters, which are likely to remain competitive due to their economies of scale…In the IT industry,

however, there is no such discernible pattern. Instead, the tech industry shows a highly decentralised network with a mix of intertwined Chinese, Korean, Japanese, "Asia ex. CN, KR, JP", and US firms."

To shed light on whether this was indeed the case following widespread pandemic-related supply-chain disruptions, we compared the GVC network structures of the auto and IT industries in early 2020 and late 2021. Chart 6 shows the pre- and post-pandemic GVC network of the Automobiles & Components (auto) industry. We can see that while the auto industry appears slightly less dense at the end of 2021 compared to early 2020, the "nested" structure of auto GVCs continues to remain well intact, as shown by the bunches of firms and interlinkages of common colour in December 2021 representing regional and country-level supply chain clusters. On the other hand, Chart 7 showing the GVC networks of the IT industry demonstrates a significantly more sparse network structure in late 2021 compared to early 2020, consistent with the IT industry being less resilient to global supply chain disruptions.

Chart 6: Global supply chain networks – Automobiles & Components industry

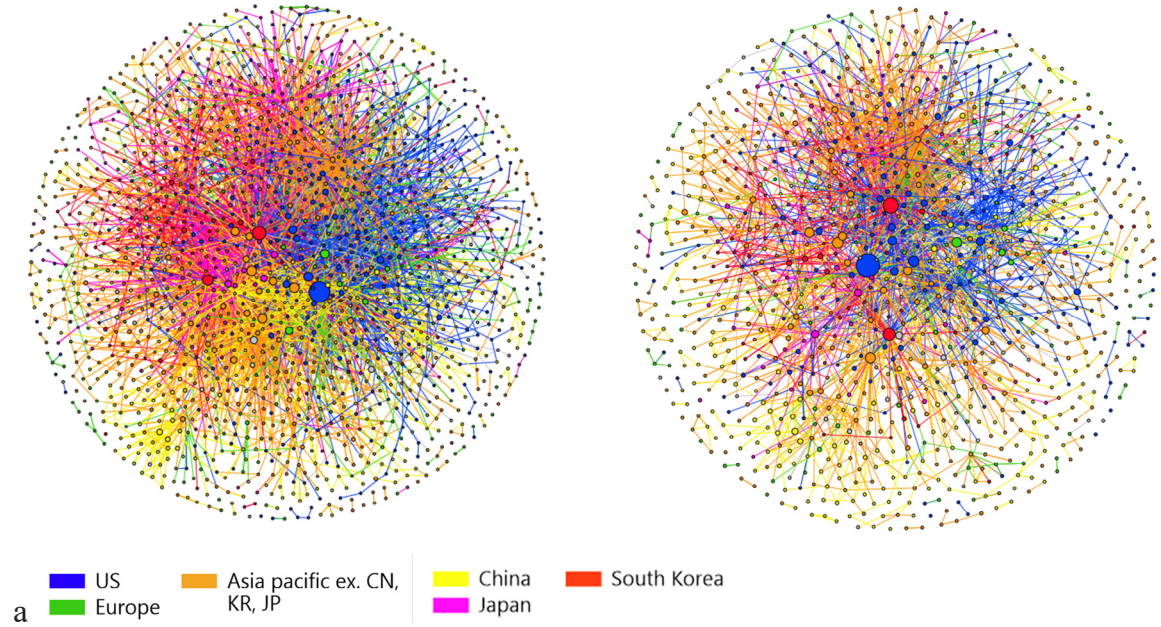
A: February 2020 **B: December 2021**



Sources: CIQ and authors' calculations.

Chart 7: Global supply chain networks – Information Technology industry

A: February 2020 **B: December 2021**



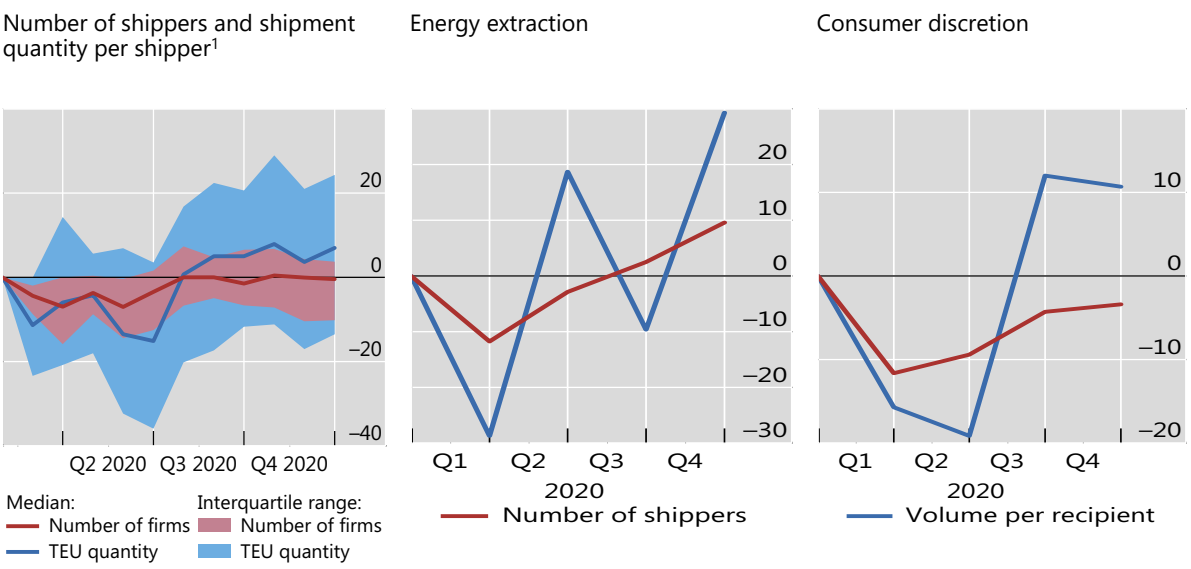
a

Sources: CIQ and authors' calculations.

While the CIQ data provides a helpful bird's-eye view of global GVC networks, they can only speak to the *existence* of interfirm supply-chain relationships, and cannot shed light on the *intensity* of these linkages. Delving further to better understand the characteristics of interfirm connections, we shift our focus to the intensity of GVC links using the Datamyne sample. We study maritime shipments, focusing on the case of US importers which tend to exhibit relatively high coverage and quality. These data show that the number of shippers per importer (ie, a proxy for firms' supplier diversification) and the corresponding shipment quantity (ie, trade intensity) generally fell in the first half of 2020 relative to pre-pandemic levels. There is, however, greater dispersion in the shipment quantity across sectors during 2020 and on net, a larger recovery in the second half of 2020 (Graph 8, left-hand panel).

Maritime shipments to the US suggest variations and limits in GVC flexibility

Jan 2020 = 0 Graph 8



Footnote[1] Average of twenty-foot equivalent units (TEU) pe consignee across respective industries. TEUs measure shipment cargo capacity.

Sources: US Census Bureau; Datamyne; authors' calculations.

At the end of 2020, BoL data indicated that shipment quantity for nearly 50% of industry sectors had recovered to or exceeded their January levels, but only 38% of sectors saw similar recovery in the number of shippers. This broader decline in the number of shippers echoes findings from the network maps that suggest a sizable reduction in the number of interfirm linkages. At the same time, those remaining "resilient" linkages helped to cushion the detrimental impact of production disruptions. For example, in some of the sectors that suffered the largest declines in shipment suppliers at the onset of the pandemic in early 2020 – eg, consumer discretion items, the number of shippers remained below their pre-pandemic levels by year end (right-hand panel). At the same time, this sector saw a large rebound in shipment quantity from existing suppliers that surpassed their January levels and helped cushion against supply disruptions. Other sectors such as energy extraction were able to rebound quickly from the decline in both shipment suppliers and quantity (centre panel). These sectoral variations and the divergence between shipper numbers and

shipment quantity highlight the importance of looking at both the extensive and intensive margins when assessing broad trends in GVC networks.

V. Shock amplification through supply chains

5.1 Methodology

To assess whether GVC participation played a role in amplifying the effect of pandemic-related disruptions, we study GVC-linked firms' equity price fluctuations in response to news of Covid lockdowns in two significant players in the global GVC network, China and Germany[7], that were also relatively early to announce large-scale lockdowns in the first quarter of 2020. Following Zhang (2021), we focus on high-frequency equity price movements, which capture the expected impact of Covid-induced disruptions on firms' future earnings in short windows surrounding lockdown announcements, rather than their actual performance (e.g. sales, profitability, etc.). The latter is of quarterly frequency and reflects the cumulative effect of multiple events; as surges in virus cases started to emerge all over the world soon after outbreaks in specific economies, the impact of supply chain disruptions on quarterly firm financials will be confounded by the direct effects of domestic virus outbreaks.

The events in focus are the 22nd and 27th of January 2020 for China, when the Wuhan lockdown and extension of the Lunar New Year holiday were announced, respectively, and the 16th of March 2020 for Germany, when border closures were announced. These events represent exogeneous shocks to the state of GVCs as they took place before broad-based supply disruptions became evident and hence before markets, firms and the public at large started anticipating these disruptions' fallout. The announcements were also not confounded initially by similar concurrent events in other parts of the world.

[7] For ranking of GVC importance, please see WTO (World Trade Organization) 2021. *Global Value Chain Development Report 2021.* Geneva. https://www.wto.org/english/res_e/booksp_e/00_gvc_dev_report_2021_e.pdf

The regression sample consists of a global set of listed firms that have declared supply-chain linkages within the past two years, as identified by CIQ, and their daily equity returns between 1 January 2019 and 17 April 2020; this period is chosen as we want to take into consideration the pre-pandemic state of equity market performance. We exclude firms headquartered in China and Germany, as we seek to study the role of GVC participation in amplifying the effect of lockdowns to firms outside of the affected economies. Moreover, we exclude non-listed companies from our firm sample and add back publicly listed firms in the other SIC industries (e.g. Wholesale Trade, Services etc.) to provide an empirical benchmark for our estimates.

Using a firm and time fixed-effects panel specification, our baseline regression is of firms' daily stock returns on their respective market returns and a key regressor that captures the impact of lockdown announcements in China and Germany on non-Chinese or non-German firms linked to these two economies in the GVC network. We estimate the following panel regression for China and Germany lockdowns and linkages:

$$Return_{i,t} = \alpha_i + \mu_t + \sum_{j=CN,DE} \beta_j Lockdown_j \times GVC_{i,j} + \delta MarketReturn_t + e_{i,t}$$

where $Return_{i,t}$ represents the daily change in firm i's last equity price in percentage terms. The dummy variable $Lockdown$ takes on a value of 1 on the date of the relevant announcements; as discussed above, this is 22 and 27 January 2020 for China and 16 March 2020 for Germany. The variable GVC represents firms' Chinese or German linkages as identified by CIQ in early 2020, thus providing a "pre-Covid" state of supply chain relationships. It takes on a value of 1 for a firm that has declared a customer or supplier relationship with China or Germany and 0 otherwise. These linkages are further defined as either upstream (ie, supplier) and downstream (ie, customer) to China or Germany, thereby allowing us to determine whether firms' GVC position relative to the lockdown economies affects perceptions of their susceptibility to Covid shocks. The variable $MarketReturn$ is the return on broad indices in the countries where the firms are listed; it allows us to control for the typical co-movements between benchmark indices and equity shares and

capture abnormal movements in equity prices during the pandemic. α_i and μ_t represent firm- and time-fixed effects, respectively.[8]

The coefficient β_{CN} and β_{DE} of the interaction terms between *lockdown* and *GVC* linkages in China and Germany are of particular interest to us as it captures the effect of a country's lockdown announcement on the stock return of firms with GVC links to the affected economy, relative to firms without such linkages. Our baseline regression is based on a one-day window where the events in China and Germany and their GVC links are assessed together in a single regression over the entire period of January 2019 to April 2020. We then extend our baseline regression by enriching the definition of the GVC link variable in two steps: (1) distinguishing between upstream linkage and downstream linkage; (2) for each type of linkage, we further consider the degree of separation to a Chinese or German firm, ie, network distance as defined in Section 3.2.

Given the potentially large economic impacts of the announced lockdowns, we further consider the persistence of the stock market effect, by looking at the cumulative returns over longer windows of up to 10 days.[9] We change the definition of the time fixed effect and the lockdown dummies accordingly, considering now only the first of the two China announcements. We employ local projections in this context.

5.2 Event study results

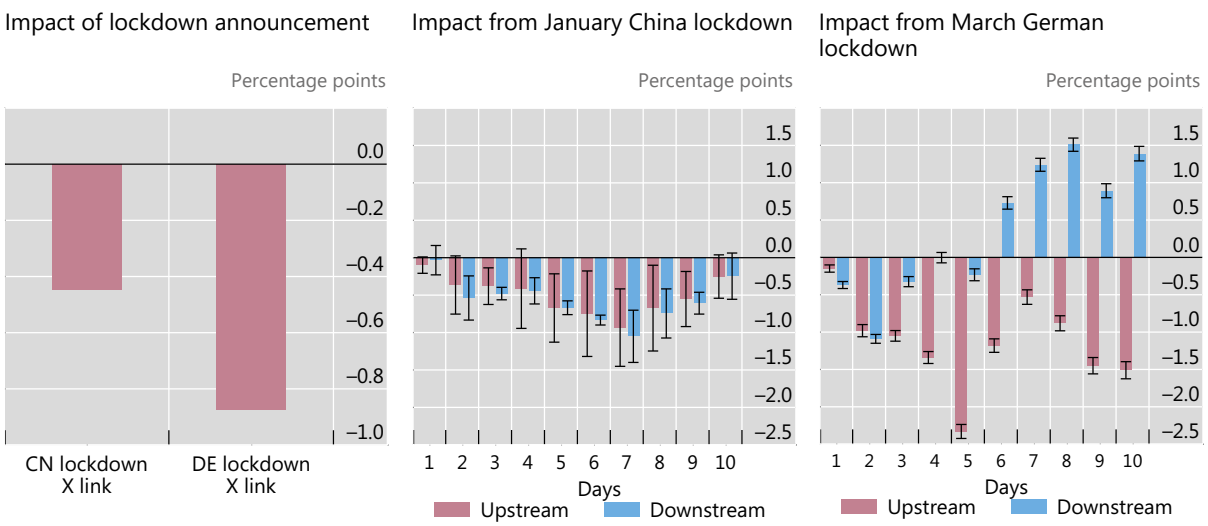
We find that stock market participants interpreted lockdown announcements as worse news for firms with GVC links to the affected country. On average, firms linked to China lost about 0.4 percentage points more than their counterparts that did not have such linkages in response to the lockdown announcements in China. For firms with German linkages, that penalty was about 0.8 percentage points (Graph 9, left-hand panel, also Column (1) in Table 1). The larger impact from

[8] This analysis uses firm and time fixed effects. As such, the GVC linkage and lockdown dummy variables (which do not vary by time and by firm, respectively) are absorbed by the fixed effects. We also accounted for significant Covid-related events during the event windows by the use of 0-1 dummy variables (see Technical Annex). The setting for dummy variables takes into account the time zone differences among stock exchanges.

[9] Local projections are used to trace the cumulative impact of lockdowns on equity price changes, starting from one day after the *first* lockdown announcements (ie, 22 Jan 2020 for China, 16 Mar 2020 for Germany). Moreover, we consider lockdowns in China and Germany in separate regressions to help us avoid the possibility of overlapping event windows. Please see Technical Annex for more information.

the German lockdown and on firms with German linkages likely reflected greater investor pessimism regarding the virus and the related growth outlook at the time of the German border closure in March (indeed, the largest market losses were first sustained in March 2020). At the time of the January lockdown in China, by contrast, the virus was still seen as largely localised and its impact limited.

Lockdown announcements affect GVC-linked firms more negatively — Graph 9



Source: Capital IQ, authors' calculations

Looking at the cumulative evolution of investor responses to these lockdown announcements, we can see that an initial, relatively muted response on the announcement day became more amplified over the subsequent days. In the course of a week, the equity prices of these firms declined by about 1.5 percentage points more than that of their peers with China or German linkages (Graph 9, center and right-hand panel; regression results in Table 2). In addition to being statistically significant, this difference is economically meaningful, as the median standard deviation of equity returns for firms in our sample is equal to 4.1% in the first quarter of 2020, compared to 2.5% for the entire year of 2019. As the increasingly global nature of the Covid pandemic became apparent shortly after each lockdown announcement, the differentiation between firms with GVC connections to China or Germany and other firms eventually dissipated.

Table 1
Firm equity returns and China / Germany supply chain linkages.

Dependent variable: Firm equity return (%)	(1)	(2)
Market return (%)	0.634***	0.634***
	(0.025)	(0.025)
Virus lockdown dummy * the following linkage dummies		
China linkage	-0.444***	
	(0.066)	
Upstream linkage		-0.381***
		(0.058)
Downstream linkage		-0.357***
		(0.073)
Germany linkage	-0.821***	
	(0.017)	
Upstream linkage		-0.504***
		(0.024)
Downstream linkage		-0.901***
		(0.022)
Observations	6,313,588	6,313,588
Number of firms	19,048	19,048
Adj. R-squared	0.093	0.093

Notes: *** p<0.01, ** p<0.05, * p<0.1; robust standard errors clustered at firm and time levels in parentheses; firm and time fixed effects included; constants and dummies for significant Covid events (see Technical Annex) are not shown. "Virus lockdown dummy" takes the value of 1 on 22 and 27 January for firms listed on North and South American stock exchanges, and on 23 and 27 January for other firms, for the China lockdown event, and the dummy takes the value of 1 on 16 March for the German lockdown event. Excludes firms headquartered in China or Germany.

Table 2

(a) Firm equity returns and China supply chain linkages – Local projections.

Dependent variable: Firm equity return (%)	(t + 1)	(t + 5)	(t + 10)
Market return (%)	0.624***	0.709***	0.707***
	(0.0165)	(0.0169)	(0.0141)
Virus lockdown dummy * the following linkage dummies			
China upstream linkage	-0.138***	-0.695***	-0.208
	(0.040)	(0.237)	(0.171)
China downstream linkage	-0.001	-0.651***	-0.208
	(0.075)	(0.066)	(0.146)
Observations	6,432,746	6,355,223	6,258,334
Adj. R-squared	0.041	0.098	0.144

(b) Firm equity returns and Germany supply chain linkages – Local projections.

Dependent variable: Firm equity return (%)	(t + 1)	(t + 5)	(t + 10)
Market return (%)	0.621***	0.745***	0.773***
	(0.016)	(0.016)	(0.013)
Virus lockdown dummy * the following linkage dummies			
Germany upstream linkage	-0.065***	-2.14***	-1.44***
	(0.024)	(0.042)	(0.058)
Germany downstream linkage	-0.470***	-0.219***	1.42***
	(0.024)	(0.040)	(0.050)
Observations	6,885,940	6,802,809	6,698,910
Adj. R-squared	0.042	0.099	0.144

Notes: *** p<0.01, ** p<0.05, * p<0.1; robust standard errors clustered at firm and time levels in parentheses; firm and time fixed effects included; constants and dummies for significant Covid events (see Technical Annex) are not shown. "Virus lockdown dummy" takes the value of 1 on 22 and 27 January for firms listed on North and South American stock exchanges, and on 23 and 27 January for other firms, for the China lockdown event, and the dummy takes the value of 1 on 16 March for the German lockdown event. Excludes firms headquartered in China or Germany. For brevity, only the 1-day-ahead, 5-day-ahead and 10-day-ahead results are shown in the tables above.

Comparing the sensitivities to lockdown announcements in China and Germany, the impact of the German lockdown was stronger. This is likely due to the fact that at the time of the January lockdowns in China, the virus was still seen as largely localised and its impact limited. By March, investors had become increasingly sensitized to the devastating impact of the pandemic and likely reacted more strongly to dramatic measures announced.

Moreover, we find that firms' position in the supply chain relative to the economies in lockdown – either upstream or downstream – and their industry sectors matter.[10] Such sectoral difference in response to lockdown announcements also underscores another nuance in GVC shifts seen during the pandemic – the nature of the shock and the industry sectors of affected firms' also matter in shock amplification. The impact of such relative positions was more notable for firms linked to Germany. For German-linked upstream firms, the peak impact was reached by day 5, when the cumulative decline totaled 2.1% more than their counterparts (Graph 2, right-hand panel, "5-day"). By contrast, the impact on downstream-linked firms turned positive roughly one week after the lockdown announcement. By comparison, the impact for both upstream and downstream firms linked to China was roughly the same (Graph 2, centre panel). The persistence of the negative impact on upstream firms linked to both China and Germany suggests broad-based expectations for prolonged supply disruptions, hampering equity price performance of firms in these sectors.

On the other hand, one possible explanation for the positive benefits accrued to firms relying on German inputs is the composition of downstream industries linked to Germany. As shown in Table 3(b), five days after the lockdown news, while downstream Germany-linked firms in cyclical sectors such as consumer discretionary, energy and industrials underperformed as expected, reflecting disruptions to their input sources, several downstream Germany-linked firms in sectors such as healthcare, information technology and communication services actually outperformed their peers in other GICS sectors, conceivably reflecting investor optimism on stronger demand for medical and work-from-home-related IT products using German inputs *despite* disruptions to Germany's supply chains. Separately, data from CIQ indicated that that firms in Germany played

[10] The breakdown of upstream and downstream exposures is not exclusive. Our results are robust to using the exclusive upstream and downstream measures.

a central role in the networks for machinery, chemical products and auto parts. German firms that supply intermediate goods could be less constrained by mobility restrictions and better able to respond to demand.

Next we consider whether *network distance* influenced how equity prices of China- and Germany-linked firms responded to lockdown announcements (Table 4). Results show that both direct and indirect supply chain linkages were important in explaining firm-specific variations in the face of lockdown news in China and Germany, with upstream firms directly and indirectly linked to Chinese companies experiencing 0.8 p.p. and 0.3 p.p., respectively, lower stock returns than other firms, and downstream firms suffering from 0.5 p.p. and 0.3 p.p., respectively, lower stock returns. The corresponding figures for Germany-linked firms are 1.0 p.p., 0.4 p.p., 1.3 p.p. and 0.8 p.p. respectively. Moreover, our results are broadly consistent with the findings of GVC literature that propagation effects tend to weaken as the shock travels along the supply chain, with the negative equity price responses of China- and Germany-linked firms generally diminishes in magnitude with the distance to Chinese or German firms in the production network (Column (2), Table 4).

Table 3

(a) Firm equity returns and China supply chain linkages – industry interactions, local projections.

Dependent variable: Firm equity return (%)	(t + 1)		(t + 5)	
Market return (%)	0.624***		0.709***	
	(0.016)		(0.0169)	
Virus lockdown dummy * the following GICS sub-sectors				
Communication services	-0.542		-0.794	
	(0.548)		(0.634)	
Consumer discretionary	-0.242		0.124	
	(0.220)		(0.191)	
Consumer staples	-0.158		0.0650	
	(0.423)		(0.272)	
Energy	-1.43		-2.39***	
	(0.995)		(0.740)	
Healthcare	-0.205		0.0807	
	(0.454)		(0.843)	
Industrials	(baseline)			
Information technology	-0.350**		-0.585***	
	(0.164)		(0.109)	
Materials	-0.403		-0.133	
	(0.487)		(0.194)	
Virus lockdown dummy * the following linkage dummies (in columns) * the following GICS sectors (in rows):				
	Upstream	**Downstream**	**Upstream**	**Downstream**
Communication services	0.680**	-1.28***	0.611	-0.397**
	(0.342)	(0.173)	(0.739)	(0.187)
Consumer discretionary	0.0451	-0.730***	-0.118	-1.60***
	(0.176)	(0.252)	(0.259)	(0.315)
Consumer staples	-0.237***	0.0628	0.0105	-0.286***
	(0.0490)	(0.325)	(0.285)	(0.0429)
Energy	-0.150	0.453	-0.333	-0.241
	(0.191)	(0.522)	(0.286)	(0.381)
Healthcare	0.423***	0.0882	0.979***	-1.15***
	(0.0756)	(0.211)	(0.242)	(0.171)
Industrials	-0.309	0.009	-1.43	-0.119
	(0.391)	(0.167)	(1.08)	(0.119)
Information technology	-0.160***	0.515***	-0.928***	-0.532
	(0.0358)	(0.136)	(0.337)	(0.436)
Materials	0.017	0.138***	-0.814***	-0.224*
	(0.163)	(0.0365)	(0.133)	(0.132)
Observations	6,432,746		6,355,223	
Number of firms	19,371		19,371	
Adj. R-squared	0.041		0.098	

(b) Firm equity returns and Germany supply chain linkages – industry interactions, local projections.

Dependent variable: Firm equity return (%)	(t + 1)		(t + 5)	
Market return (%)	0.621***		0.746***	
	(0.016)		(0.016)	
Virus lockdown dummy * the following GICS sub-sectors				
Communication services	0.492***		1.69***	
	(0.040)		(0.058)	
Consumer discretionary	-1.66***		-2.30***	
	(0.029)		(0.054)	
Consumer staples	2.80***		6.08***	
	(0.035)		(0.069)	
Energy	-2.56***		-2.14***	
	(0.085)		(0.151)	
Healthcare	0.134***		3.48***	
	(0.046)		(0.076)	
Industrials	(baseline)			
Information technology	-0.788***		-0.934***	
	(0.034)		(0.051)	
Materials	2.54***		3.57***	
	(-0.036)		(0.079)	
Virus lockdown dummy * the following linkage dummies (in columns) * the following GICS sectors (in rows):				
	Upstream	**Downstream**	**Upstream**	**Downstream**
Communication services	-2.95***	0.674***	-8.04***	5.68***
	(0.124)	(0.144)	(0.219)	(0.221)
Consumer discretionary	1.92***	-0.585***	-1.33***	-0.967***
	(0.0431)	(0.0448)	(0.0745)	(0.0730)
Consumer staples	-1.51***	-0.307***	-3.60***	-2.28***
	(0.0625)	(0.0499)	(0.101)	(0.0749)
Energy	-0.293***	-1.87***	0.207*	-0.407***
	(0.0900)	(0.0919)	(0.121)	(0.129)
Healthcare	1.45***	-0.535***	0.408***	0.588***
	(0.0658)	(0.0721)	(0.0967)	(0.102)
Industrials	-0.0986**	-0.0105	-2.46***	-0.867***
	(0.0394)	(0.0478)	(0.0643)	(0.0763)
Information technology	0.174***	-0.628***	-1.42***	0.152**
	(0.0422)	(0.0459)	(0.0709)	(0.0730)
Materials	-0.333***	-0.829***	-1.45***	-2.15***
	(0.0383)	(0.0421)	(0.0652)	(0.0725)
Observations	6,885,940		6,802,809	
Number of firms	20,773		20,773	
Adj. R-squared	0.042		0.102	

Notes (for both Table (a) and (b)): *** p<0.01, ** p<0.05, * p<0.1; robust standard errors clustered at firm and time levels in parentheses; firm and time fixed effects included; constants and dummies for significant Covid events (see Technical Annex) are not shown. "Virus lockdown dummy" takes the value of 1 on 22 and 27 January for firms listed on North and South American stock exchanges, and on 23 and 27 January for other firms, for the China lockdown event, and the dummy takes the value of 1 on 16 March for the German lockdown event. Excludes firms headquartered in China or Germany. For brevity, only the 1-day-ahead and 5-day-ahead results are shown in the tables above.

Table 4.
Firm equity returns and China / Germany supply chain linkages – network distance.

Dependent variable: Firm equity return (%)	(1)	(2)
Market return (%)	0.634***	0.634***
	(0.025)	(0.025)
Virus lockdown dummy * the following linkage dummies		
China		
Direct upstream linkage	-0.813***	-0.815***
	(0.129)	(0.132)
Indirect upstream linkage	-0.270***	
	(0.047)	
Distance 2		-0.435***
		(0.107)
Distance 3		-0.194***
		(0.058)
Direct downstream linkage	-0.508***	-0.493***
	(0.137)	(0.138)
Indirect downstream linkage	-0.283***	
	(0.057)	
Distance 2		-0.471***
		(0.073)
Distance 3		-0.280*
		(0.149)
Germany		
Direct upstream linkage	-0.983***	-0.957***
	(0.029)	(0.030)
Indirect upstream linkage	-0.354***	
	(0.027)	
Distance 2		-0.588***
		(0.032)
Distance 3		-0.327***
		(0.041)
Direct downstream linkage	-1.323***	-1.345***
	(0.038)	(0.041)
Indirect downstream linkage	-0.825***	
	(0.022)	
Distance 2		-1.200***
		(0.030)
Distance 3		-1.016***
		(0.036)
Observations	6,313,588	6,313,588
Number of firms	19,048	19,048
Adj. R-squared	0.093	0.093

Notes: *** p<0.01, ** p<0.05, * p<0.1; robust standard errors clustered at firm and time levels in parentheses; firm and time fixed effects included; constants and dummies for significant Covid events (see Technical Annex) are not shown. "Virus lockdown dummy" takes the value of 1 on 22 and 27 January for firms listed on North and South American stock exchanges, and on 23 and 27 January for other firms, for the China lockdown event, and the dummy takes the value of 1 on 16 March for the German lockdown event. Excludes firms headquartered in China or Germany. Distance "X" represents the degree of separation to one or more Chinese / German firms.

5.3 Robustness test

As robustness checks, we construct an alternative measure of firms' equity performance as the dependent variable and used different event windows. For firms' equity performance, we used a measure of "abnormal returns" – ie, deviation of firms' equity share performance relative to market benchmark returns, as an alternative means to take into consideration the impact of overall market performance on individual share prices. For event windows, we considered two variations. Firstly, we continue to consider daily equity returns but we narrowed the estimation period to 15 trading days before and after the lockdown announcements for daily returns, instead of using the full sample between 2019 and 2020. A second variation is to assess the impact of lockdowns and linkages on weekly (Wednesday-to-Wednesday) returns in order to smooth out noises in daily equity return data, while changing the associated event window one week before and after the week of lockdown announcement. In both variations, the shorter event windows are non-overlapping, thus allowing us to assess the impact of China and Germany lockdowns separately. The results of these checks offer qualitatively similar results as the baseline regression and are included in the Technical Annex.

VI. Conclusions

GVC networks are complex. Granular customer-supplier data can offer greater insights into the firm-level interlinkages that have the potential to drive aggregate GVC trends. Using data on customer and supplier connections from a global sample of firms as well as incoming shipments to the US following the outbreak of the pandemic, we find that GVC networks have been slow to recover to pre-pandemic levels. In addition, our empirical analysis shows that GVC links can amplify the effect of supply shocks on company share prices. Such negative impacts tend to persist, affecting in particular firms that are upstream to the lockdown economies, underscoring investor concerns that the Covid pandemic could damage GVC supply networks.

REFERENCES

Ando, M., and K. Hayakawa (2022): "Does the Import Diversity of Inputs Mitigate the Negative Impact of Covid19 on Global Value Chains?" The Journal of International Trade & Economic Development 31(2): 299-320.

Barrot, J. N. and J. Sauvgnat (2016): "Input Specificity and the Propagation of Idiosyncratic Shocks in Production Networks," The Quarterly Journal of Economics 131(3): 1543-1592.

Brenton, P, M J Ferrantino, and M Maliszewska (2022): "Reshaping Global Value Chains in Light of COVID-19: Implications for Trade and Poverty Reduction in Developing Countries", Washington, DC: World Bank.

Flaaen, A., F. Haberkorn, L. Lewis, A. Monken, J. Pierce, R. Rhodes, and M. Yi (2021): "Bill of Lading Data in International Trade Research with an Application to the COVID-19 Pandemic," Finance and Economics Discussion Series 2021-066. Washington: Board of Governors of the Federal Reserve System.

Huang, Y., C. Lin, S. Liu, and H Tang (2019): "Trade Networks and Firm Value: Evidence from the U.S.-China Trade War", CEPR Discussion Papers 14173, CEPR. Discussion Papers.

Mohommad, A, Lan. T, and D. Malacrino (2022): "Global Trade and Value Chains in the Pandemic", IMF World Economic Outlook April 2022, International Monetary Fund, Washington, DC.

Kashiwagi, Y, Y. Todo, and P. Matous (2021): "Propagation of Economic Shocks through Global Supply Chains: Evidence from Hurricane Sandy", Review of International Economics 29(5): 1186-1220.

Zhang, S. Y. (2021): "Using equity market reactions and network analysis to infer global supply chain interdependences in the context of Covid-19", Journal of Economic and Business, Volume 115.

TECHNICAL ANNEX

Tables 1 – 4: In the regression models, we include a 0-1 dummy variable for each of the following Covid-related significant event: (1) 20 January 2020, when China announced that the Covid virus was transmittable among humans; (2) 11 March 2020, when the World Health Organisation announced that Covid was a global pandemic and (3) 17 March 2020, when the US Federal Reserve announced large-scale interventions to stabilise financial markets. All these variables are statistically insignificant, their effects conceivably absorbed by the time fixed effect.

Table A1
Firm equity abnormal return and China / Germany supply chain linkages.

Dependent variable: Firm equity abnormal return (%)	(1)	(2)
Virus lockdown dummy * the following linkage dummies		
China linkage	-0.297***	
Upstream linkage		-0.256***
		(0.047)
Downstream linkage		-0.243***
		(0.065)
Germany linkage	-0.987***	
	(0.043)	
Upstream linkage		-0.851***
		(0.103)
Downstream linkage		-0.734***
		(0.100)
Observations	6,313,588	6,313,588
Adj. R-squared	0.009	0.009

Table A2
Firm daily equity return and China / Germany supply chain linkages – short event window.

Dependent variable: Firm equity return (%)	(China)	(Germany)
Market return (%)	0.803***	0.609***
	(0.022)	(0.0409)
Virus lockdown dummy * the following linkage dummies		
Upstream linkage	-0.313***	-0.646***
	(0.0674)	(0.100)
Downstream linkage	-0.241***	-0.751***
	(0.0729)	(0.134)
Observations	596,411	638,316
Adj. R-squared	0.074	0.208

Table A3
Firm weekly equity return and China / Germany supply chain linkages.

Dependent variable: Firm equity return (%)	(China)	(Germany)
Market return (%)	0.771***	0.943***
	(0.0593)	(0.0411)
Virus lockdown dummy * the following linkage dummies		
Upstream linkage	-0.140	-0.567
	(0.166)	(0.832)
Downstream linkage	0.0564	-2.033
	(0.245)	(1.442)
Observations	77,117	62,021
Adj. R-squared	0.023	0.223