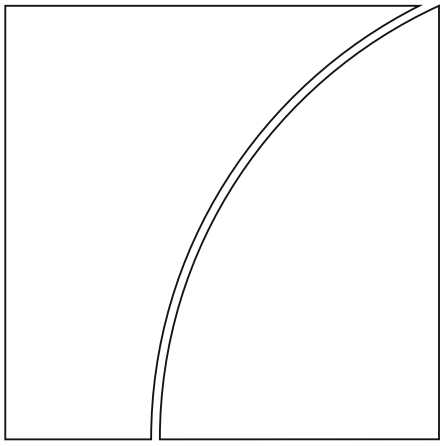

BIS Working Papers

No 1123

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by Sally Chen, Eric Tsang and Leanne (Si Ying) Zhang

Monetary and Economic Department

September 2023

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This publication is available on the BIS website (www.bis.org).

ISSN 1020-0959 (print)
ISSN 1682-7678 (online)

Global supply chain interdependence and shock amplification – evidence from Covid lockdowns[1]

Sally Chen, Eric Tsang and Leanne (Si Ying) Zhang[2]

Abstract

Supply disruptions from the Covid-19 pandemic raise questions about the benefits and costs of global value chain (GVC) participation and the possibility that supply chain networks may have shifted during this period. Using firm-level data on supply chain linkages, we document the evolution of GVCs during the pandemic by comparing GVC network diagrams and firms' shipment data over the course of the pandemic. Furthermore, we study how such linkages affected equity investors' reaction to pandemic-related disruptions. Our findings suggest that GVCs contracted following the pandemic outbreak and were slow to recover in some sectors. We also find that firms with GVC links to countries undergoing Covid-related lockdowns suffered larger stock price losses than those without such links. In addition, sectoral responses to lockdown announcements varied, underscoring the need to consider sectoral differences in the study of GVC shifts.

JEL classification: F10, G12, G14, O24.

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

[1] This paper is based on the work conducted by the authors for the March 2023 issue of BIS Quarter Review. 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 Luca Iavarone, Jimmy Shek and Ronald Yip for excellent research assistance.

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Contents

1. Introduction

The Covid-19 pandemic and ensuing supply disruptions have reignited a longstanding debate over the benefits of global value chains (GVCs)[3] – the organisation of production, trade and investment across different locales to optimise production. This debate is informed by a rich academic literature that has documented the trade-offs in GVC participation. In particular, GVC participation can propagate and amplify risks (eg Barrot and Sauvgnat (2016), Kashiwagi et al (2021)), but also reduce production costs and improve economies' resilience (eg Ando and Hayakawa (2022), Mohommad et al (2022)). More recently, work related to the impact of the Covid pandemic delved into spillovers from supply chain disruptions, including the possibility that disruptions from lockdowns could have propagated downstream through supplier linkages (Cerdeiro and Komaromi (2020)).

While the literature has largely focused on aggregate trade data, there has been growing recognition of the importance of granular input-output linkages in shedding light on GVC participation and the propagation of shocks. Aggregate trade generally rebounded across much of the globe during the second half of 2020; still, there were striking divergences in performance across industry sectors during the Covid pandemic. The unique nature of the Covid crisis boosted global demand for medical and work-from-home supplies, lifting the share price of companies in the healthcare, information technology (IT) and telecommunications equipment industries. At the same time, supply chain disruptions severely hampered sectors such as automobiles that are heavily dependent on inputs from overseas suppliers. Furthermore, the deep economic contraction constrained spending, reducing demand for consumer discretionary items early in the pandemic. These diverging impact on different sectors and the heterogeneity in sectoral responses highlight the patchwork nature of trade and the possibility that sectoral differences could have shaped the response of GVC networks to shocks such as the pandemic.

This paper seeks to tap into insights from firm-level data on supply chain linkages to shed light on how GVCs might have evolved during the Covid years. Moreover, leveraging these granular data, we consider the role of GVC participation in shock amplification, as proxied by firms' stock market performance. 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 (eg, Boehm et al (2014), Carvalho et al (2016), Inoue and Todo (2017)) and the corporate finance literature that studies the effects of supply chain linkages on asset pricing (eg, Ramirez (2017), Grant and Yung (2019), Huang et al (2019), Zhang (2021)).

To gauge shifts in GVCs in response to the Covid pandemic, we first create network visualisations of global firm-level supply-chain interconnections before and after the pandemic, building on the analysis of Zhang (2021). We then construct measures of supplier shipments and the associated quantities to shed light on GVC participants' flexibility in responding to Covid-related disruptions and to further assess differences in sectoral responses to the pandemic. Finally, we examine whether GVC participation can propagate and amplify the effect of shocks through the lens of stock market investors; we use an equity pricing model to assess whether firms linked to two major manufacturing economies in Covid-related lockdowns – China and Germany – saw a larger negative equity price reaction to news of such lockdowns.

The network maps of global GVCs reveal complex, extensive structures with sizeable heterogeneity across sectors. Firms in Asia, the United States and Europe all exert significant influence, with their interconnectedness likely acting as important propagators of Covid-related shocks. Comparing network structures in early 2020 and late 2021 shows that GVCs had been slow to recover to their pre-pandemic levels with declines in the number of linkages still evident two years following the onset of the pandemic. And, a more geographically dispersed and decentralised network structure likely subjected sectors to greater disruptions, as seen in the particularly notable contraction of inter-firm linkages in the IT industry.

Furthermore, our empirical analysis of stock-market returns suggests that firms' supply chain linkages amplified the spillover effects from pandemic-related production disruptions. The share prices of firms

[3] We use supply chains and value chains interchangeably in this paper.

linked to two major manufacturing countries that announced lockdowns early in the pandemic (China and Germany) exhibited greater declines than to those without such linkages. Over the course of a week following lockdown announcements, the cumulative returns on these firms' equities declined, on average, by an additional 0.9 percentage points for China-linked firms and 1.7 percentage points for Germany-linked firms relative to the returns on other firms. Such underperformance of firms with ties to China and Germany after their lockdown announcements highlights the economic significance of global production network linkages in propagating the Covid shock. Our findings also show that the extent of underperformance depends on the degree of separation in the supply chain vis-à-vis the lockdown-affected firms (network distance) as well as the sectors to which the firms belong. 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 position on equity returns, however, is more nuanced and sector-specific: China- and Germany-linked firms in cyclical sectors (eg, consumer discretionary, industrial goods), and those with more dispersed and global production networks (eg, IT) exhibited greater equity price declines than those without such linkages to the affected economies or in other sectors. And speaking to the public health nature of the Covid-19 shock, firms in the healthcare sector outperformed their counterparts in other industry sectors.

The rest of this article is organised as follows. Section 2 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 third section provides stylised facts on GVC developments over a two-year period during Covid. Section 4 assesses equity investors' sensitivities to firms' GVC linkages. The last section concludes.

2. Data and sample construction

2.1 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 in 2020 and 2021, based on companies' SEC filings; and ii) shipping manifests from government public records compiled by Datamyne for all ocean freight entering the United States[4]. The CIQ dataset provides balance sheet and interfirm business-linkage information for a global sample of firms. Each CIQ supply-chain linkage is determined by a firm's declared customer or supplier relationship over a two-year period. In our sample, these two years include 2020 and 2021. 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) as well as the volume of shipments, allowing for detailed and quantitative 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 tens of thousands of publicly listed and private companies covering eight of the eleven Global Industry Classification Standard (GICS) sectors in over 150 economies[5] and five regions (Graph 1). Following Zhang (2021), we only look at firms in the "Manufacturing", "Mining" and "Agriculture, Forestry and Fishing" SIC industry classifications for network

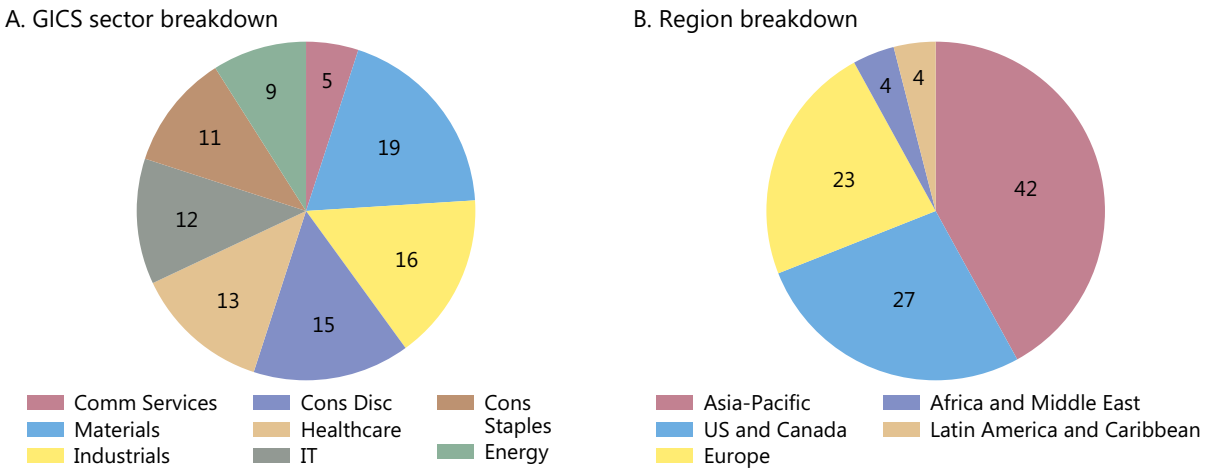
[4] We focus on the US given the quality and high coverage of data.

[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 (eg, 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.

visualisations of supply-chain-linkages (excluding Services and Wholesale and Retail trade, for example)[6]. In the second half of our paper where we focus on the empirical analysis of risk amplification, we take a subset of these firms that are publicly listed and add back firms in the other sectors to provide an empirical benchmark for our estimates.

Breakdown of firms by GICS sector and region

In per cent | Graph 1



Cons Staples = Consumer Staples; Cons Disc = Consumer Discretionary; Comm Services = Communication Services.

Sources: S&P Capital IQ; authors' calculations.

It should be noted that a 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 snapshot of existing linkages at a time and does not capture the *intensity* of such linkages, as it is simply a binary variable representing the existence of a relationship.

To mitigate potential concerns that the CIQ database might not capture significant, yet undisclosed, GVC linkages due to the self-reported nature of the interfirm linkages in CIQ, and to shed light on the intensity of GVC relationships, we make use of US firms' BoL data, compiled by Datamyne, as a complementary data set of interfirm linkages. This dataset consists of over 400,000 shipment-level details associated with unique consignees headquartered in the US for 2020. By comparing the two datasets, we can 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. It is likely that because not all firms receive shipments every month, some CIQ linkages will be missing from the BoL data. Meanwhile, roughly 85% of firms identified in bills of lading for US imports in 2020 were not in the CIQ dataset[7]. These firms were mostly private entities not subject to SEC reporting requirements; they are therefore likely not captured by CIQ, which covers listed firms primarily.

[6] While the default industry classification used by CIQ is GICS, it provides a mapping system to SIC primary industry categorisation 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.

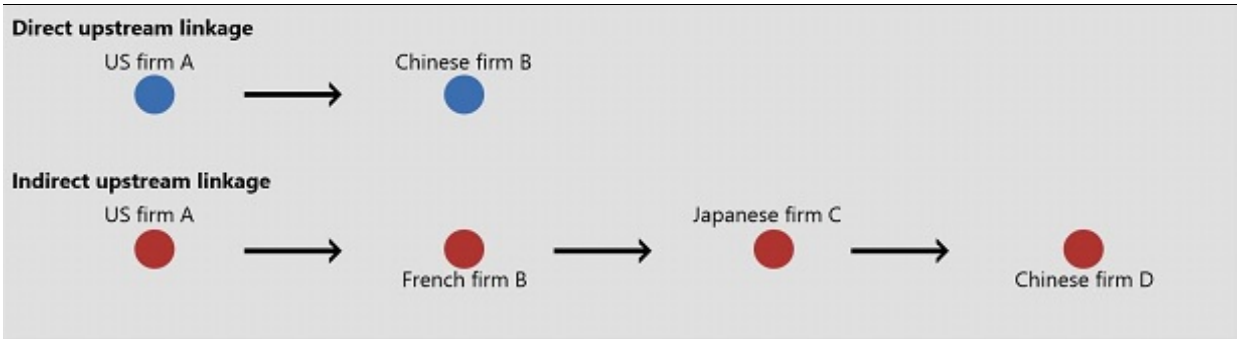
[7] In 2020, there were roughly 4,550 US firms having records of imports in the BoL dataset, of which about 700 had company names that were sufficiently similar to be matched with the universe of publicly listed firms in the CIQ database. This seemingly large gap in CIQ coverage does not affect our subsequent regression analysis in Section 4, as we rely on stock prices as a proxy of the impact of Covid lockdown news.

2.2 Mapping supply chain exposures to China and Germany

To assess the effect of GVCs in propagating Covid disruptions, we construct measures of global firms' supply chain exposure to two major manufacturing countries that announced lockdowns early in the pandemic – China and Germany. We start with the full sample of CIQ supply chain data (excluding aforementioned industries) and remove firms headquartered in China and Germany. We construct dummy variables representing network distances of the remaining firms to Chinese or German companies using those firms' declared business relationships, differentiating between upstream (ie, supplier) and downstream (ie, 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 and Germany through multiple layers of bilateral relationships, following Zhang (2021) (see Graph 2 below for an illustrative example). It is important to note that we try to measure neither a firm's position in nor the length of the overall value chain of a product or sector. Rather, we measure a firm's position, and the length of the supply chain, relative to a firm in China or Germany in the same production network.

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

Graph 2



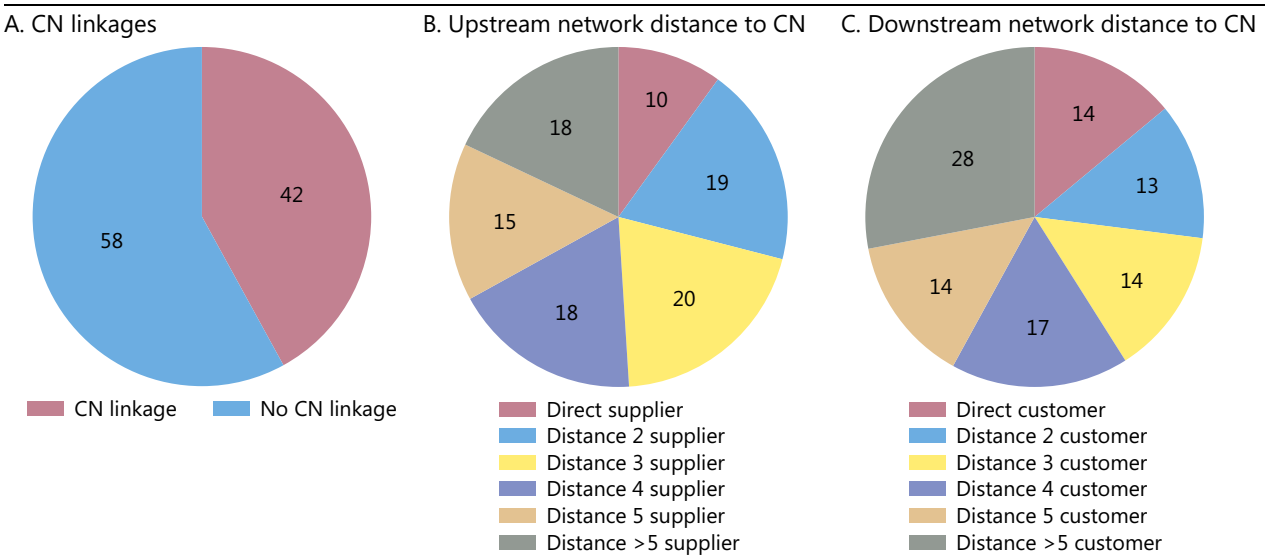
Sources: authors' calculations.

Echoing findings from Zhang (2021) who considers links to China exclusively, our mapping exercise shows 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 (Graphs 3A and 4A), underscoring the interconnectedness of GVCs as well as China and Germany's significance in global manufacturing. Moreover, a majority of China- and German-linked firms are connected to these countries through indirect linkages, often with multiple degrees of separation (Graphs 3B and 3C, and Graphs 4B and 4C). Such linkages highlight the complexity of GVCs and underscore the importance of looking beyond the immediate inter-firm business ties when assessing production network exposures.

Supply chain linkages with China ("CN"), among non-CN firms

In per cent

Graph 3

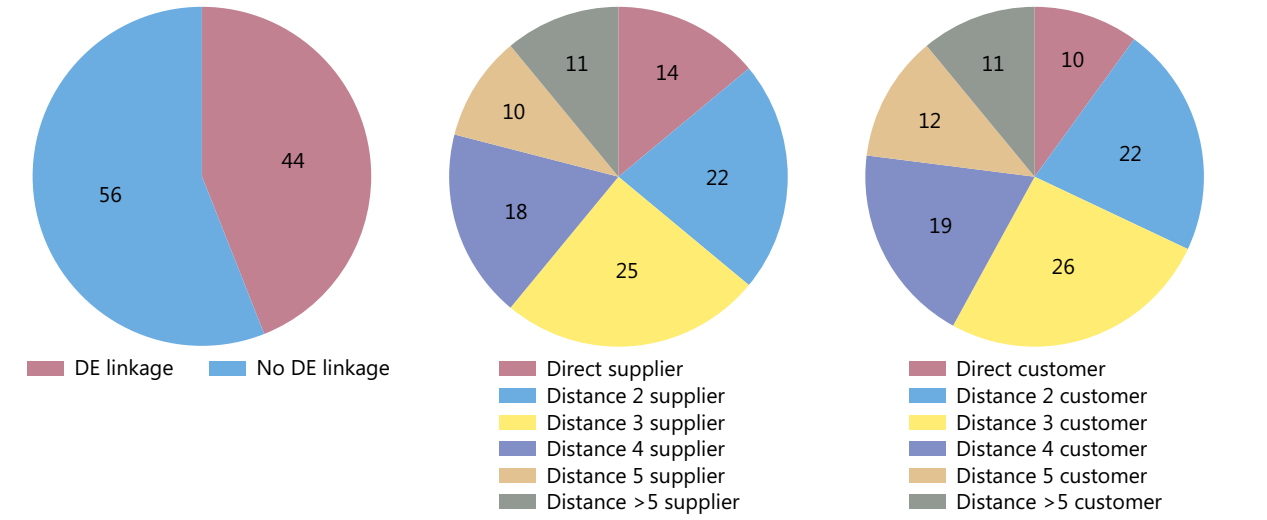


Sources: CIQ; authors' calculations.

Supply chain linkages with Germany ("DE"), among non-DE firms

In per cent

Graph 4



Sources: CIQ; authors' calculations.

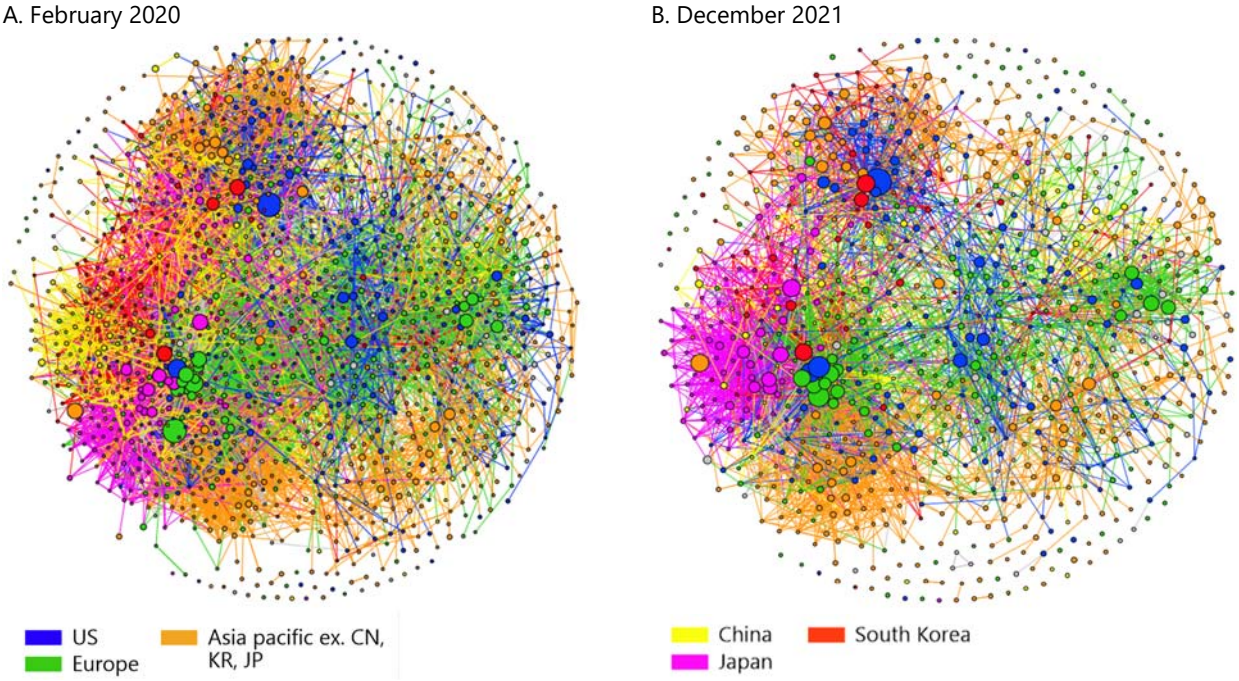
3. GVC trends during the Covid pandemic – stylised facts

To shed light on granular GVC interlinkages and how GVCs might have evolved during the pandemic, we create detailed graphical depictions of firm interlinkages based on CIQ data to get a sense for global trade's extensive margins. And, to get a glimpse of possible changes in trade's intensive margins, we also study changes in the number of suppliers and shipment volumes based on BoL data from Datamyne.

First, using the CIQ data sample and building on the work in Zhang (2021), we create two cross-sectional snapshots of global firms' supply chain linkages: one snapshot from February 2020 as a proxy for the stance of global GVCs pre-pandemic; and the other from December 2021, as a proxy for the post-pandemic stance of global 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 the number of connections a node has as well as the centrality of the nodes to which it is connected. While all nodes start off equal, those 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 – these are the connecting lines between two nodes, with edge colour being the same as that of the supplier node, thus identifying the source of the connection. The network maps are structured so that nodes sharing more connections are placed closer together. Denser patches featuring a greater number of edges and/or nodes suggest more integrated networks; the reverse – ie, thinner patches with a smaller number of edges and/or nodes – suggests less integrated networks.

Using data on global firm customer-supplier interlinkages in February 2020 and December 2021, we provide a birds-eye view of the pre- and post-pandemic global supply chain networks which highlights the complexity and interconnectedness of global manufacturing production networks (Graph 5). Firms in Asia, Europe and the United States all exert significant influence. Moreover, these complex and densely connected networks likely acted as an important transmission mechanism of the Covid-19 shock from economies affected early in the pandemic.

Global supply chain networks — Graph 5



Data are from CIQ, where firms' customer and supplier relationships are sourced from company filings, news aggregators, press releases etc.

Sources: CIQ and authors' calculations.

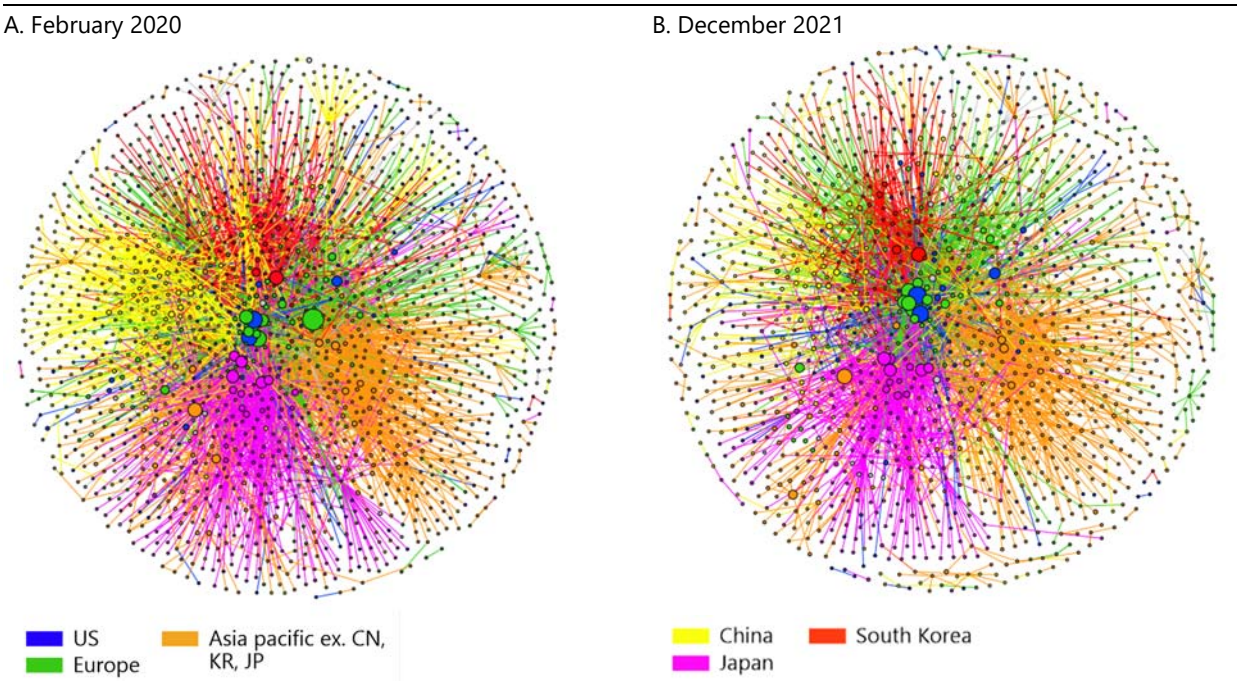
Comparing the network map from late 2021 (Graph 5B) to that from early 2020 (Graph 5A) suggests that GVC networks had yet to fully recover two years into the pandemic. Customer-supplier networks appeared less interconnected at the end of 2021 compared to in early 2020, as shown by the less dense patches and the presence of more empty space in 2021.

A closer look at the inter-firm connections on a sectoral basis reveals additional insights. Notably, two major manufacturing industries – automobiles (auto) and IT – demonstrate highly globalised interconnections with differing network structures, echoing findings from Zhang (2021).

The auto industry is characterised by regional and country "subnetworks" nested within the global auto supply chain. Specifically, auto firms from the same country and region tend to cluster together in bunches, implying extensive intra-country and intra-regional linkages, as noted by Zhang (2021). This is in line with literature, which documents evidence of specialised spatial distribution of production in Asia and Europe for auto productions (Jetin (2018) and Bungche (2018)) and notes that limited room for homogenising global demand contributed to a coalescing of auto production and development on a regional level for many auto producers (Frigant and Zumpe (2017)). Such regional networks suggest that automakers may be more resilient to global supply chain disruptions compared to other globalised industries, as they can leverage the well-established regional supply chain networks (Zhang (2021)).

Indeed, comparing the GVC network structures of the auto industry in early 2020 and late 2021, we see that while the auto industry appears slightly less dense at the end of 2021 compared to early 2020 (Chart 6), the "nested" structure of auto GVCs remains intact, as seen in the bunching of central nodes and interlinkages of common colours in February 2020 and December 2021.

Global supply chain networks – Automobiles & Components industry Graph 6



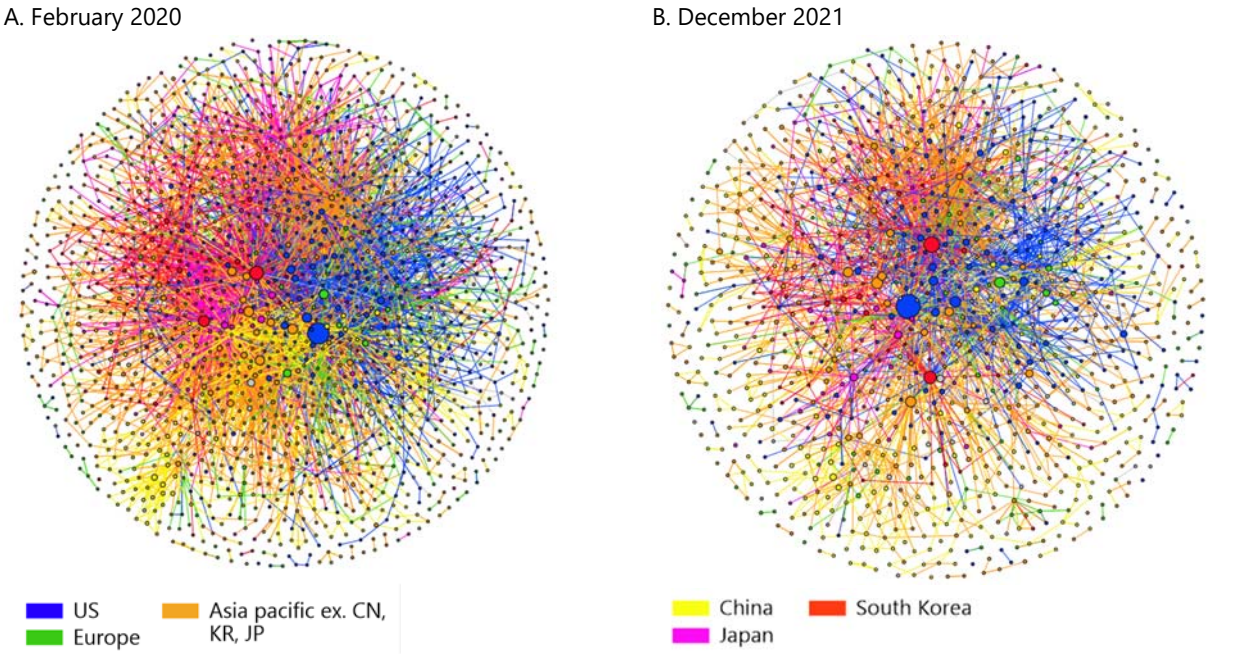
Includes only firms/nodes in the auto industry and their interlinkages.

Sources: CIQ and authors' calculations.

In the IT industry, however, there is no discernible country or regional subnetworks. Instead, the IT industry displays a highly globally dispersed and decentralised network with a mix of intertwined firms in Asia and the United States (ie, specifically, Chinese, Korean, Japanese, Asian excluding Chinese, Korean and Japanese, and US firms (as noted by Zhang (2021)). These dispersed cross-country and cross-regional interconnections suggest that foreign disruptions could upend dependencies throughout the supply chain, making the IT GVC network more vulnerable to global shocks. Looking at the network, we find that

the IT industry shows a significantly less dense structure in December 2021 than in early 2020 (Graph 7), which is consistent with the IT industry potentially being less resilient to global supply chain disruptions.

Global supply chain networks – Information Technology industry Graph 7



Includes only firms/nodes in the IT industry and their interlinkages.

Sources: CIQ and authors' calculations.

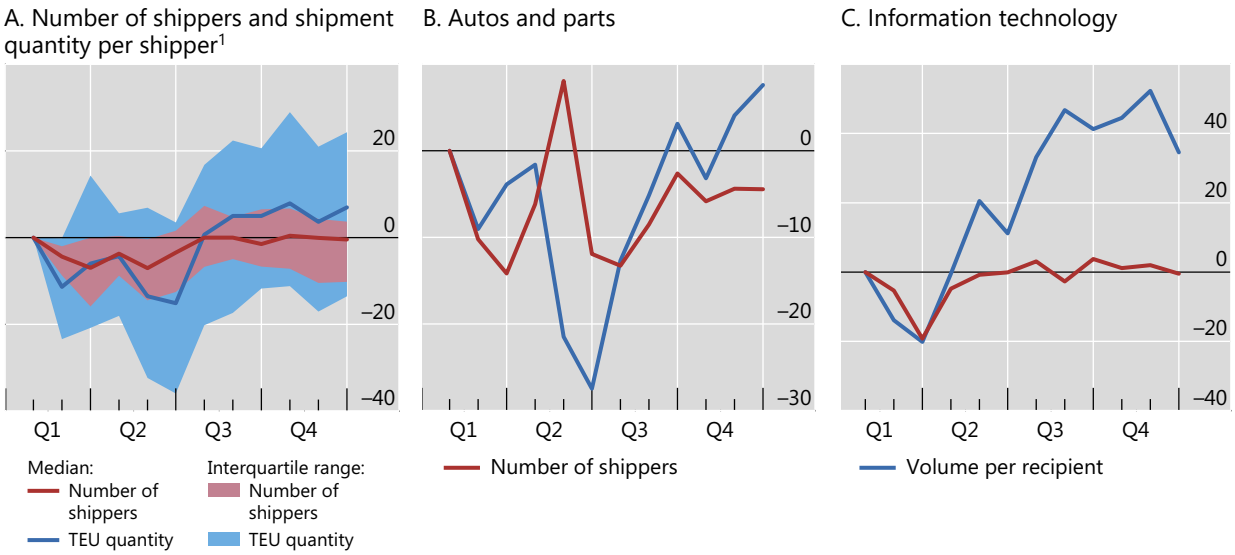
While the CIQ data provides a helpful bird's-eye view of global GVC networks, they can only speak to the existence of inter-firm supply-chain relationships and cannot shed light on the intensity of these linkages. To better understand the characteristics of interfirm connections, we consider insights on trade intensity from US bills of lading using data compiled by Datamyne.

Before we delve into the bills of lading data, it is important to take stock of BoL's limitations. Bills of lading are maritime shipments into to the United States. These data are available at the shipment level, offering details on the company names for both the shipper (exporter or freight forwarder) and consignee (the importer or firm taking final delivery of the shipment). However, shipment data are only available on those that ship by vessels; air freights or land transports are not captured by BoL. And, under US laws, companies have the right to redact their names from these records, hampering efforts to comprehensively map global shipment transactions. Meanwhile, shipment values are not captured, although quantity measures and descriptions are included. That said, for our analysis, the high frequency nature of the BoL data and the information on shipment volume could shed light on shippers' intensive margin in responses to the Covid pandemic – insights that could complement those from the CIQ data on extensive margins.

BoL data show that the number of shippers per importer (ie, a proxy for firms' supplier diversification) and the corresponding shipment quantity (ie, trade intensity, proxied by twenty-foot equivalent units or TEU) generally fell in the first half of 2020 relative to pre-pandemic levels, echoing insights from network map snapshots. 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, both of which are not evident in the network maps (Graph 8).

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

Index, January 2020 = 0 Graph 8



[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 in the US had recovered to or exceeded their January levels, but only 38% of sectors saw similar recovery in the number of shippers (Graph 8A). This broader decline in the number of shippers is in line with the findings from the network maps that suggest a sizable reduction in the number of interfirm linkages (recall Graph 5). For example, in sectors that suffered some of the largest declines in the number of suppliers at the onset of the pandemic in early 2020 – eg, consumer discretionary items – the number of shippers remained below their pre-pandemic levels by year end (Annex Graph 1). At the same time, surviving firms – despite fewer in number – helped cushion the impact of production disruptions through higher outputs, as proxied by an increase in shipment quantity, measured in shipment volume or TEUs per shipper. For example, surviving firms in the consumer discretionary sector saw a large rebound in shipment quantity that surpassed their January levels, thus helped offset losses from the number of available suppliers. Other sectors such as energy extraction were able to rebound quickly despite the initial decline in both shipment suppliers and quantity (Graph A1 in Annex).

There are also striking differences across sectors in their responses to the pandemic, seen, for example, in the number of shippers and twenty-foot-equivalent units (TEUs) per shipper for the auto and IT sectors. In the auto sector, the number of shippers was 4% lower at the end of 2020, relative to the beginning of year (Graph 8B). The average TEU per shipper, meanwhile, rebounded by the second half of 2020 to end the year 7% higher, suggesting some flexibility in companies' productive capacity. In the IT sector, both the number of shippers to the United States and the average shipment volume rebounded swiftly by the end of Q1 2020, likely motivated by greater demand from work-from-home arrangements during the pandemic (Graph 8C). Notably, while the number of shippers ended the year largely unchanged, the shipment volume surged to 34% above the level seen at the beginning of the year.

The variations in the changes in both the intensive margin of trade – ie, TEU per shipper – and extensive margins – ie, the number of shippers associated with each importer – across the auto and IT sectors add greater nuance to the intuitions gleamed from the network maps. Notably, while network structures suggest that the IT sector could be more vulnerable to global supply disruptions, the shipment data to the United States highlights sizable industry resilience from surviving firms. It is possible that the nature of the crisis boosted demand for goods from these sectors. It is also noteworthy that shipment data to the US as indicated by BoL might not fully represent industry responses on a global scale.

Therefore, the network maps were drawn from a global sample from CIQ. On net, these sectoral variations and the divergence between shipper number and shipment quantity highlight the importance of looking at both the extensive and intensive margins when assessing broad trends in GVC networks.

4. Shock amplification through supply chains

4.1 Methodology

To assess whether GVC participation played a role in amplifying the effect of pandemic-related disruptions, we study GVC-linked firms' equity price response to news of Covid lockdowns in China and Germany. These two economies are significant players in the global GVC network[8]; they were also relatively early to announce large-scale lockdowns in the first quarter of 2020, allowing for a cleaner identification of the GVC propagation effect of the Covid shock that later became a global phenomenon. Following Zhang (2021), we focus on high-frequency equity price movements, which capture equity investors' expected impact of Covid-induced disruptions on firms' future earnings. We limited our analysis to short windows surrounding lockdown announcements, rather than their actual performance (eg, sales, profitability, etc) as the latter is of quarterly frequency and likely reflected the cumulative effect of multiple events, including the direct effects of domestic virus outbreaks as well as supply chain disruptions on firm earnings following the emergence of virus cases all over the world.[9]

The events in focus are the 23rd and 27th of January 2020 for China, when the Wuhan lockdown and the extension of the Lunar New Year holidays were announced, respectively, and the 16th of March 2020 for Germany, when border closures were announced.[10] These events represent exogeneous shocks to GVCs as they took place before broad-based supply disruptions became evident and hence before markets, firms and the public at large started anticipating the global disruption fallout.

The regression sample consists of a global set of listed firms that have declared supply-chain linkages in 2020 and 2021, as identified by CIQ. Specifically, our sample consists of 21,340 publicly listed firms around the globe, of which 6,756 (32%) were customers or suppliers of Chinese firms, either directly or indirectly connected via GVCs. Of the sample with German linkages, 6,127 firms (or 29%) were customers or suppliers of German firms connected via GVCs either directly or indirectly. For each firm, we compute their daily equity returns between 1 January 2019 and 17 April 2020; this period was chosen 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, as mentioned in Section 2.1, we exclude non-listed companies from our firm sample – as we seek to assess the impact of lockdown announcements on equity share prices – and add back publicly listed firms in the other SIC industries (eg, 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, respectively, linked to these two economies in the GVC network. We estimate the following for China and Germany lockdowns and linkages:

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[8] 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

[9] Compared to Zhang (2021), we look at the impact of China's early lockdowns as well as that of Germany's. Furthermore, we extend the event window beyond one day (as used in Zhang (2021)) to study the persistence of the effect of lockdown announcements.

[10] The Federal Reserve announced a number of large-scale interventions on the 17th of March, including the commercial paper funding facility, which boosted equity market sentiment. We controlled for this event in our regression analysis and found that the Fed's announcement helped to offset some of the losses from lockdown announcements but its impact dissipated within 2 days.

$$Return_{i,t} = \alpha_i + \mu_t + \sum_{j=CN,DE} \beta_j Lockdown_{jt} \times GVC_{i,j} + \delta MarketReturn_{i,t} + e_{i,t} \quad (1)$$

where $Return_{i,t}$ represents the daily change in firm i's last equity price on date t 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 23 and 27 January 2020 for China and 16 March 2020 for Germany.[11] The variable $GVC_{i,j}$ represents firm i's Chinese or German linkages as identified by CIQ in early 2020, thus providing a "pre-Covid" state of supply chain relationships. *GVC* takes on a value of 1 if a firm declared a customer or supplier relationship with China or Germany in early 2020 and 0 otherwise. This variable is later further broken down by supply chain position, as either upstream (ie, supplier) and downstream (ie, customer) to China or Germany and their industry sectors, thereby allowing us to determine whether firms' GVC position relative to the lockdown economies affects perceptions of their susceptibility to Covid shocks. The variable $MarketReturn_t$ is the return on date t on the broad stock market index in the country where firm i is 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, following the event study literature (eg see Binder (1998) and Campbell et al (1997)). Of particular interest to us are interaction terms between *lockdown* and *GVC* for China and Germany, represented by coefficients β_{CN} and β_{DE}, respectively. These variables capture the effect of a country's lockdown announcement on the stock return of firms with GVC links to that economy, relative to firms without such linkages; in other words, they are a proxy for the effect of GVC amplification. We incorporate firm- and time-fixed effects, as represented by α_i and μ_t, respectively.[12]

In our baseline regression, the events in China and Germany and their GVC links – both direct and indirect – are assessed together in a single regression over the entire period of January 2019 to April 2020. We subsequently extend this analysis with the following: (1) distinguishing between upstream and downstream positions relative to a Chinese or German firm; (2) examining whether firms in different sectors might respond differently to lockdown news; and (3) studying the effect of degree of separation to a Chinese or German firm (for upstream and downstream positions), ie, network distance as defined in Section 2.2.

Given the potentially large economic impacts of the lockdown announcements, we further consider the persistence of the impact on equity prices, looking at the cumulative returns over longer windows (as opposed to the single-day return) using local projections. Our estimation suggests that a window of up to 10 trading days[13] best captures the lockdown announcement effect, and we change the definition of the time fixed effect and the lockdown dummies accordingly. For the events in China, we now only consider the first of the two announcements given the overlap between the second announcement – the extension of the national Chinese New Year holidays – and the longer event window.

[11] In China, the Hubei authorities announced a lockdown of the city of Wuhan at 9:45AM on 23 January, China Standard Time (CST). However, news broke out earlier through a Chinese state media tweet at 2:37AM CST, before the close of the North and South American stock exchanges on 22 January. To take into account such time zone differences, the "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.

[12] 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, but none of them is statistically significant (see Technical Annex).

[13] 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, 23 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 should we need to extend the horizon of investigation to beyond 10 trading days. The window of a maximum of 10 days is determined by analysis, as seen in subsequent sections, that suggest diminishing impacts after a two-week window. Please see Technical Annex for more information.

4.2 Event study results

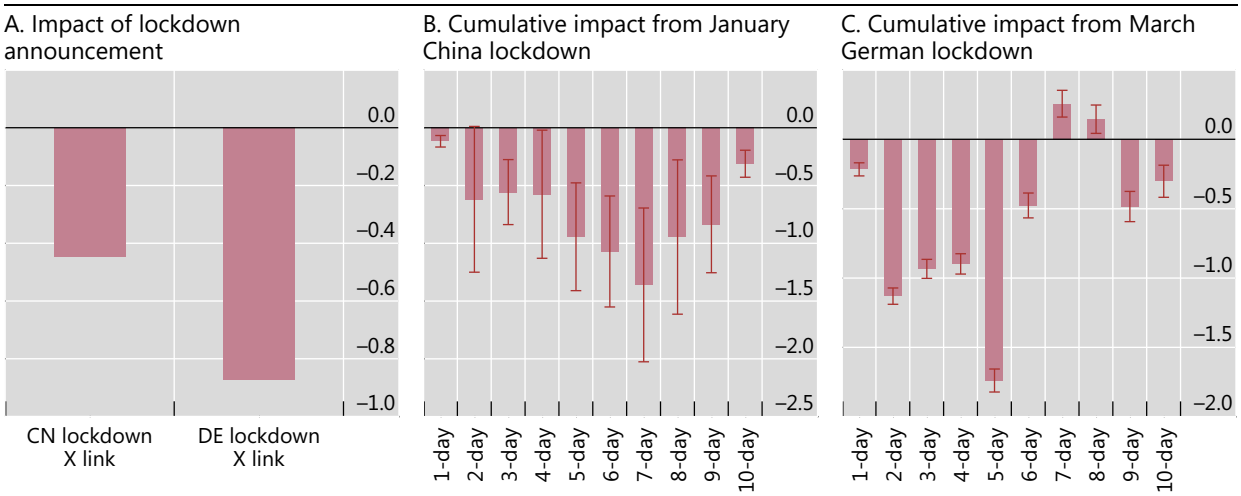
Impact of lockdown announcements

Consistent with findings from the literature that GVC participation can propagate and amplify the impact of shocks, including earlier work by Zhang (2021)[14], we find that stock market participants interpreted lockdown announcements as worse news for firms with GVC links to the affected country. On average, firms that are either directly or indirectly linked to China lost about 0.4 percentage points more in their equity price returns, measured in percent, in response to lockdown announcements in China than their counterparts that did not have such linkages (Graph 9A). For firms with German linkages, the penalty was about 0.8 percentage points (see Graph 9A and Table 1 for the China and German lockdown announcement impacts). The larger impact from the German lockdown on firms with German linkages likely reflect 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 2020 lockdown in China, by contrast, the virus was still seen as largely localised and its impact limited.

Extending the event window beyond one day to study the cumulative evolution of investor responses to these lockdown announcements, we find that an initial, relatively muted response on the announcement day became more amplified over subsequent days. Over the course of roughly two weeks, the peak cumulative impact on the equity prices of China- and German-linked firms was seen on day 5, with shares declining by about 0.9 and 1.7 percentage points more than that of their peers without such linkages, respectively (Graphs 9B and 9C, respectively, and 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. Beyond the one-week window, however, the effect dissipates, as the increasingly global nature of the Covid pandemic became apparent shortly after each lockdown announcement.

Lockdown announcements affect GVC-linked firms more negatively

Percentage points — Graph 9



Notes: Bars represent coefficients; whisker lines represent 95% confidence interval.

Sources: S&P Capital IQ; authors' calculations.

[14] Zhang (2021) also looks at the announcement effect of China's early lockdowns.

Firm equity returns and China/Germany supply chain linkages

Table 1

	Dependent variable: Firm equity return (%)
Market return (%)	0.634***
	(0.025)
Virus lockdown dummy * the following linkage dummies	
China linkage	-0.444***
	(0.066)
Germany linkage	-0.821***
	(0.017)
Observations	6,313,588
Number of firms	19,048
Adj. R-squared	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. China or German-linked firms are assessed in separate regressions.

Sources: authors' calculations.

Firm equity returns and China supply chain linkages – local projections

Table 2.1

	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)
Lockdown * China linkage (either upstream or downstream)	-0.116***	-0.943***	-0.311***
	(0.025)	(0.237)	(0.059)
Observations	6,432,746	6,355,223	6,258,334
Adj. R-squared	0.041	0.098	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 are included. Constants and dummies for significant Covid events (see Technical Annex) are not shown. For brevity, only the 1-day-ahead, 5-day-ahead and 10-day-ahead results are shown. "Alternative specification" shows the results from separate local projections using linkage dummies as defined in Table 1.

Sources: authors' calculations.

Firm equity returns and Germany supply chain linkages – local projections

Table 2.2

	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)
Lockdown * Germany linkage (either upstream or downstream)	-0.216***	-1.74***	-0.302***
	(0.024)	(0.042)	(0.059)
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 are included. Constants and dummies for significant Covid events (see Technical Annex) are not shown. For brevity, only the 1-day-ahead, 5-day-ahead and 10-day-ahead results are shown. "Alternative specification" shows the results from separate local projections using linkage dummies as defined in Table 1.

Sources: authors' calculations.

Impact of supply chain positions – upstream vs downstream firms

Given the complexity of GVCs highlighted by our earlier network charts, we delve further into firms' positioning in the supply chain relative to the affected economies – ie, upstream or downstream to China and Germany and the network distance – and whether these characteristics affect equity investors' response to lockdown announcements. To do so, we break down the GVC variable in the interaction term in our baseline regression (recall equation 1) to $Upstream_{i,j}$ and $Downstream_{i,j}$, which are dummy variables that identify whether a firm is upstream or downstream to either China or Germany. The key variables of interest represent the interaction between the lockdown announcement and a firm's position in the supply chain relative to China or Germany (if any such relationship exists).

$$Return_{i,t} = \alpha_i + \mu_t + \sum_{j=CN,DE} \beta_j Lockdown_j \times Upstream_{i,j} + \sum_{j=CN,DE} \beta_j Lockdown_j \times Downstream_{i,j} + \delta MarketReturn_t + e_{i,t} \quad (2)$$

We find that firms' position in the supply chain relative to the economies in lockdown – either upstream or downstream – matters.[15] The share prices of both upstream and downstream firms were more negatively affected than their non-linked counterparts (Table 3). Furthermore, similar to the baseline specification, this effect was more negative for firms downstream to Germany, which saw a 0.9 percentage point loss in share price returns, than for those downstream to China, which saw the penalty of about 0.4 percentage points.

Firm equity returns and China/Germany supply chain linkages – upstream vs downstream

Table 3

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

Sources: authors' calculations.

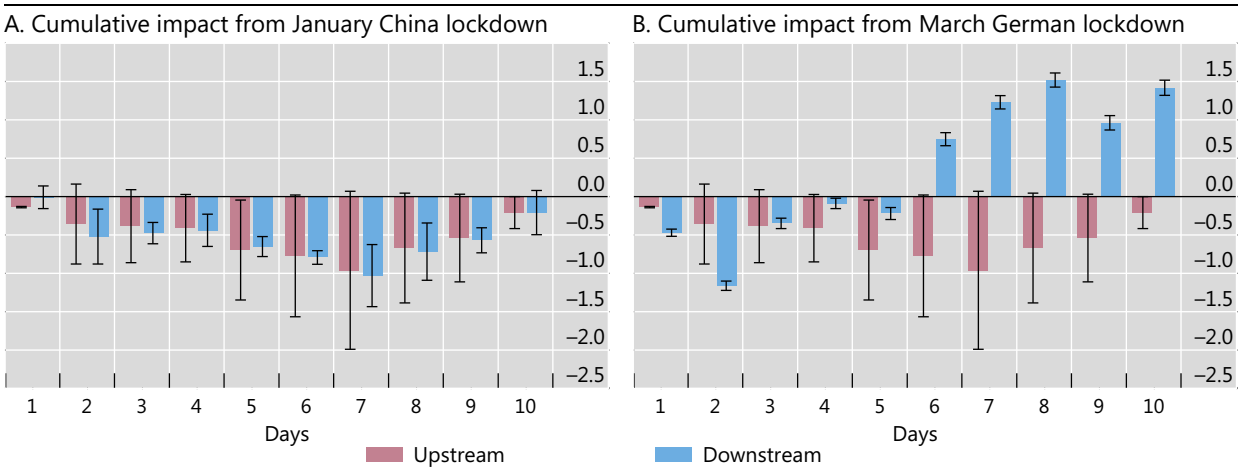
Extending the event window to a longer period, we find that the punitive impact tends to peak roughly a week after the announcement date. For China-linked firms, the impact peaked on day 7, with a

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

cumulative decline of roughly 1 percentage point for the share price returns of firms that are downstream to China; for those firms that are upstream to China, the decline totalled slightly less than 1 percentage point on day 7 (Graph 10A, and Table 4.1). For German-linked firms, the impact cumulated in a decline of 2.1 percentage points for firms upstream to Germany relative to their counterparts by day 5 (Graph 10B, "5-day", and Table 4.2). For those firms that are downstream to Germany, the penalty was more modest, peaking at 1.2 percentage points two days following the announcement before moderating and turning positive roughly one week after the lockdown announcement. The persistence of the negative impact on firms upstream to both China and Germany suggests broad-based investor expectations of prolonged supply disruptions, hampering equity price performance of firms in the two economies' supply chains. The share price response of firms downstream to Germany, on the other hand, warrants a closer look and suggests greater nuance of GVC interconnections could be at work. We consider such nuances by diving into the industry breakdowns next.

Lockdown announcements affect GVC-linked firms more negatively

Percentage points — Graph 10



Notes: Bars represent coefficients; whisker lines represent 95% confidence interval.

Sources: S&P Capital IQ; authors' calculations.

Firm equity returns and China supply chain linkages – local projections

Table 4.1

	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

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 are included. Constants and dummies for significant Covid events (see Technical Annex) are not shown. For brevity, only the 1-day-ahead, 5-day-ahead and 10-day-ahead results are shown. "Alternative specification" shows the results from separate local projections using linkage dummies as defined in Table 1.

Sources: authors' calculations.

Firm equity returns and Germany supply chain linkages – local projections Table 4.2

	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 are included. Constants and dummies for significant Covid events (see Technical Annex) are not shown. For brevity, only the 1-day-ahead, 5-day-ahead and 10-day-ahead results are shown. "Alternative specification" shows the results from separate local projections using linkage dummies as defined in Table 1.

Sources: authors' calculations.

Impact of firm industry sectors

To explore potential driving factors behind the upstream and downstream results, especially in the case of German-linked firms, we introduced a new interaction term between a firm's sector and a lockdown announcement – to equation (1) where *Sectors* is a categorical dummy variable representing a firm's GICS sector. We further add a triple interaction term between *Lockdown*, *Sectors* and *GVC*, where *GVC* is the linkage dummy as defined in Regression (1):

$$Return_{i,t} = \alpha_i + \mu_t + \beta_j Lockdown_j \times Sectors_{i,j} + \gamma_j Lockdown_j \times Sectors_{i,j} \times GVC_{i,j} + \delta MarketReturn_t + e_{i,t} \quad (3)$$

Here, j = China or Germany (i.e., we separately estimate China linkages and German linkages), β captures the unconditional impact of lockdown news on stock returns of firms in a specific sector, and γ captures the *incremental* impact of China / Germany linkages to sector-specific stock returns following lockdown news. The industry sector classification used here is CIQ's GICS.[16] For the categorical variable *Sectors*, we chose "consumer staples" as the baseline, given that firms in this sector are arguably more insulated from cyclical swings in demand and they mostly sell finished products (i.e., less susceptible to domestic supply chain disruptions), and may hence better serve as a benchmark for comparison.

One day after the lockdown announcement in China, the penalty on stock prices varied across sectors but were mostly statistically insignificant (Table 5, column (t+1)). For firms linked to China, the penalty of linkage was mostly negative and insignificant at the start of the lockdown announcement, with the notable exception of healthcare firms which outperformed, likely reflecting expectations of increased demand for healthcare products and services. Even five days after the lockdown announcement (Column (t+5)), stock returns of sectors susceptible to supply chain disruptions continued to underperform. The IT sector, for example, suffered an average cumulated penalty of 0.7%p after 5 days, with those linked to China suffering an *additional* cumulated penalty of 1.6%p. This finding supports insights from the network maps – ie, the more dispersed nature of IT networks could subject the IT sector to greater disruptions. For equity investors, such perceptions likely played a role in the penalty levied on the share prices of IT companies. Elsewhere, the share prices of firms in the industrial and materials sectors linked to China suffered an *additional* cumulative decline of 1.1%p and 0.7%p by day 5 respectively, relative to those industrial / materials firms without China linkages, conceivably reflecting the disruptions to industrial production following the lockdown announcements.

[16] See https://www.spglobal.com/spdji/en/landing/topic/gics/.

Firm equity returns and China supply chain linkages – industry interactions, local projections

Table 5

	Dep. variable: Firm equity return (%)	
	(t+1)	(t+5)
Market return (%)	0.624***	0.709***
	(0.017)	(0.017)
Virus lockdown dummy * the following GICS sub-sectors (β in Equation (3))		
Communication services	-0.200	-0.091
	(0.001)	(0.004)
Consumer discretionary	-0.000	-0.102
	(0.002)	(0.001)
Consumer staples	(baseline)	
Energy	-1.000**	-2.380***
	(0.006)	(0.005)
Healthcare	-0.100	-0.079
	(0.001)	(0.006)
Industrials	0.100	-0.304
	(0.004)	(0.002)
Information technology	-0.190	-0.659*
	(0.003)	(0.004)
Materials	-0.293***	-0.258***
	(0.001)	(0.001)
Virus lockdown dummy * the following GICS sectors * Linkage dummy (γ in Equation (3))		
Communication services	0.400**	0.100
	(0.001)	(0.006)
Consumer discretionary	-0.300**	-0.800***
	(0.001)	(0.001)
Consumer staples	-0.000	-0.300
	(0.002)	(0.002)
Energy	0.000	-0.601
	(0.002)	(0.001)
Healthcare	0.500***	-0.600
	(0.001)	(0.002)
Industrials	-0.381	-1.14**
	(0.005)	(0.006)
Information technology	0.139	-1.55**
	(0.001)	(0.006)
Materials	0.223	-0.657***
	(0.002)	(0.001)
Observations	6,432,746	6,355,223
Number of firms	19,371	19,371
Adj. R-squared	0.041	0.098

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 are included. Constants and dummies for significant Covid events (see Technical Annex) are not shown. For brevity, only the 1-day-ahead and 5-day-ahead results are shown.

Sources: authors' calculations.

Analysis of linkages to Germany also reflected the relative outperformance of sectors that benefitted from shifting demands during the Covid pandemic (Table 6). For example, firms in the communications and healthcare sectors outperformed their peers in other GICS sectors and without similar German

linkages after 5 days (Column (t+5)), likely reflecting investor optimism over stronger demand for medical and work-from-home-related communications products during lockdowns. Other sectors that are more vulnerable to supply disruptions such as IT, industrials and materials underperformed as expected, likely reflecting disruptions to their inputs.

Firm equity returns and Germany supply chain linkages – industry interactions, local projections

Table 6

	Dep. variable: Firm equity return (%)	
	(t+1)	(t+5)
Market return (%)	0.621***	0.746***
	(0.016)	(0.015)
Virus lockdown dummy * the following GICS sub-sectors (β in Equation (3))		
Communication services	-2.300***	-4.300***
	(0.000)	(0.001)
Consumer discretionary	-4.500***	-8.300***
	(0.000)	(0.001)
Consumer staples	(baseline)	
Energy	-5.200***	-7.900***
	(0.001)	(0.002)
Healthcare	-2.500***	-2.400***
	(0.001)	(0.001)
Industrials	-2.700***	-5.900***
	(0.000)	(0.001)
Information technology	-3.500***	-6.800***
	(0.000)	(0.001)
Materials	-0.300***	-2.500***
	(0.000)	(0.001)
Virus lockdown dummy * the following GICS sectors * Linkage dummy (γ in Equation (3))		
Communication services	-1.900***	-5.200***
	(0.001)	(0.002)
Consumer discretionary	1.400***	-1.600***
	(0.000)	(0.001)
Consumer staples	-0.600***	-2.800***
	(0.000)	(0.001)
Energy	-1.400***	-0.600***
	(0.001)	(0.001)
Healthcare	-0.100	0.200*
	(0.001)	(0.001)
Industrials	-0.100***	-2.600***
	(0.000)	(0.001)
Information technology	-0.100***	1.400***
	(0.000)	(0.001)
Materials	-0.500***	-2.100***
	(0.000)	(0.001)
Observations	6,885,940	6,885,940
Number of firms	20,773	20,773
Adj. R-squared	0.042	0.099

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 are included. Constants and dummies for significant Covid events (see Technical Annex) are not shown. For brevity, only the 1-day-ahead and 5-day-ahead results are shown.

Sources: authors' calculations.

Impact of supply chain network distance

Finally, we explore the impact of network distance on the response of equity prices of China- and Germany-linked firms to lockdown announcements (Table 7). We find that both direct and indirect supply chain linkages contribute to equity price fluctuations in response to lockdown news in China and Germany. Moreover, we find that the negative equity price responses of China- and Germany-linked firms generally diminished in magnitude with the distance to China and Germany in the production network (column (2)).

Firm equity returns and China/Germany supply chain linkages – network distance Table 7

		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. Distance "X" represents the degree of separation to one or more Chinese / German firms.

Sources: authors' calculations.

Our results are broadly consistent with the findings of the GVC literature that amplification effects tend to weaken as the shock travels along the supply chain (eg, Carvalho (2016), Zhang (2021)).

Specifically, upstream firms directly and indirectly linked to Chinese companies experienced declines of 0.8 and 0.3 percentage points, respectively, relative to other firms, while downstream firms suffered a penalty of 0.5 and 0.3 percentage points, respectively. The results for Germany-linked firms are qualitatively similar, suggesting that an increase in distance on the supply chain reduces the impact from shock amplification.

4.3 Robustness test

As robustness checks, we consider alternative measures of firms' equity performance and different event window lengths. In particular, instead of looking at the absolute changes of share prices as dependent variables and controlling for market benchmark movements, we construct a measure of "abnormal returns" as the dependent variable. This measure is the deviation of firms' equity share performance relative to market benchmark returns. For event windows, we considered two variations. First, we keep the daily equity returns but narrow the estimation period to 15 trading days before and after the lockdown announcements, 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 event windows are non-overlapping, thus allowing us to assess the impact of China and Germany lockdowns separately. The results from these checks offer qualitatively similar results to those from the baseline regression, and are reported in Tables A1–A3 in the Technical Annex.

5. Conclusion

The complexity and interconnections of GVC networks are often hidden in aggregate data. 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 complex and extensive GVC network structures. A tally of the total inter-firm linkages indicates that GVCs were slow to recover to pre-pandemic levels. The contraction of GVC networks was particularly evident in the IT industry, consistent with its more geographically dispersed and decentralised network structure.

We also uncover sizable variations in the network structure of industry sectors, underscoring the patchwork nature of global trade. The structural differences in networks across industry sectors could have shaped sectoral responses to shocks – a subject that could be explored in future research. Meanwhile, a closer look at maritime shipment data offered additional insights on the resilience of global trade during the Covid pandemic. While the number of linkages declined, surviving firms' flexibility in ramping up production – in some cases, exceeding quantities shipped before the pandemic – helped cushion the fall in global trade. This nuance in trade flexibility and the interplay between intensive and extensive margins that underpinned trade recovery was not visible without close inspection of granular sectoral data.

Our empirical analysis, meanwhile, shows that GVC links can amplify the effect of supply shocks on company share prices. This "penalty" on share prices tends to peak around a week and persist up to two weeks. The negative effect on stock returns heavily affected firms in cyclical industries that were particularly affected by the pandemic such as those in consumer discretionary sectors and those that are more vulnerable to supply disruptions, including those in materials, industrials and IT. Moreover, those that are more directly linked to firms in economies in lockdown – as measured by the incremental impact of China or German linkages and their network distance – tend to be more negatively affected by the lockdown announcements. Taken together, the varied sectoral responses to lockdowns – as suggested by the empirical analysis – and the different network structures – as indicated by the network maps – highlight the need for looking beyond the aggregate data in assessing GVC shifts and shock responses.

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Technical annex

Tables 1–5: In the regression models, $Return_{i,t}$ and $MarketReturn_{i,t}$ are winsorised at the 1st and 99th percentiles. Robust standard errors clustered at firm and time levels are used. 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 across Tables 1 – 4, their effects conceivably absorbed by the time fixed effect.

Table 2: The local projection framework is used to investigate the persistence of the impact of lockdown news on equity returns, as it is able to accommodate a panel structure and does not require any constraints on the shape of the impulse response function (i.e., it is more robust to possible misspecifications). The benchmark specification for different horizons (h = 1, …, 10) in days is as follows:

$$R_{i,t+\mathrm{h}} = \alpha_{i,\mathrm{h}} + \mu_{t,\mathrm{h}} + \beta_{j,h} Lockdown_j \times GVC_{i,j} + \delta_{\mathrm{h}} MarketReturn_{j,h} + e_{i,t+\mathrm{h}}$$

where $R_{i,t+\mathrm{h}}$ denotes the h-day cumulative equity return of firm i; $Lockdown_j$ is the lockdown dummy, taking the value of 1 in the days of lockdown announcements and zero otherwise (j = China or Germany); $GVC_{i,j}$ is a dummy variable indicating whether firm i has a supply chain relationship with a Chinese or German firm; $MarketReturn_{j,h}$ is the h-day cumulative return of the Chinese or German equity market benchmarks. This specification also includes firm ($\alpha_{i,\mathrm{h}}$) and time ($\mu_{t,\mathrm{h}}$) fixed effects to capture time-invariant firm features and time-specific shocks that are common across firms, respectively. In this regression, the coefficients of interest are $\{\beta_{j,h}\}_{h = 1, \ldots, 10}$ which trace out the cumulative impact of a lockdown news on the equity returns of GVC-linked firms.

Firm equity abnormal return and China/Germany supply chain linkages (robustness check) – abnormal returns

Table A1

	Dependent variable: Firm equity abnormal return (%)	
	(1)	(2)
Virus lockdown dummy * the following linkage dummies		
China linkage	-0.297***	
	(0.054)	
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)
China announcement - Covid transmissible	0.028	0.028
	(0.087)	(0.087)
WHO announcement – Covid is pandemic	-0.506*	-0.506*
	(0.201)	(0.201)
FED large-scale market intervention	-0.664	-0.664
	(1.058)	(1.058)
Observations	6,313,588	6,313,588
Adj. R-squared	0.009	0.009

Sources: authors' calculations.

Firm daily equity return and China/Germany supply chain linkages – 15-day window (robustness check)

Table A2

	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

Sources: authors' calculations.

Firm weekly equity return and China/Germany supply chain linkages – Wednesday to Wednesday (robustness check)

Table A3

	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

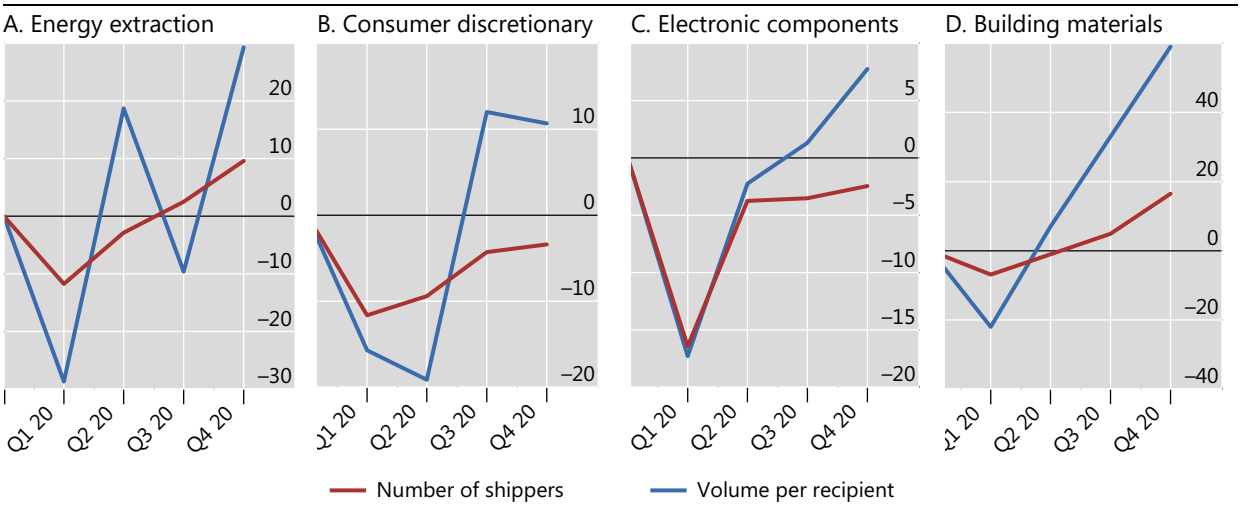
Sources: authors' calculations.

Annex Graph 1 – *Average number of shippers and TEU per sector*

Shipments to the United States: slow recovery and GVC flexibility[1]

Cumulative growth rates, Q1 2020 = 0, in per cent

Graph A1



[1] Shipment quantities are measured by 20-foot equivalent units (TEU) per US consignee. TEUs measure shipment cargo capacity.

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

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