Global Supply Chain Restructuring During the COVID-19 Pandemic

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Abstract

This paper uses transaction-level import data at the shipment level to examine how multinational companies importing to the US have restructured their supply chains during the COVID-19 pandemic. We find that companies sourced from fewer locations, reduced the share of imports from China, and increased the share of imports from other Asian countries, such as India and Vietnam, and North American countries, such as Canada and Mexico. We also observe a shift towards lower frequency, higher quantity shipments during the pandemic. However, the specific responses depend on industry and product characteristics. While the sourcing of commoditized consumer goods shifts towards lower-cost countries, "critical" goods such as medical products and semiconductor materials are increasingly sourced from the Americas. The effects are partially moderated by the number of COVID-19 cases in supplier countries. For managers, our results imply that a one-size-fits-all mentality regarding supply chain disruption responses is not appropriate, and companies' disruption-response strategies need to be tailored to individual supply chains' circumstances.

Key words: global supply chain management, COVID-19 pandemic, disruption risk, resilience strategies

1. Introduction

In the first quarter of 2020, news about the novel coronavirus COVID-19 reached a global audience. On January 21, the Financial Times reported the "spread of a SARS-like coronavirus" in China (Lockett and Georgiadis 2020). One week later, governments imposed the first restrictions on businesses: China halted manufacturing activities in all but essential industries (Hille et al. 2020b), and Russia closed its land border with China (Foy et al. 2020).

Early reports speculated about these measures' impacts on global supply chains. In February, the Financial Times warned that Apple might have to delay the launch of its next iPhone generation due to production disruptions (Hille et al. 2020a). The paper's editorial board even announced that "Coronavirus has put globalization into reverse", as border closures interrupted international trade (Financial Times 2020).

Within a few weeks, the coronavirus spread across all of the world's major economies. On March 11, the World Health Organization (WHO) declared COVID-19 a global pandemic. To prevent further propagation of the virus, governments across the world shut down large parts of their economy. These interventions included closing manufacturing plants, logistics facilities, and offices. While initially announced as short-term "circuit breaker" lockdowns, in many regions these measures remained in place as the virus persisted (Centers for Disease Control and Prevention 2022).

As a result, companies experienced an unprecedented level of supply chain disruptions (Ivanov and Dolgui 2021). 94% of the Fortune 1000 companies reported being affected by supply shocks related to COVID-19 (Sherman 2020). Automotive manufacturers throttled production due to shortages of semiconductors, FMCG brands lacked packaging and raw materials, and retailers could not keep toilet paper stocked on their shelves (Frikkee 2020, Lee 2020, World Economic Forum 2022).

Amidst these circumstances, response to supply chain disruptions has become a top priority of executives (World Economic Forum 2022), leading to the reconsideration of previously widespread strategies. Manufacturers re-evaluated their dependence on single sources of supply and geographically concentrated suppliers (Krause 2021). COVID-related port closures called into question the viability of long-distance imports from Asia (Graves et al. 2022). Many observers saw in these events the Achilles heel of lean inventory systems premised upon just-in-time replenishments (McKinsey 2020).

The discussion turned into a search for supply chain strategies for increasing robustness and resilience (Cohen and Kouvelis 2021). Jung (2020) examined the benefits of reshoring, i.e., moving sourcing and production back to a company's home country. A compromise strategy is nearshoring, which moves manufacturing to countries geographically close to a company's headquarters (Berger 2023). Others, such as Cohen et al. (2022a), also called for specific types of diversification of the supplier base. Companies who could not or would not quit China so quickly began laying the groundwork for a "China + 1" strategy, whereby companies develop additional sources of supply outside of China.

These ideas seem sensible but talk is cheap and much of the evidence regarding which strategies were actually being implemented with long-term intentions has been piecemeal. This paper goes beyond anecdotal evidence by examining transactional data that reveals large-scale changes in the supply chain sourcing patterns of multinational corporations. Therefore, our approach provides data-driven insights that can inform broader supply chain management practices.

Our analysis is based on US customs import data. These come from the Panjiva dataset, comprising the bills of lading (BoL) of all shipments received by US ports between 2019 and 2021. For that period, the data includes all shipments of 4,444 products recorded by U.S. importing companies that source from global suppliers in 235 countries of origin. Thus, the data allows us to conduct an in-depth analysis of the supply chain configurations of US-based companies before and during the COVID-19 pandemic. Unless noted otherwise, in this paper the term import refers specifically to materials that enter a country directly by sea, and we make no claim that this is the final link in the given supply chain.

We find that companies have indeed made significant changes to their supply chains during the pandemic. First, companies have consolidated their suppliers' locations. Second, companies have decreased sourcing from China but increased sourcing from other Asian countries such as India and Vietnam. Companies have also shifted their imports to neighboring North American countries, such as Canada and Mexico. Third, companies' delivery patterns have evolved towards larger, less frequent shipments.

We identify major differences across industries. In industries with low capital intensity, such as apparel, changes in sourcing locations are larger in magnitude than in industries with high capital requirements, such as semiconductors. Moreover, the shift in the geographic distribution of supply sources differs depending on the type of product. For fast-moving consumer goods (e.g., textiles or electronic appliances), imports increase the most from India and ASEAN countries, especially Vietnam. In contrast, critical materials and medical supplies are increasingly imported from North and Central America as well as from Western Europe. These results imply that preferred disruption-response strategies differ by industry and product type, suggesting a lack of confidence in a "one-size-fits-all" approach to sourcing.

1.1. Pre-COVID supply chains

Over the past decades, companies have developed increasingly globalized supply chains (Cohen et al. 2018). From new manufacturing locations to serve their home market to an expansion towards new consumers, supply chain footprints spanning multiple continents became widespread and led to a growing number of multinational corporations. With the globalization of supply chains, global corporate governance standards have also converged (Peng et al. 2023), and cross-border financing and investment have also become popular (Hertzel et al. 2023).

We outline the development of global supply chains before the disruption from the COVID-19 pandemic across three phases.

Phase 1: Striving for cost efficiencies via offshoring

As production locations overseas offered large advantages in both cost and other dimensions compared to domestic manufacturing, Western companies have offshored substantial parts of their supply chains to developing countries (McKinsey 2003, Farrell 2004). This trend gathered momentum in the 1980s.

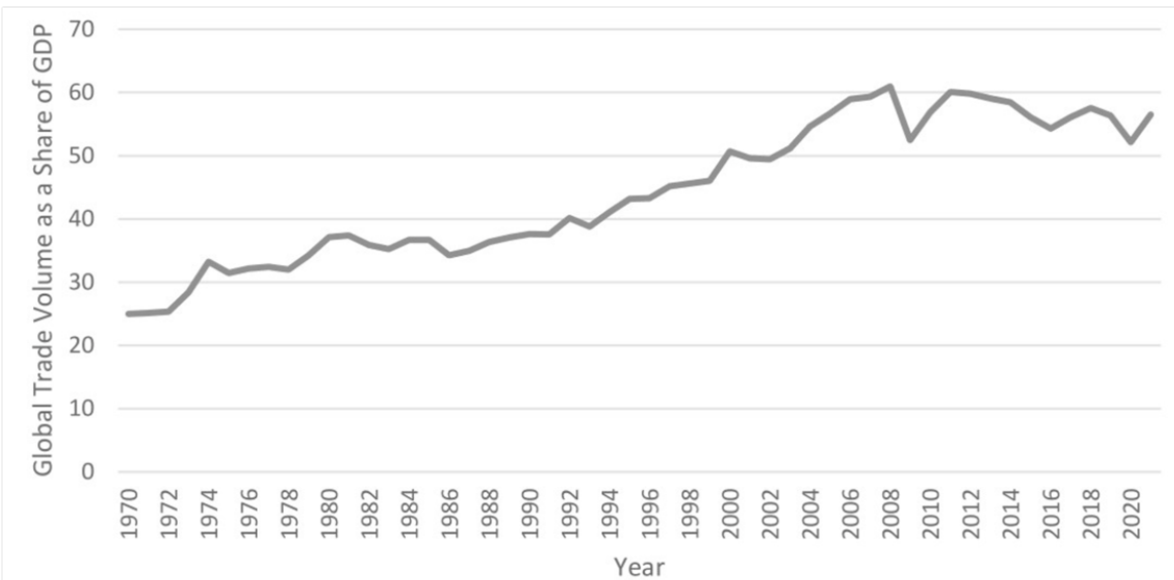
A main recipient of these offshoring activities has been China. Thanks to low labor costs, the advantage of scale, industrial clusters, cheap logistics, and the liberalization of trade, offshoring manufacturing activities to China became attractive for companies across multiple industries. In fact, the country has been named the "world's factory" due to its high share of global manufacturing activities (The Economist 2021).

Phase 2: Chasing growth in new emerging markets

In the following years, the allure of the burgeoning Chinese market has played an important role in companies' supply chain decisions. Industrial policies making local production a condition for market access, or natural advantages of proximity to customers, compelled foreign companies to place manufacturing activities in China (Tsay 2014). The same holds true for other regions where growing markets have attracted investments in local production capacity (Cohen et al. 2018).

With the leveling of production costs in China and its declining comparative advantage vis-à-vis Western countries, global supply chain decisions then focused on a more complex range of factors. This includes the entry into emerging markets, the availability and quality of the workforce, access to supply and technology, and the flexible matching of changing demand with production capacities (Cohen et al. 2018).

In line with these bi-directional developments, the share of global trade in relation to the world's GDP peaked in 2008 and stagnated thereafter (see Figure 1).



Source Data: World Bank (2022).

Figure 1 **Global trade volume as a percentage of GDP since 1970**

Phase 3: Balancing cost efficiency and security of global sourcing

The US government's support for free global trade and offshoring strategies came to an end with President Trump's "America First" policy. This policy calls for altering the US' trade relationships with China to combat the US trade deficit and alleged intellectual property theft by Chinese companies (Ikenson 2017, The Economist 2020).

In 2018, the Trump administration initiated the Chinese-American "trade war". Starting with new tariffs on particular goods such as solar panels, US import restrictions quickly escalated in other industries such as steel, machinery, and electronics. China retaliated by imposing tariffs on imports from the American agriculture and automotive industries (Bown and Kolb 2023).

1.2. The COVID-19 pandemic

Amidst these circumstances, global supply chains were hit by the COVID-19 pandemic. On December 31, 2019, Chinese health authorities informed the World Health Organization about a cluster of novel coronavirus cases in the city of Wuhan. Over the following weeks, the number of cases not only increased within the region but also grew internationally in a multitude of countries.

On January 30, 2020, the WHO designated COVID-19 as a Public Health Emergency of International Concern. Thereafter, over 150 countries imposed measures to contain the spread of the virus. Restrictions included stay-at-home orders, closures of schools and businesses, border closures, and travel restrictions.

From May 2020 onwards, governments alternated between partial lifts and the re-introduction of restrictions. Some countries, such as Australia and New Zealand, focused on strict border controls but resumed most economic activities. Others, such as Germany, aimed to strike a balance between closed event venues, mask and quarantine requirements, and re-opened production plants and logistics links. In China, strict lockdowns with stay-at-home orders were enforced in provinces with new cases, while restrictions were lifted elsewhere in the country. In the US, mitigation measures varied by state, city, and even subdivisions.

At the end of 2020, several vaccines protecting against COVID-19 were approved by the US Food and Drug Administration (FDA). Vaccines were made available to most highly developed countries during the first half of 2021, and subsequently to the rest of the world.

Meanwhile, variants of COVID-19 continued to emerge. As transmissibility and mortality increased, governments in Europe and India re-intensified containment measures, whereas several US states and Middle Eastern countries kept their economies open. As the highly transmissible "Omicron" variant surged at the end of 2021, containment measures in most countries failed or were abolished, so that global case numbers reached their peak.

In 2022, the vast majority of countries lifted their restrictions and returned to pre-pandemic regulations. As one of the last countries to respond, China abolished its nation-wide restrictions at the end of December 2022.

A COVID-19 timeline is shown in Appendix A.

2. The need for resilience amidst global supply chain disruptions

Since the offshoring of production to low-cost countries, supply chains have become increasingly complex and vulnerable to disruptions (Sodhi et al. 2012). As a consequence, considerable research has been devoted to the topic of supply chain disruptions.

Initially, researchers focused on the disruption of single plant locations. For instance, Chopra and Sodhi (2004) analyzed the impact of a fire at a semiconductor plant in New Mexico owned by Philips. The plant supplied microchips to customers from the telecommunications industry, such as Nokia and Ericsson. While Nokia's multi-sourcing approach facilitated the shifting of orders to other plants, Ericsson employed a single-sourcing policy and was fully dependent on the disabled plant. Ericsson lost $400m in sales from months of forced shutdown in production.

Later research targeted the impact of larger-scale disruptions caused by natural disasters, such as floods and earthquakes. Durach et al. (2022) explain that following the Great East Japan Earthquake of 2011, firms affected by the disruption increased their inventory levels and their volume flexibility as a response. Yet, Japan's vehicle production still fell by 80% in the month after the earthquake, as input materials and production facilities became unavailable.

Similarly, Sheffi (2020) uses the example of the Thai floods in 2011 to illustrate the impact of disruptions. As the floods disrupted the production of hard disk drive manufacturers located in the affected region, the previous market leader, Western Digital, lost its place to its less affected competitor, Seagate Technology. However, as the lost supply could not be fully replaced, hard disk drive prices spiked, and ripple effects impacted downstream buyers.

Agca et al. (2021) use a panel of credit default swap (CDS) spreads and supply chain links to observe that both favorable and unfavorable credit shocks significantly propagate through supply chains in the financial market. The study finds that these contagion effects are approximately twice as large for adverse credit shocks originating from natural disasters. The study also finds that industry competition and financial linkages between supply chain partners, such as trade credit and large sales exposure, amplify the shock propagation along supply chains.

In light of these disruptions, a body of literature has emerged on the topic of supply chain risk management (Sodhi et al. 2012). In his seminal paper on Triple-A supply chains, Lee (2004) argued that competitive supply chains need to be not only efficient, but also agile, adaptable, and aligned. Agility refers to a supply chain's ability to react quickly to sudden changes in supply or demand. Adaptation means that supply chains evolve over time as market structures and strategies shift. The alignment of firms' incentives in the supplier network is required to ensure common interests and high performance.

Subsequent publications have proposed specific policies to prepare supply chains for disruptions. Early papers called for supply chain robustness, where the configuration of a supply chain should be able to withstand disruptions, e.g., by diversification and redundancy (Tang 2006). Sheffi (2005) introduced the concept of supply chain resilience, where supply chains pursue flexibility to allow "bouncing back"after disruptions.

Cohen and Kouvelis (2021) revisited the Triple-A supply chain framework and proposed an extended version that includes robustness, resilience, and realignment. While agility provides a quick response to predictable short-term fluctuations in supply and demand, robustness is required to prepare supply chains for low-probability, high-impact "black swan" events, accounting for the risk of large-scale disruptions of operations. Adaptability is extended by resilience, referring to a supply chain's ability to not only adapt to changed market circumstances in the long term, but also to "bounce forward" to changed conditions in the aftermath of disruption and mitigate the risks of future, unpredictable shocks. A realignment of incentives may be necessary after large-scale disruptions to adjust to a "new normal".

While these concepts and frameworks provided companies with a general orientation on approaches to supply chain risk management, recent research emphasizes the need for differentiated, practice-oriented implementation strategies. In an empirical study with multiple multinational companies, Cohen et al. (2022a) identify a set of supply chain attributes shaping corporate resilience strategies. According to their Triple-P framework, resilience strategies should reflect a company's product, partnership, and process complexity. Accordingly, the authors propose process standardization, visibility enhancement, and footprint diversification (in a combination that reflects each company's Triple-P profile) to mitigate disruptions.

In spite of the extensive discussion on supply chain disruptions, the focus of existing research has been on events affecting single plants or regions. The COVID-19 pandemic differs from previous disruptions as it simultaneously impaired supply chains across the globe on an unprecedented scale. Therefore, our study focuses on the impact of COVID-19 on global supply chains and reveals how companies actually responded to this disruption.

2.1. Impact of COVID-19 on global supply chains

The COVID-19 pandemic presented a large-scale disruption of global supply chains. Based on media coverage over the course of 2020, Graves et al. (2022) identify the impacts of the pandemic on the demand side as well as on the supply side. On the demand side, the consequences include changes in the total volume of demand, the distribution of demand, and the channels through which demand is fulfilled. On the supply side, the consequences primarily lie in supplier shutdowns and supplier slowdowns, as safety protocols and illness reduce the availability of labor.

Similarly, Dohmen et al. (2023) explain that the COVID-19 pandemic led to increased volatility in supply as well as in demand. The authors collect data on demand and production rates from a non-perishable food manufacturer and use these inputs to calculate the supply chain's service level over the first half of 2020. Their findings show that existing buffer inventories were insufficient to maintain high service levels during the pandemic, as the firm's production capacity could not match the sharp increase in demand.

In terms of supply availability, Xu et al. (2023) identify three main types of disruption in the context of pandemic outbreaks based on a literature review of 49 papers. First, the lockdown of manufacturers causes a supply disruption in global value chains. Second, the unavailability of input materials due to a shift in resource allocations toward the healthcare sector impacts companies' supply. Third, the pandemic caused issues in global logistics operations, as transportation became subject to lockdowns.

Han et al. (2022) present evidence of the pandemic's impact on Alibaba, China's largest online retailer. Their analysis measures the average delivery time for orders placed at the company's online shop before, during, and after the Wuhan lockdown. The results show that the average package delivery time increased by 31% after the imposition of the lockdown. The authors conclude that the firm's logistics capacity was severely impacted by the government-mandated lockdowns and prevented the fulfillment of e-commerce orders, possibly due to the unavailability of workers to complete deliveries. To confirm the association between average delivery times and sales quantity, the authors show a significant correlation between the two variables, where the variation of the estimates in delivery times can explain approximately 60% of the variation in sales. In addition, their analysis also shows that the firm recovered its sales quantity within only a few weeks despite ongoing lockdowns, as the firm's delivery times reverted nearly back to pre-pandemic levels.

Shen and Sun (2023) confirm these findings by analyzing the Chinese online retailer JD.com. They compute the average share of available products in the retailer's online platform. Unavailable products serve as an indicator of supply chain issues. At the start of China's first COVID lockdown, the authors detected a drop in product availability rates of over 10 percentage points. Yet, again, the product availability rate returned to its pre-COVID value within two months, while lockdowns were still in place. Based on a case study at JD.com and referencing government policies, the authors identify three main drivers of supply chain disruptions caused by the pandemic. First, the prohibition of workers to travel to their workplaces resulted in a labor shortage. Second, the lockdown took offline one of the firm's central warehouses. Third, social distancing measures made door-to-door deliveries impossible and required new delivery methods.

At the same time, the pandemic has led to the development of "ad hoc" supply chains. Müller et al. (2023) explain that these supply chains are targeted to a specific, immediate, and time-limited need, such as the production of personal protective equipment and medical supplies. Based on interviews with 34 German companies, the authors propose that companies with dynamic capabilities (collaboration with external partners, engaged leaders and employees), entrepreneurial orientation (risk-taking behavior, competitive aggressiveness), and a temporary orientation (focus on short-term solutions and pragmatic processes) were able to build new supply chains within weeks. While the majority of companies retained their ad hoc supply chains only for the short term, five of the interviewed companies turned their new supply chains into permanent businesses.

In summary, existing empirical research on the impact of COVID-19 has been focused on qualitative data or on single-firm quantitative case studies. To our knowledge, no publications have attempted a holistic quantitative analysis of supply chain changes across such a comprehensive swath of companies and industries. Our study of supply chain adaptations embedded in the raw transaction data in the Panjiva dataset recording all sea-based imports to the US since 2016 reveals firm-level developments and industry-specific trends, notably global supply chain strategies companies have employed in response to the COVID-19 pandemic. An overview of potential supply chain resilience strategies discussed in the literature is provided in the following section.

2.2. New supply chain structures as a response?

Reshoring and nearshoring. Reshoring is defined as the relocation of value chain activities, and especially of production, to firms' home countries. In recent years, reshoring has attracted attention from academic researchers as well as from practitioners (Pedroletti and Ciabuschi 2023). Similarly, nearshoring refers to relocating value chain activities not to a company's home country itself, but to surrounding countries in close geographic proximity.

Regarding the choice between reshoring and nearshoring, Merino et al. (2021) find that larger companies tend to prefer nearshoring over reshoring more frequently than smaller companies. However, reshoring is preferred when remnants of a previous industry with skilled laborers exist in the companies' home country, but not in alternative nearshoring locations.

Jung (2020) argues that while reshoring on its own might increase market responsiveness and reduce risk, a combination of reshored and offshored supply sources can reduce risk via risk pooling. However, dual sourcing might not offer the best outcome under competition, as higher output correlation between firms negatively affects their total profits.

When consumers place a higher valuation on locally produced products, companies benefit from local sourcing. However, incentivizing reshoring via tariffs might backfire when the domestic market is small and the foreign market is large, as manufacturers then gain pricing leverage over suppliers when choosing one global sourcing strategy for two different markets (Chen et al. 2022).

Friend-shoring. A company that friend-shores is locating its supply chains in countries that adhere to a set of shared values or are considered to be allies or at least not adversaries, rather than prioritizing geographic proximity (Hsu et al. 2022).

Charoenwong et al. (2022) study policy uncertainty and find that firms shift suppliers from countries with higher policy uncertainty to ones with lower uncertainty. Paché (2022) introduces the term "geopolitical convergence" in supply chains. As geopolitical uncertainty in certain cross-country relationships increases, companies reinforce the robustness of their supply chains by concentrating trade with countries that are culturally and politically close. At the same time, the implementation of such a supply chain policy might vary by industry. For example, due to the sparsity of sources certain raw materials, such as cobalt, may be obtainable only from countries whose core values do not align with those of the buyer.

Global diversification. In a similar vein, some researchers have proposed global diversification of supply chains to mitigate the risk of disruption (Tomlin and Wang 2011). Especially for supply chains with high product complexity, recent research advocates for diversifying the global production footprint to build redundancy. This diversification focuses on establishing capacities in new countries, either by incentivizing existing strategic suppliers to diversify into new countries, or by gaining new suppliers in target countries (Cohen et al. 2022a).

A special case of this strategy is the "China + 1" manufacturing strategy. In that case, companies that previously concentrated their production in China aim to extend their production base to at least one additional country to reduce their dependence on a single source (Cohen et al. 2022a).

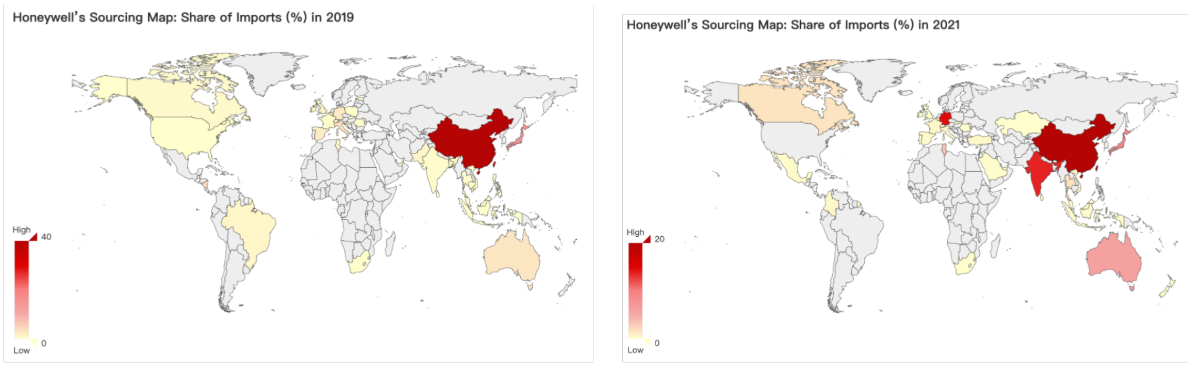
Supplier relationships. Supply chain decisions such as the diversification of suppliers and the duration of supplier relationships have been found to influence time-to-recovery from a disruption. A higher degree of supplier diversification has been associated with slower time-to-recovery, whereas long-term relationships with suppliers have been associated with faster time-to-recovery (Jain et al. 2021).

For supply chains with broad product portfolios and high process complexity, reducing complexity via portfolio streamlining and supplier rationalization has been found to be a preferred resilience strategy. In that case, focusing on SKUs with the greatest profit margins and reducing the variety of suppliers helps companies respond to disruptions (Cohen et al. 2022a).

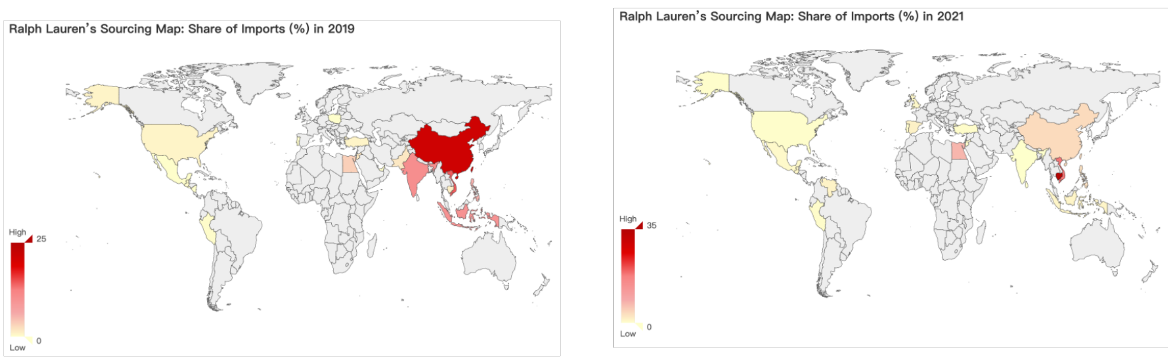
3. Case examples

To help the reader understand the power of the dataset, this section provides an initial view into changes implemented by four exemplary companies. Our statistical analysis will then compare these changes with evidence of broader trends.

Consider the appliance manufacturer Honeywell (see Panel (a) of Figure 2). Before the pandemic, the company imported materials into U.S. ports from 44 different countries. In 2021, only 37 countries were represented. Countries such as Pakistan, Turkey, and Brazil dropped out completely while other countries grabbed a bigger share. Notably, while less than 5% of Honeywell's imports by sea came from India in 2019, this figure increased to over 10% in 2021.



(a) Honeywell's sourcing map: 2019 VS 2021



(b) Ralph Lauren's sourcing map: 2019 VS 2021

Figure 2 Typical firms' sourcing maps in 2019 and 2021

More drastic changes have been made by the fashion company Ralph Lauren (see Panel (b) of Figure 2). Within two years, the company increased its share of imports from Cambodia from 1.27% to 34.58% of total import weights. In 2021, the company's direct imports consisted of 39% newly onboarded sources, compensating for a reduced number in China.

While Ralph Lauren kept its emphasis on Asian suppliers despite shifts in origin countries, other companies turned to suppliers outside of Asia. Boeing, for instance, followed a nearshoring approach. In 2019, China was the largest source of imports for the US-based airplane manufacturer. In 2021, Boeing reduced its imports from China by more than 50% in terms of import weight. Canada became the company's largest source of imports, while the role of Asian countries besides China remained unchanged.

While these examples illustrate large-scale supply chain changes during the COVID-19 pandemic, we also find examples for multinational companies which did not fundamentally restructure their supply chains. One such company is General Electric: From 2019 to 2021, the firm added only two additional countries to its supplier footprint, while still sourcing the vast majority of its products from China and India.

4. Hypotheses

In this section, we introduce the various hypotheses that are suggested by research and practice concerning the nature of company responses to supply chain disruptions. We focus on changes in importing companies in three aspects: sourcing concentration, geographic distribution, and delivery patterns.

4.1. Sourcing concentration

Supplier base diversification has been proposed as a strategy to mitigate supplier disruption risk. Tomlin and Wang (2011) argue that sourcing products from multiple vendors or facilities protects a company from disruption, as supply problems at one site only affect a portion of the total supply. Tang and Kouvelis (2011) show that dual sourcing reduces output inefficiency even when the buying firms are not price takers but are facing a duopoly. Ang et al. (2016) consider multi-tier supply chains. If multiple tier 1 suppliers share tier 2 suppliers subject to disruption risk in a "diamond-shaped" supply chain, manufacturers' optimal strategy is to induce tier-1 suppliers to mitigate disruption risk rather than multi-sourcing in tier 1 themselves. Yang et al. (2012) explain that buyers' inclination towards diversification depends on their degree of information on supplier disruption risks. With better information, diversification becomes more beneficial.

An alternative to fully-fledged multi-sourcing is the use of a backup supplier. Chakraborty et al. (2020) suggest that in the presence of supply disruption, a retailer would prefer to have access to a backup supplier. Sting and Huchzermeier (2010) show that supply options with capacity reservations are effective for contracting backup suppliers, while firm commitment contracts reduce supply chain efficiency.

Demirel et al. (2017) however argue that manufacturers typically do not benefit from backup suppliers when suppliers are strategic price setters, as the additional reliability is more costly. In support of the consolidation hypothesis, Cohen et al. (2022a) explain that for supply chains with broad product portfolios and high process complexity, reducing complexity via portfolio streamlining and supplier rationalization has been found to be a preferred resilience strategy. In that case, focusing on SKUs with the greatest profits and reducing the variety of suppliers helps companies to respond to disruptions. Similarly, Jain et al. (2021) found that a higher degree of supplier diversification has been associated with slower time-to-recovery, whereas long-term relationships with suppliers have been associated with faster time-to-recovery.

Assuming that the benefits of supplier diversification to mitigate supply disruption risk dominate the increased cost and complexity of coordination leads to the following hypothesis:

Hypothesis 1. *Companies increase the number of import sources during the COVID-19 pandemic.*

4.2. Geographic distribution

A standard diversification strategy postulates that companies should reduce their dependence on single sources of supply. In previous literature, such proposals mainly referred to not depending on single suppliers, in order to eliminate the risk of supplier bankruptcy or firm-wide quality and process issues (Sheffi 2005). During the COVID-19 pandemic, we suggest that diversification strategies would not only be concerned with risky suppliers but also with risky countries. COVID-19-related policies, such as lockdowns or border closures, were established by national or subnational administrations. Therefore, such policies affected all suppliers located in one country or region. To mitigate this risk, importing companies would thus need to diversify their suppliers' geographic footprint rather than their supplying firms.

For firms importing to the US, the main source of imports on a country level is China. According to the Office of the United States Trade Representative (2021), imports from China accounted for 18.6% of the US overall import value in 2020. In the sample of our subsequent analysis, 35.6% of the products imported by listed companies in the United States are sourced exclusively from China. Consequently, we would expect companies seeking to diversify their imports' geographic footprint to reduce their reliance on China in favor of alternative locations.

However, previous research also suggests arguments against relocations away from China. First, Cohen et al. (2018) emphasize the relevance of the growing Chinese market for location decisions. To benefit from economies of scale, companies might choose to concentrate their production in their largest market, i.e., adopt natural hedging, rather than spreading their footprint across multiple smaller locations.

If the risk reduction benefits of geographic diversification were to dominate the benefit of concentrating supply on one large market, companies may decrease their dependence on imports from their largest source of supply, leading to the following hypothesis:

Hypothesis 2. *Companies decreased their dependence on imports from China during the COVID-19 pandemic.*

In line with the previously discussed idea of geographic footprint diversification, companies might seek to increase their share of imports from secondary sources. While China is the largest source for firms importing to the US, several countries come into consideration as secondary sources that could partially replace imports from China.

According to Cohen et al. (2018), companies consider several factors when deciding from which countries to source. Such criteria include cost advantages, the availability of input materials and technology, political stability and trade relationships, local market growth, and the quality of manufacturing. With regard to these criteria, we expect India and ASEAN countries, such as Vietnam, to offer business conditions the most similar to China. In addition, these countries benefit from geographic proximity to existing Tier-2 supplier networks in China, facilitating partial shifts in production volumes. Accordingly, we suppose that companies increase their share of imports from the aforementioned countries.

However, the large range of factors influencing location decisions according to Cohen et al. (2018) leads to complex trade-offs between alternative options. Depending on companies' priorities, they might also strive for even lower-cost locations in Africa, or for more local supply chains in the Americas. The need for companies to strike a balance between resilience and cost efficiency leads to the following hypothesis:

Hypothesis 3. *Companies increased their dependence on secondary sources of imports from other Asian countries such as Vietnam and India during the COVID-19 pandemic.*

Recent research also put forward the benefits of reshoring and nearshoring (Jung 2020, Pedroletti and Ciabuschi 2023). According to Pedroletti and Ciabuschi (2023), reshoring is seen as improving supply chain resilience and avoiding potential disruptions. Similarly, Jung (2020) discusses the advantages of onshore sourcing for market responsiveness and how a combination of offshore and onshore sourcing reduces supply chain risk. During COVID-19, we expect supply chain resilience to become a more important factor for companies' location decisions. Therefore, we suppose that companies importing to the US will increasingly source from countries in North and Central America.

However, complex decision processes balance the security of supply chains with other factors such as cost, the availability of supplier networks, and market growth (Cohen et al. 2018), so that reshoring and nearshoring are not necessarily best for all firms.

In certain industries, researchers already observed a reshoring pattern associated with COVID-19. Agca et al. (2022) investigated the effect of the pandemic on US companies sourcing decisions for medical supplies. While US companies increased their imports from China to satisfy surge demand during the initial phase of COVID-19, these imports were later replaced by domestic production capacities. If the heightened concerns about supply chain resilience were to dominate cost and other considerations, companies would increase sourcing from home or near-home locations, leading to the following hypothesis:

Hypothesis 4. *Companies increased their sourcing from their home country and nearby countries during the COVID-19 pandemic.*

4.3. Delivery patterns

Several arguments suggest a change in delivery patterns during disruptions such as the COVID-19 pandemic. First, the bullwhip effect might have induced importing companies to place larger, but less frequent orders in times of increased demand variability (Bray and Mendelson 2012). According to Lee et al. (2022), this effect is especially strong for multinational supply chains with foreign subsidiaries.

Bray et al. (2019) argue that the bullwhip effect can also be triggered by the scarcity of supply, as buyers increase order sizes in times of perceived supply shortages. This is consistent with previous empirical investigations showing that companies increased their inventory levels during disruptions, e.g., during the Great East Japan Earthquake in 2011 (Durach et al. 2022). As demand does not increase accordingly, this implies a lower frequency of reordering.

Second, disruptions on the supply side might have forced suppliers to stop deliveries during lockdowns but compensate for backlog orders with larger quantities once factories reopened. Similarly, the sharp increase in container freight rates during COVID-19 indicates a reduction in available shipping capacities. This potentially forced importers to reduce the frequency of deliveries and bundle orders until capacity became available again.

However, previous research also suggests arguments in opposition to larger, less frequent deliveries. Supplier diversification would have companies receive smaller but more frequent deliveries, as orders are spread across more suppliers. Smaller orders allow a better ability to match supply to demand, especially valuable in times of increased demand uncertainty.

In addition, some firms might not have been able to place larger orders during the COVID-19 pandemic due to liquidity constraints. Demmou et al. (2021) showed that companies' liquidity significantly decreased at the beginning of the pandemic. In response, suppliers often limit their trade credit to buyers in financial distress (Aral et al. 2021).

Concerns about shortage of supply during disruptions dominating the efficiency benefits of smaller more frequent deliveries lead to the following two hypotheses:

Hypothesis 5. *Companies' orders exhibit less frequent deliveries during the COVID-19 pandemic.*

Hypothesis 6. *Companies' orders exhibit higher-volume deliveries during the COVID-19 pandemic.*

5. Methodology

5.1. Data and sample

Our investigation makes use of data from two sources. First, we use the Panjiva dataset that comprises the bills of lading for all sea-based imports into the US.[1] For each import transaction, the bill of lading includes the name and address of the importer, the name and address of the overseas supplier, information about the goods shipped (number of containers, 6-digit Harmonized System (HS) Code, country of origin, written description, weight, quantity, and units, volume in terms of TEUs (Twenty-feet Equivalent Units), Panjiva estimated value (in USD), and transportation carrier and vessel information (name and International Maritime Organization (IMO) number). The government form capturing this information for individual transactions appears in Appendix B. The original dataset is organized at the enterprise level, with the enterprise name serving as the identifier. We have refined the names and matched them to their respective listed parent firms, allowing us to merge them with a second dataset focused on financial fundamentals. Second, we collect firm-quarter-level financial fundamentals from Compustat. Limiting our analysis to publicly listed firms allows our analysis to control for firm attributes. Merging the two datasets and retaining firms with overlapping observations produced a final dataset

[1] According to the Bureau of Transportation Statistics, the proportion of U.S. imports arriving via sea shipments in terms of weight is 61.99% in 2019, 59.15% in 2020, and 62.71% in 2021.

categorized at the firm-product (six-digit HS code)-quarter level. This encompasses 284,017 observations from 1,533 listed US importing companies, representing 4,444 products, and spans from the first quarter of 2019 to the last quarter of 2021.[2]

5.2. Metrics

We collect a set of metrics from 2019 to 2021 to observe US importers' decisions before and during the COVID-19 pandemic. Firm-level metrics include the weight and volume of imports, the number of suppliers and their countries of origin, and the number of received shipments. Firm attributes contain a set of financial performance metrics derived from public firms' quarterly financial statements, corresponding to the control variables employed in previous literature (Kesavan et al. 2016, Rumyantsev and Netessine 2007). Table 1 defines the variables and our mathematical notation.

We use these metrics to construct a set of variables of interest for our hypotheses. For the hypothesis on sourcing concentration, we compute the average number of suppliers and the number of countries and regions of origin. For the hypotheses on geographic distribution, we compute the share of imports in terms of the importing weights (tons) for countries of interest. We categorize our sourcing locations into nine distinct regions: China, Vietnam, India, North and Central America, South America, Japan & South Korea, Western Europe, Eastern Europe & Russia, and Taiwan. The classification is grounded in geographic clustering, and each region accounts for a minimum of 1% of the total weight of U.S. imports. For the hypotheses on delivery patterns, we compute the number of shipments per quarter as well as their average weight and volume. An overview of the variables' mean values before and during COVID is shown in Table 2.

5.3. Test specifications

We investigate the change in sourcing patterns following the start of the COVID-19 pandemic. We analyze changes at public US importing firms aggregated at the firm (i), quarter (t), and product (6-digit HS code) (p) level. The specification for our test is given by equation (1) below:

$$\begin{aligned} Y_{ipt} = &\beta_0 + \beta_1 \cdot DuringPandemic_t + \beta_2 \cdot FirmControls_{it} + FirmFE + QuarterFE \\ &+ ProductFE + \epsilon_{ipt} \end{aligned} \tag{1}$$

[2] Of the 1,533 listed US importing companies in our final dataset, 1,139 appear in both the pre-pandemic and during-pandemic epochs. A robustness check considering only the firms present both before and during the pandemic validated all empirical conclusions in the following section.

Table 1 Variable descriptions

Variable	Measurement	Data source
Dependent variable: Sourcing concentration		
$Number\,of\,Origins_{ipt}$	Number of countries from which a company sources a specific product (6-digit HS code) in a quarter.	Panjiva
$Number\,of\,Regions_{ipt}$	Number of sourcing regions[1] from which a company sources a specific product in a quarter.	Panjiva
$Number\,of\,Suppliers_{ipt}$	Number of suppliers from which a company sources a specific product in a quarter.	Panjiva
$Number\,of\,New\,Suppliers_{ipt}$	Number of suppliers with whom a company has not partnered for sourcing a specific product up to the current quarter.	Panjiva
$Ratio\,of\,New\,Suppliers_{ipt}$	Number of new suppliers as a proportion of the total suppliers from which a company sources a specific product in a quarter.	Panjiva
Dependent variable: Geographic distribution		
$Share\,of\,Imports\,from\,\{Region\}_{ipt}$	Import size from {Region} as a proportion of the total import size in terms of weight (tons), volumes (TEU), and number of transactions for a company sourcing a specific product in a quarter.	Panjiva
Dependent variable: Delivery patterns		
$Shipment\,per\,Quarter_{ipt}$	Total number of shipment transactions for a company when sourcing a specific product in a quarter.	Panjiva
$Quantity\,per\,Shipment_{ipt}$	Total shipment quantity as a proportion of the number of transactions for a company sourcing a specific product in a quarter.	Panjiva
$Volume\,per\,Shipment_{ipt}$	Total shipment volume measured in TEUs (Twenty-foot equivalent units) as a proportion of the total number of transactions for a company sourcing a specific product in a quarter.	Panjiva
Core independent variable		
$During\,Pandemic_t$	A dummy variable equals one if the period is from the first quarter of 2020 or later.	Panjiva
Firm attribute control variables		
$Cash\ Efficiency_{ipt}$	Account payables as a proportion of the total inventory for a company in a quarter.	Compustat
$Gross\,Margin_{ipt}$	Net income minus the cost of goods sold for a company in a quarter.	Compustat
$Capital\,Intensity_{ipt}$	Total assets as a proportion of the total sales for a company in a quarter.	Compustat
$Sales\,Growth_{ipt}$	The sales difference between this quarter and the last, expressed as a percentage of the sales from the previous quarter for a company.	Compustat
$Size_{ipt}$	The logarithm of the total asset plus one for a company in a quarter.	Compustat
$COGS_{ipt}$	Cost of goods sold for a company in a quarter.	Compustat
ROA_{ipt}	Net income as a proportion of the total assets for a company in a quarter.	Compustat
$Net\,Income_{ipt}$	Net income for a company in a quarter.	Compustat
$PPENT_{ipt}$	Net property plant and equipment for a company in a quarter.	Compustat
$Inventory_{ipt}$	Total inventory as a proportion of the total asset for a company in a quarter.	Compustat
$Inventory\,Turnover_{ipt}$	Cost of goods sold as a proportion of the total inventory for a company in a quarter.	Compustat

Note. The data is organized at the firm (i)-product(p)-quarter(t) level. [1]Sourcing regions include China, Vietnam, India, North and Central America, South America, Japan & South Korea, Western Europe, Eastern Europe & Russia, and Taiwan.

We perform regressions for a variety of measures of sourcing patterns depending on the hypothesis in question, e.g., the number of suppliers or the share of imports from particular countries. We denote the dependent variable in each different model as Y_{ipt}. The independent variable $DuringPandemic_t$ is a binary indicator of before and during the COVID-19 pandemic, set to zero until 2020 Q1 and set to unity thereafter. The fixed

Table 2 Summary statistics

Dimension	Variables	Mean (Before COVID-19)	Mean (During COVID-19)	Percentage change
Sourcing concentration	*Number of Origin Countries*	1.4155	1.4019	-0.96%
	Number of Origin Regions	1.2812	1.2749	-0.49%
	Number of Suppliers	1.8942	1.8973	1.62%
	Number of New Suppliers	0.6330	0.7077	11.80%
	Ratio of New Suppliers	0.4007	0.4535	13.20%
Geographic distribution	*Share of Imports from China*	0.4553	0.4460	-2.02%
	Share of Imports from Vietnam	0.0212	0.0269	27.36%
	Share of Imports from India	0.0493	0.0530	7.51%
	Share of Imports from North & Central America	0.0391	0.0412	5.37%
	Share of Imports from South America	0.0205	0.0207	0.98%
	Share of Imports from Japan & South Korea	0.0499	0.0462	-7.41%
	Share of Imports from Western Europe	0.1760	0.1821	3.47%
	Share of Imports from Eastern Europe & Russia	0.0096	0.0101	4.17%
	Share of Imports from Taiwan	0.0610	0.0617	1.15%
Delivery patterns	*Shipments per Quarter*	19.7496	18.7327	-5.15%
	Quantity per Shipment	646.8495	706.7000	9.25%
	Volume per Shipment	1.4486	1.5460	6.72%

Note. Share of imports from regions is measured by weight (in tons).

effects variables (variable names that end with FE) control for attributes specific to the firm, season, and product. We include a set of firm financial performance metrics as control variables, as shown in Table 1.

6. Results

6.1. Sourcing concentration

Table 3 shows evidence of consolidation of supplier locations during COVID-19, which refutes Hypothesis 1. In column (1), we find that the number of countries of origin of US firms' suppliers decreases significantly in statistical terms. In column (2), we confirm that firms do not only source from fewer countries in each world region but also from fewer world regions overall. Column (3) shows that despite the consolidation of supplier locations, US importing firms still source from the same number of suppliers. While the overall number of suppliers per firm does not exhibit significant changes, we observe an increase in the number and the ratio of new suppliers (columns (4) and (5), respectively). This shows that during the pandemic, companies more frequently replaced existing suppliers with alternative ones compared to before the pandemic.

6.2. Geographic distribution

In Table 4, we observe a significant, albeit small reduction in the share of imports from China, thus supporting Hypothesis 2. Column (1) shows the effect in terms of shipment weights, column (2) in terms of shipment volumes, and column (3) in terms of the number of shipments.

Table 3 Changes in the sourcing concentration

VARIABLES	(1) Number of origin countries	(2) Number of origin regions	(3) Number of suppliers	(4) Number of new suppliers	(5) Ratio of new suppliers
DuringPandemic	**-0.020*****	**-0.010*****	**-0.015**	**0.055*****	**0.045*****
	(-4.542)	**(-3.256)**	**(-0.888)**	**(7.101)**	**(23.810)**
Net Income	-0.000**	-0.000***	0.000	0.000	0.000***
	(-2.519)	(-4.522)	(0.645)	(1.524)	(3.937)
PPENT	0.000	0.000	0.000	0.000	0.000
	(0.484)	(0.959)	(0.212)	(1.371)	(1.188)
COGS	0.000***	0.000***	0.000	0.000	-0.000**
	(5.682)	(7.381)	(1.051)	(0.156)	(-2.571)
Cash Efficiency	-0.001	-0.000	0.003	0.003**	0.001***
	(-0.830)	(-0.939)	(1.028)	(2.370)	(2.944)
Gross Margin	0.000***	0.000***	0.000	0.000	-0.000
	(4.573)	(6.563)	(0.327)	(0.139)	(-0.694)
Capital Intensity	-0.009	-0.006	-0.000	0.003	0.002
	(-1.514)	(-1.431)	(-0.010)	(0.253)	(0.637)
Sales Growth	-0.042***	-0.029***	-0.106**	-0.015	0.042***
	(-3.270)	(-3.387)	(-2.334)	(-0.694)	(8.051)
Size	0.023	0.005	-0.004	-0.031	-0.017**
	(1.435)	(0.478)	(-0.064)	(-1.111)	(-2.536)
ROA	-0.046	-0.044	0.257	0.121	-0.023
	(-0.750)	(-1.076)	(1.169)	(1.160)	(-0.906)
Inventory	0.040	0.001	0.377**	0.346***	0.055***
	(0.985)	(0.034)	(2.517)	(4.877)	(3.240)
Inventory Turnover	0.004***	0.004***	-0.001	-0.002	-0.001**
	(4.569)	(6.275)	(-0.164)	(-0.946)	(-2.036)
Firm FE	Y	Y	Y	Y	Y
Quarter FE	Y	Y	Y	Y	Y
Product FE	Y	Y	Y	Y	Y
Observations	284,017	284,017	284,017	284,017	284,017
R-squared	0.180	0.180	0.121	0.114	0.165

Note. $^{*}p<0.1$, $^{**}p<0.05$, $^{***}p<0.01$ using two-tailed tests. OLS estimates with robust t statistics are in parentheses.

Table 4 Changes in the geographic distribution

	Share of imports from					
	China			**Vietnam**		
VARIABLES	(1) By weight (tons)	(2) By volume (TEU)	(3) By number of shipments	(4) By weight (tons)	(5) By volume (TEU)	(6) By number of shipments
DuringPandemic	-0.012***	-0.012***	-0.011***	0.005***	0.006***	0.005***
	(-6.862)	(-7.010)	(-6.809)	(9.443)	(9.794)	(5.629)
Controls	Y	Y	Y	Y	Y	Y
Firm FE	Y	Y	Y	Y	Y	Y
Quarter FE	Y	Y	Y	Y	Y	Y
Product FE	Y	Y	Y	Y	Y	Y
Observations	284,017	284,017	284,017	284,017	284,017	284,017
R-squared	0.381	0.381	0.386	0.200	0.204	0.258
	India			**North and Central America**		
VARIABLES	(7) By weight (tons)	(8) By volume (TEU)	(9) By number of shipments	(10) By weight (tons)	(11) By volume (TEU)	(12) By number of shipments
DuringPandemic	0.005***	0.005***	0.005***	0.002**	0.003***	0.002**
	(5.639)	(5.612)	(9.443)	(2.145)	(3.528)	(2.122)
Controls	Y	Y	Y	Y	Y	Y
Firm FE	Y	Y	Y	Y	Y	Y
Quarter FE	Y	Y	Y	Y	Y	Y
Product FE	Y	Y	Y	Y	Y	Y
Observations	284,017	284,017	284,017	284,017	284,017	284,017
R-squared	0.258	0.267	0.200	0.326	0.214	0.334

Note. $^{*}p<0.1$, $^{**}p<0.05$, $^{***}p<0.01$ using two-tailed tests. OLS estimates with robust t statistics are in parentheses. Control variables include *Net Income, PPENT, COGS, Cash Efficiency, Gross Margin, Capital Intensity, Sales Growth, Size, ROA, Inventory,* and *Inventory Turnover*.

For Vietnam, we observe a significant increase in import weights (column (4)), import volumes (column (5)), and the number of shipments (column (6)) in Table 4. We find that the same results hold true for India, namely an increase in import weights, volumes, and number of shipments shown in columns (7), (8), and (9). Thus we find support for Hypothesis 3 that companies increased their dependence on imports from secondary sources from other Asian countries such as Vietnam and India.

In addition, companies increase their share of imports from North and Central America (columns (10), (11), and (12)). This supports Hypothesis 4.

6.3. Delivery patterns

In Table 5, columns (1) and (2) show that the weight and the volume of received shipments have increased after the emergence of COVID-19, respectively. In column (3), we find that this is accompanied by a significant decrease in shipment frequency. The pre- and post-samples contain companies that are randomly selected from the same population. Compared with the average batch size in the pre-pandemic era (597.53 units per shipment and 1.45 TEUs per shipment) and average sourcing frequency (47.90 shipments per quarter), our results suggest that after COVID-19 pandemic, the quantity per shipment increases by 9.12%, volume per shipment increases by 3.3%, and the sourcing frequency decreases by 2.2%.

These results support Hypotheses 5 and 6, as we observe less frequent shipments with higher quantities compared to pre-COVID delivery patterns.

Table 5 Changes in sourcing frequency and shipment batch size

VARIABLES	(1) Shipments per quarter	(2) Quantity per shipment	(3) Volume per shipment
DuringPandemic	-0.808***	55.924***	0.048***
	(-11.416)	(8.493)	(5.384)
Controls	Y	Y	Y
Firm FE	Y	Y	Y
Quarter FE	Y	Y	Y
Product FE	Y	Y	Y
Observations	284,017	284,017	284,017
R-squared	0.155	0.217	0.227

Note. $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$ using two-tailed tests. OLS estimates with robust t statistics are in parentheses. Control variables include *Net Income, PPENT, COGS, Cash Efficiency, Gross Margin, Capital Intensity, Sales Growth, Size, ROA, Inventory,* and *Inventory Turnover.*

6.4. Industry variation

To understand the composition of the effects previously observed, we drill down to the level of specific industries. Our findings reveal that sourcing pattern changes differ strongly across industries. First, the share of new suppliers significantly increases in all industries but semiconductors, showing that the semiconductor industry constitutes an outlier to the general trend. Second, the degree of change varies across industries. While there are significant shifts in import sources in the textile and apparel industry, other industries, such as hygiene goods or minerals and fuels, are not subject to significant changes. These differences might be driven by the capital intensity of an industry, as our robustness checks show a lower variation in sourcing patterns for capital goods (see Appendix C). Third, the geographic distribution of imports evolves differently across industries. In the semiconductor industry, we observe a significant decrease in imports from Taiwan, the largest supplier of semiconductors. Instead, semiconductor imports increase from nearly all other regions. For critical materials, e.g., rare earth materials required for batteries, chips, or medicines, companies decreased their imports from China and increased their sourcing from Western Europe. In other industries such as machinery and electrical goods, imports from China are replaced by sourcing from India and Vietnam, indicating a variance by industry in the viability of alternative locations. Table 6 presents details of differences by industry.

6.5. The effect of COVID-19 cases

We extend our analysis to examine the impact of the growth rate in COVID-19 cases in supplier countries on our results. We obtain the data on the COVID cases in each country from the Coronavirus COVID-19 Global Cases Database. This dataset is published by the Center for Systems Science and Engineering (CSSE) at Johns Hopkins University (JHU).[3] The dataset provides the daily COVID-19 cases from more than 180 economies starting on January 22, 2020. For this purpose, we construct a test specification considering the number of weighted cases:

$$\begin{aligned} Y_{ipt} =& \beta_0 + \beta_0 \cdot WeightedCases_t + \phi' FirmControls_{it} + FirmFE + QuarterFE \\ &+ ProductFE + \epsilon_{ipt} \end{aligned} \tag{2}$$

The variable $WeightedCases_{it}$ is the import-share weighted COVID-19 growth rate $WeightedCases_{it} = \sum_{i \in C_{it}} ImportShare_{ic} \times CovidGrowth_{ct}$. And the COVID-19 growth rate is calculated as $CovidGrowth_{ct} = ln(CumulativeCases_{ct} + 1) -$

[3] https://github.com/owid/COVID-19-data/tree/master/public/data

Table 6 Industry variation

Regions / VARIABLES	Machinery and Electrical Goods Diff(During-Before)	Machinery and Electrical Goods Percentage Change	Semiconductor Goods Diff(During-Before)	Semiconductor Goods Percentage Change	Hygiene Goods Diff(During-Before)	Hygiene Goods Percentage Change	Critical Materials Diff(During-Before)	Critical Materials Percentage Change
Number of Origins	0.0014	0.10%	-0.0900	-6.05%	-0.0480**	-3.05%	0.0273	2.29%
Number of Regions	0.0082	0.67%	-0.0132	-1.07%	-0.0235	-1.69%	-0.0123	-1.06%
Number of Suppliers	0.0134	0.81%	-0.2068	-9.05%	-0.0264	-1.25%	-0.0153	-1.14%
Number of New Suppliers	0.0993***	18.21%	0.0496	8.29%	-0.1290***	-20.05%	-0.0843*	-21.87%
Ratio of New Suppliers	0.0674***	18.69%	0.0125	4.19%	0.0744***	24.65%	0.0750**	26.08%
Share of Imports from:								
China	-0.0020	-0.43%	-0.0222	-3.44%	0.0043	0.88%	-0.0613*	-14.46%
Vietnam	0.0062***	89.03%	0.0125	186.30%	0.0024	10.23%	0.0089	100%
India	0.0046***	14.90%	0.0005	3.12%	0.0011	3.60%	0.0039	40.23%
North & Central America	0.0003	0.95%	0.013	106.71%	0.0064*	15.43%	-0.01086	-36.67%
South America	0.0008	6.87%	0.0019	100%	0.0014	14.97%	0.0022	60.08%
Japan & South Korea	0.0005	0.97%	0.0105	18.23%	0.0020	5.63%	0.0000	0.07%
Western Europe	0.0056*	3.12%	0.0296	49.26%	0.0087	5.53%	0.0977***	45.57%
East Europe and Russia	0.0004	3.62%	-0.0100	-100.00%	0.0002	3.18%	-0.0104	-68.66%
Taiwan	0.0034*	4.34%	-0.0309**	-40.68%	0.0003	0.47%	-0.0248	-22.34%

Regions / VARIABLES	Mineral and Fuels Diff(During-Before)	Mineral and Fuels Percentage Change	Transportation Diff(During-Before)	Transportation Percentage Change	Textiles and Apparel Diff(During-Before)	Textiles and Apparel Percentage Change	Chemicals Diff(During-Before)	Chemicals Percentage Change
Number of Origins	-0.0504	-3.41%	-0.0284	-1.81%	-0.0042	-0.25%	-0.0064	-0.49%
Number of Regions	-0.0495	-3.91%	-0.0191	-1.37%	0.0017	0.12%	-0.0024	-0.21%
Number of Suppliers	-0.0877	-5.09%	0.0146	0.63%	-0.0135	-0.57%	-0.0190	-1.32%
Number of New Suppliers	0.0520	8.83%	0.1571***	25.17%	0.0780***	9.02%	0.0300***	7.07%
Ratio of New Suppliers	0.0553***	16.54%	0.0826***	25.49%	0.0464***	12.66%	0.0322***	10.48%
Share of Imports from:								
China	0.0031	1.82%	0.0382***	9.02%	-0.0305***	-5.99%	-0.0025	-1.03%
Vietnam	0.0041	149.15%	0.0031*	46.70%	0.0070**	8.58%	0.0023*	28.43%
India	0.0086	24.96%	0.0036	7.43%	0.0087***	9.51%	0.0070**	11.92%
North & Central America	0.0150	29.80%	0.0059	11.29%	0.0052***	18.05%	0.0025	4.31%
South America	-0.0153**	-43.41%	0.0019	10.22%	0.0000	0.46%	0.0036	12.60%
Japan & South Korea	0.0101	17.31%	0.0023	3.41%	-0.0062***	-21.09%	-0.0090**	-11.13%
Western Europe	0.0220	8.50%	0.0013	0.98%	0.0067***	12.67%	0.0026	0.75%
East Europe and Russia	0.0063	34.65%	0.0004	3.66%	-0.0019***	-42.09%	0.0004	3.94%
Taiwan	0.0015	11.11%	0.0131**	15.81%	-0.0042**	-12.80%	0.0012	5.20%

Note. $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$ using two-tailed t-tests.

$ln(CumulativeCases_{ct-1} + 1)$ where C_{it} is the group of sourcing countries for company i in quarter t.

Our results in Table 7 show that the impact of COVID-19 cases is consistent with our previous findings on sourcing concentration and delivery patterns. As such, a higher number of cases in a company's supplying countries is associated with fewer origin countries, a higher share of new suppliers, and with less frequent, but larger shipments.

7. Discussion and conclusion

7.1. Implications of the results

i. The COVID-19 pandemic has not been a catalyst for de-globalization.

In spite of press stories suggesting the demise of global supply chains due to pandemic-related disruptions, our results show that companies still maintain high shares of imports from offshore suppliers. Instead, we observe a geographic shift away from China and towards other Asian countries such as Vietnam and India. This development is consistent with the idea of companies striving for improved supply chain responses to disruptions while maintaining the cost advantage of global supply chains. As such, companies aim to

Table 7 Impact of COVID-19 cases on sourcing concentration and delivery patterns

	Sourcing concentration			Delivery patterns		
VARIABLE	(1) Number of origin countries	(2) Number of suppliers	(3) Number of new suppliers	(4) Shipments per quarter	(5) Quantity per shipment	(6) Volume per shipment
$WeightedCases_{it}$	-0.009*	-0.025	0.018**	43.296***	0.038***	-0.628***
	(-1.873)	(-1.395)	(2.096)	(5.898)	(3.789)	(-7.956)
Controls	Y	Y	Y	Y	Y	Y
Firm FE	Y	Y	Y	Y	Y	Y
Quarter FE	Y	Y	Y	Y	Y	Y
Product FE	Y	Y	Y	Y	Y	Y
Observations	284,017	284,616	284,616	284,017	284,017	284,017
R-squared	0.180	0.121	0.114	0.217	0.227	0.154

Note. $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$ using two-tailed tests. OLS estimates with robust t statistics are in parentheses. Control variables include *Net Income, PPENT, COGS, Cash Efficiency, Gross Margin, Capital Intensity, Sales Growth, Size, ROA, Inventory,* and *Inventory Turnover*.

reduce their dependence on countries responsible for a large share of their supply and seek out alternative low-cost locations instead. This falls in line with the findings of Alfaro and Chor (2023), who propose the term "great reallocation" to describe current changes in global supply chains. While their results focus on the descriptive analysis of trade data aggregated at the country level, our investigation provides further insights by including industry- and product-specific data thanks to the use of transaction-level shipment data. Our earlier research points out the limitations of using aggregate country-level data (see Cohen et al. 2022b).

ii. Supply chain restructuring occurs at a slow pace.

Our results provide evidence for shifts in supply chain structures. Yet, these changes are less dramatic than expected at the beginning of the pandemic. Despite restrictive lockdowns and high COVID-19 case numbers, companies keep most of their existing suppliers and locations. While a few companies, such as Ralph Lauren, are able to onboard a large share of new suppliers in different countries, such extensive shifts appear to have been infeasible or undesirable for most firms. Supposedly, supply chain restructuring occurs primarily via location decisions for new greenfield investments, but rarely includes a complete overhaul of existing supply chains. This is an indication that trade-offs and constraints are being considered as firms decide what changes to make to their supply chain strategy. These findings are consistent with Cohen et al. (2018) who observed that multinationals take into account a broad range of factors when configuring their supply chain footprint and typically do not replace existing capacities when making new supply chain location decisions.

iii. Companies shift beyond mitigating firm-level supplier risks to mitigating country-level location risks.

In contrast to our intuition, companies do not increase the number of their suppliers to improve diversification. Instead, firms shifted the geographic distribution of their imports. This development underscores a change in the type of risks present in supply chains: While previous risk management strategies focus on the failure of individual suppliers, e.g., due to bankruptcy, the risks emerging from COVID-19 are associated with country-level government interventions and the availability of cross-border trade links. Therefore, the emphasis now moves to eliminating risky locations from the supply chain rather than risky suppliers, echoing the findings on country-level policy uncertainty in Charoenwong et al. (2022). This development is consistent with the idea of friend-shoring, where the relationship between countries becomes a determinant of supply chain location decisions (Hsu et al. 2022). In our results, this fits with the reduction of imports from China and the increase in imports from other Asian countries, such as India and Vietnam, and North and Central American countries, such as Canada and Mexico.

iv. Reshoring and nearshoring happen, but only in select industries.

Our findings support the relevance of current discussions around reshoring and nearshoring. While the total quantity of imports from the Americas remains low, we observe a disproportional increase in North and Central American suppliers. This strategy is especially present for critical materials, suggesting that reshoring and nearshoring are preferred disruption-response strategies for vulnerable but essential inputs in supply chains. In addition, nearshoring is particularly relevant for high-tech industries where the necessary production capabilities reside in just a few locations, as illustrated by the case of Boeing.

v. There is no one-size-fits-all approach to responding to disruptions.

Our analyses show that chosen disruption-response strategies strongly differ by industry. In capital-intensive industries such as semiconductors, we only observe small changes in sourcing patterns. In contrast, companies in less capital-intensive industries such as apparel exhibit larger degrees of supply chain restructuring. For companies that cannot easily shift manufacturing locations due to high capital requirements, drastic supply chain changes have not been feasible. This underlines the higher importance of pre-emptive resilience measures to develop robust supply chains for capital-intensive companies. A similar conclusion also holds true for companies closely tied to existing production locations due to high-quality expectations and existing supplier networks, as in the case of Apple.

7.2. Managerial discussion

For managers, our results imply that their companies require unique disruption-response strategies tailored to their industry's circumstances. While companies have made changes to their supply chains during the COVID-19 pandemic, the extent and nature of these changes differ from one firm to another. For managers to conduct the right restructuring of their supply chain, we propose a four-step approach (see Figure 3).

Risk Assessment	1. How is your current sourcing footprint (strategy) vulnerable to supply chain disruption? 2. Where is the greatest risk, i.e., what products and supplier sources are most vulnerable? 3. What future scenarios that can disrupt supply chain sourcing are you most concerned about?
Option Identification	4. How can your sourcing be modified to mitigate these risks? I.e., new suppliers in same countries, new suppliers in new countries, adjusted sourcing mix? 5. How do factors specific to your location, industry, company, and products impact available options?
Option Evaluation	6. What metrics should you use to track supply chain risk and efficiency? 7. What is your current status (performance) with regard to these metrics? 8. What resource constraints are closest to being binding?
Plan of Action	9. What is your plan of action to respond to future disruptions, i.e., short term for agility and long term for resilience? 10. What timelines are necessary to implement changes to your supply chain footprint?

Figure 3 Questions for managerial discussion

First, managers need to assess the disruption risks present in their supply chains. Given the industry differences we observe, this requires the consideration of product, firm, and industry-specific characteristics in their supply chain. Moreover, we recommend emphasizing the location of suppliers to examine the potential impact of government interventions and identify cluster risks.

Second, managers should identify alternative supply options. As shown by our analysis, such alternatives could either be a shift to new suppliers at the same location, the onboarding of new suppliers in new locations, or an adjustment in the amounts sourced from existing suppliers. Once more, we expect the technological specificity and capital intensity of an industry to inform the range of possible options.

Third, managers need to evaluate the viability of alternative supply options. This requires a careful balancing of goals related to the supply chain responding to disruptions and to supply chain efficiency. We suggest the definition of clear target metrics to compare alternative options to the status quo. Moreover, companies will need to consider resource constraints that might prevent large degrees of supply chain restructuring.

Fourth, managers should transform their intended supply chain changes into a comprehensive plan of action. As we observe different paces of restructuring in our analysis, we suggest reflecting on the timelines required to implement changes to a company's supply chains.

Following these questions in line with our observations, it becomes apparent that supply chain disruptions-responding strategies are subject to complex trade-offs and company-specific circumstances. While it is too soon to evaluate changes made during the COVID-19 pandemic, the extent of supply chain restructuring during this once-in-a-generation global disruption underscores the need for persistent managerial focus on resilience.

7.3. Limitations of the study and further research directions

Our study is subject to a few limitations that might be alleviated by further research. First, the scope of our study focuses on seaborne imports to the US. Consequently, we do not observe changes in the sourcing of finished goods and components arriving at other destinations. Investments in production capacities for other markets, e.g., by Siemens or the semiconductor manufacturer STMicroelectronics in China, are not part of our analysis. As we consider only direct imports to the US, we also cannot observe changes in lower-tier suppliers. Future research could extend our analysis by analyzing whether the supply chain restructuring is driven by new locations for product assembly while keeping existing Tier-2 supplier locations, or whether complete industrial ecosystems including lower-tier suppliers are shifted.

Besides, we limit the scope of our study to an analysis of changes in sourcing patterns but do not demonstrate the financial impacts associated with these. At this time, it is too early to tell whether the changes in the supply chain structures will contribute to companies' long-term competitiveness. For future researchers, however, shedding light on the effectiveness of the observed strategies could offer valuable insights. Additionally, future research could investigate the long-term effects of these supply chain adaptations and how they may shape global trade patterns in the post-pandemic era.

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Appendix A. COVID-19 timeline

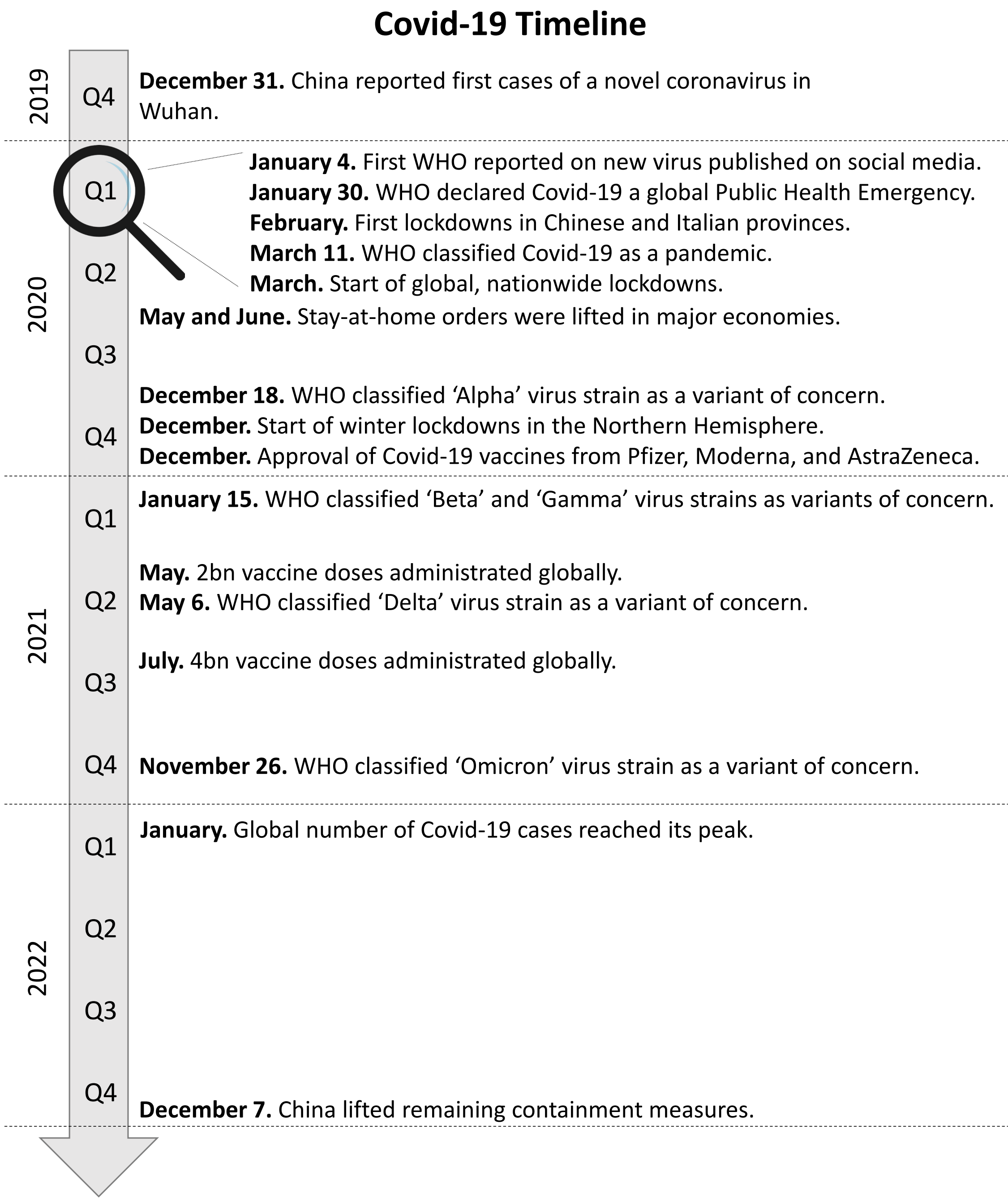
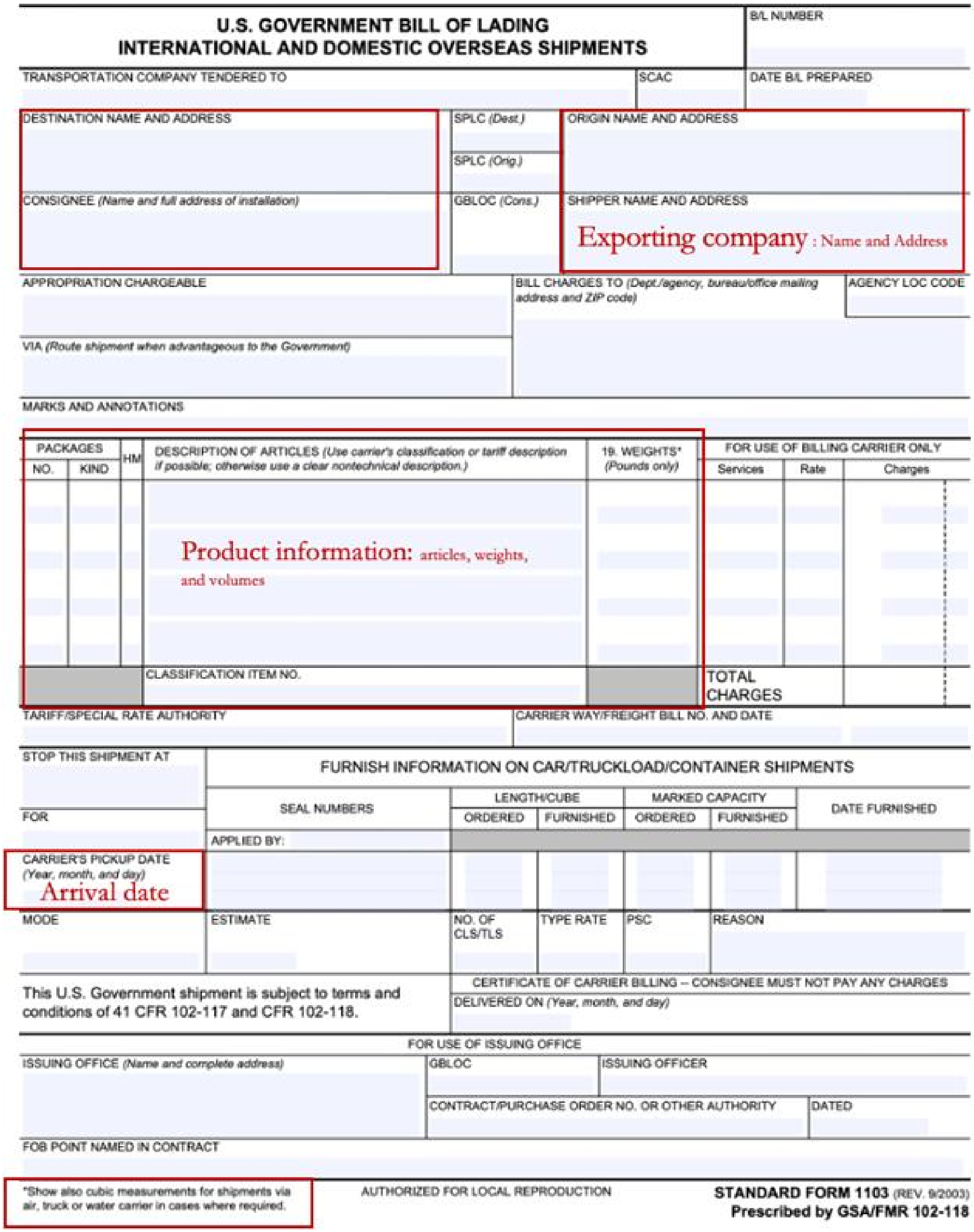


Figure A1 **COVID-19 timeline**

Appendix B. Original format of U.S. bill of lading


U.S. GOVERNMENT BILL OF LADING
INTERNATIONAL AND DOMESTIC OVERSEAS SHIPMENTS
B/L NUMBER
TRANSPORTATION COMPANY TENDERED TO
SCAC
DATE B/L PREPARED
DESTINATION NAME AND ADDRESS
SPLC (Dest.)
ORIGIN NAME AND ADDRESS
SPLC (Orig.)
CONSIGNEE (Name and full address of installation)
GBLOC (Cons.)
SHIPPER NAME AND ADDRESS
Exporting company : Name and Address
APPROPRIATION CHARGEABLE
BILL CHARGES TO (Dept./agency, bureau/office mailing address and ZIP code)
AGENCY LOC CODE
VIA (Route shipment when advantageous to the Government)
MARKS AND ANNOTATIONS

PACKAGES NO.	PACKAGES KIND	HM	DESCRIPTION OF ARTICLES (Use carrier's classification or tariff description if possible; otherwise use a clear nontechnical description.)	19. WEIGHTS* (Pounds only)	FOR USE OF BILLING CARRIER ONLY Services	Rate	Charges
			Product information: articles, weights, and volumes				
			CLASSIFICATION ITEM NO.		TOTAL CHARGES		

TARIFF/SPECIAL RATE AUTHORITY
CARRIER WAY/FREIGHT BILL NO. AND DATE
STOP THIS SHIPMENT AT
FOR
FURNISH INFORMATION ON CAR/TRUCKLOAD/CONTAINER SHIPMENTS

SEAL NUMBERS	LENGTH/CUBE ORDERED	LENGTH/CUBE FURNISHED	MARKED CAPACITY ORDERED	MARKED CAPACITY FURNISHED	DATE FURNISHED
APPLIED BY:					

CARRIER'S PICKUP DATE (Year, month, and day)
Arrival date
MODE
ESTIMATE
NO. OF CLS/TLS
TYPE RATE
PSC
REASON
This U.S. Government shipment is subject to terms and conditions of 41 CFR 102-117 and CFR 102-118.
CERTIFICATE OF CARRIER BILLING -- CONSIGNEE MUST NOT PAY ANY CHARGES
DELIVERED ON (Year, month, and day)
FOR USE OF ISSUING OFFICE
ISSUING OFFICE (Name and complete address)
GBLOC
ISSUING OFFICER
CONTRACT/PURCHASE ORDER NO. OR OTHER AUTHORITY
DATED
FOB POINT NAMED IN CONTRACT
*Show also cubic measurements for shipments via air, truck or water carrier in cases where required.
AUTHORIZED FOR LOCAL REPRODUCTION
STANDARD FORM 1103 (REV. 9/2003)
Prescribed by GSA/FMR 102-118

Figure B1 **U.S. bill of lading: government standard form 1103**

Appendix C. Changes in sourcing patterns of capital goods

Table C1 Changes in share of capital goods imports by region of origins

	Share of imports from					
	China			Vietnam		
VARIABLE	(1) By weight (tons)	(2) By volume (TEU)	(3) By number of shipments	(4) By weight (tons)	(5) By volume (TEU)	(6) By number of shipments
DuringPandemic × *IsCapitalGoods*	0.008**	0.007*	0.007*	-0.004***	-0.003***	-0.004***
	(2.016)	(1.906)	(1.793)	(-2.771)	(-2.598)	(-2.888)
DuringPandemic	-0.015***	-0.015***	-0.014***	0.007***	0.006***	0.007***
	(-6.601)	(-6.601)	(-6.469)	(8.802)	(8.563)	(9.059)
IsCapitalGoods	0.025***	0.024***	0.024***	-0.006***	-0.006***	-0.006***
	(7.725)	(7.342)	(7.471)	(-5.500)	(-5.561)	(-5.610)
Controls	Y	Y	Y	Y	Y	Y
Firm FE	Y	Y	Y	Y	Y	Y
Quarter FE	Y	Y	Y	Y	Y	Y
Product FE	Y	Y	Y	Y	Y	Y
Observations	246,146	246,146	246,146	246,146	246,146	246,146
R-squared	0.289	0.290	0.294	0.149	0.147	0.151
	India			North and Central America		
VARIABLE	(7) By weight (tons)	(8) By volume (TEU)	(9) By number of shipments	(10) By weight (tons)	(11) By volume (TEU)	(12) By number of shipments
DuringPandemic × *IsCapitalGoods*	0.001	0.001	0.001	-0.005***	-0.001	-0.004**
	(0.678)	(0.528)	(0.682)	(-2.936)	(-0.902)	(-2.497)
DuringPandemic	0.003***	0.003***	0.003***	0.004***	0.004***	0.004***
	(2.582)	(2.747)	(2.663)	(3.769)	(3.907)	(3.521)
IsCapitalGoods	-0.013***	-0.012***	-0.013***	-0.002	-0.004**	-0.003*
	(-7.849)	(-7.687)	(-7.888)	(-1.299)	(-2.531)	(-1.855)
Controls	Y	Y	Y	Y	Y	Y
Firm FE	Y	Y	Y	Y	Y	Y
Quarter FE	Y	Y	Y	Y	Y	Y
Product FE	Y	Y	Y	Y	Y	Y
Observations	246,146	246,146	246,146	246,146	246,146	246,146
R-squared	0.128	0.129	0.135	0.265	0.149	0.273

Note. $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$ using two-tailed tests. OLS estimates with robust t statistics are in parentheses. Control variables include *Net Income, PPENT, COGS, Cash Efficiency, Gross Margin, Capital Intensity, Sales Growth, Size, ROA, Inventory,* and *Inventory Turnover.*

Table C2 Changes in sourcing frequency and shipment batch size

VARIABLE	(1) Shipments per quarter	(2) Quantity per shipment	(3) Volume per shipment
DuringPandemic × *IsCapitalGoods*	-60.581***	-0.047**	0.236
	(-4.266)	(-2.422)	(1.568)
DuringPandemic	81.302***	0.088***	-0.793***
	(9.706)	(7.677)	(-8.925)
IsCapitalGoods	-100.272***	-0.061***	-0.738***
	(-8.354)	(-3.714)	(-5.792)
Observations	246,146	246,146	246,146
R-squared	0.161	0.123	0.086
Controls	Y	Y	Y
Firm FE	Y	Y	Y
Quarter FE	Y	Y	Y
Product FE	Y	Y	Y
Observations	246,146	246,146	246,146
R-squared	0.161	0.123	0.086

Note. $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$ using two-tailed tests. OLS estimates with robust t statistics are in parentheses. Control variables include *Net Income, PPENT, COGS, Cash Efficiency, Gross Margin, Capital Intensity, Sales Growth, Size, ROA, Inventory,* and *Inventory Turnover.*

Appendix D. Absolute changes in imports by region

Table D1 Changes in total imports by region of origin

	Logarithm of total imports from					
	China			Vietnam		
VARIABLE	(1) By weight (tons)	(2) By volume (TEU)	(3) By number of shipments	(4) By weight (tons)	(5) By volume (TEU)	(6) By number of shipments
DuringPandemic	-0.053***	-0.036***	-0.058***	0.024***	0.013***	0.011***
	(-8.435)	(-9.040)	(-17.559)	(8.845)	(7.956)	(7.624)
Controls	Y	Y	Y	Y	Y	Y
Firm FE	Y	Y	Y	Y	Y	Y
Quarter FE	Y	Y	Y	Y	Y	Y
Product FE	Y	Y	Y	Y	Y	Y
Observations	284,017	284,017	284,017	284,017	284,017	284,017
R-squared	0.395	0.383	0.387	0.183	0.172	0.198
	India			North and Central America		
VARIABLE	(7) By weight (tons)	(8) By volume (TEU)	(9) By number of shipments	(10) By weight (tons)	(11) By volume (TEU)	(12) By number of shipments
DuringPandemic	0.017***	0.008***	0.003*	0.005	0.002	-0.001
	(5.144)	(4.400)	(1.709)	(1.534)	(1.227)	(-0.412)
Controls	Y	Y	Y	Y	Y	Y
Firm FE	Y	Y	Y	Y	Y	Y
Quarter FE	Y	Y	Y	Y	Y	Y
Product FE	Y	Y	Y	Y	Y	Y
Observations	284,017	284,017	284,017	284,017	284,017	284,017
R-squared	0.246	0.230	0.256	0.224	0.175	0.221

Note. $^{*}p < 0.1$, $^{**}p < 0.05$, $^{***}p < 0.01$ using two-tailed tests. OLS estimates with robust t statistics are in parentheses. Control variables include *Net Income, PPENT, COGS, Cash Efficiency, Gross Margin, Capital Intensity, Sales Growth, Size, ROA, Inventory,* and *Inventory Turnover*.