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How Resilient Was Trade to Covid-19?

Abstract

We examine the supply-side characteristics - unskilled labor, imported input intensity, dependence on inputs from China, production complexity - that determine different potential vulnerabilities of traded products to the COVID-19 pandemic. Relying on monthly exports at the product level by all countries to the United States, Japan, and all 27 European Union countries from January 2018 to December 2020, we estimate a difference-in-differences specification of the COVID-19 incidence (deaths per capita) mediated by product vulnerabilities. We account for the precise lag between when the COVID-19 shock hit the exporting country and when exports reach their destination country relying on the products' type of transportation and distance between exporter and importer countries. Higher reliance on foreign inputs, on China as input supplier, on unskilled labor and a lower degree of complexity negatively affected exports as a result of this shock.

JEL-Codes: F140, F610, D200.

Keywords: exports, vulnerability, resilience, Covid-19, shock, high-frequency data.

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Introduction

The sudden onset of the COVID-19 shock in early 2020 resulted in substantial disruptions to economic activities as a large share of the global population was confined at home and a myriad of restrictions aimed at reducing the spread of the virus were put in place. Between January and June 2020, the volume of global trade retraced by 13 percent with a sharp rebound from then onwards as the COVID-19 situation temporarily improved (World Bank, 2020). Global shortages in facial masks, medical equipment, which led many countries to ban their exports, and a negative demand shock accounts for some of trade decrease (Evenett, 2020; Stelliner et al., 2020). The sudden drop in the supply of products from China led to debates on whether the increased exploitation of global comparative advantage, which in the decade prior to COVID-19 turned China into the world's manufacturing powerhouse, had produced a dangerous dependence on global production networks. The unprecedented social distancing restrictions brought by the COVID-19 pandemic presented additional challenges to global production with reductions in in-person production activity.

An unexplored question we address in this paper is which are the supply-side characteristics of products that determined the vulnerability, or its contrary the resilience, of their trade to the pandemic in 2020. We focus on how key characteristics of exported products mediate the impacts of the COVID-19 crisis. The key characteristics follow from the production function framework and regard different inputs (labor, intermediate inputs, and capital) and technology/productivity. The following specific characteristics are considered as potential channels for the effects of the COVID-19 shock on trade: unskilled labor-intensive production, production relying more on imported inputs, on inputs from dominant suppliers and for which China is a dominant supplier, and complex knowledge-intensive production.

Our identification strategy is based on a stringent difference-in-differences specification with bilateral monthly product exports (at Harmonized System (HS) 4-digit level) by all countries to 29 major markets - the 27 European Union (EU) countries, Japan, and the United States (US) - as dependent variable. The main regressors are interaction terms between measures of COVID-19 incidence (death over population) and proxies for production vulnerability. Our measures of COVID-19 incidence account for the distance and transport mode between countries through the use of specific lags at the HS 4-digit product - henceforth HS4 product - and country-pair level. For products that are mostly transported by air a one-month lag is used while for other products the lag length depends on the number of shipping days and the number of days for road transportation between a country pair (if exporter or importer country do not have a port). We capture the effect of the COVID-19 shock by exploring how the response of exports for a given exporting country-importing country pair at the product level over time is mediated by production vulnerability measures. Our specification includes exporting country-importing country-product fixed effects and thereby exploits variation *within* exporting country-importing country-product triplets over time as the pandemic unfolded, relative to the period before the pandemic. Moreover, it includes exporting country-time (month-year) and importing country-time (month-year) fixed effects which control for time-varying unobservable supply and demand shocks affecting exports during this period.

Our main findings are as follows. First, we find that the reliance on inputs for which China is a dominant supplier and unskilled intensity in production resulted in major negative effects of the COVID-19 shock on exports. Specifically, our estimates show that countries with higher COVID-19 deaths per capita decreased their exports of products that rely more on either inputs for which China is a dominant supplier or on unskilled workers. Our findings also suggest that exported products relying more on imported inputs suffered more from the COVID-19 shock. Finally, we find that exports of less complex and knowledge-intensive products were more vulnerable to the COVID-19 shock. Our estimates imply that countries with higher COVID-19 incidence by its median value experience larger declines in exports of: more unskilled labor-intensive products by 1.5 percentage-points, products with a higher reliance on inputs for which China is a dominant supplier by 1.69 percentage points, products with higher reliance on foreign inputs by 0.81 percentage points products, and products with a lower degree of complexity by 1.09 percentage points, with higher vulnerability captured by the difference between the 10th and 90th percentiles of the measures. The findings are robust to the use of alternative measures of production vulnerability and COVID-19 incidence (including the lag structure used), clustering of standard errors, and sample periods.

Second, we identify specific dynamics in the effects of different product vulnerabilities as the pandemic evolved throughout 2020. The negative effects of reliance on imported inputs and unskilled labor were more important in the last quarter of 2020, while the negative effects of reliance on inputs for which China is a dominant supplier were concentrated in the second quarter of 2020 at the onset of the COVID shock.

Third, regarding product type heterogeneity, we find that our main results for the different product vulnerabilities are mainly driven by exports of intermediate products. We interpret this finding as evidence of the importance of global value chains (GVCs) in the transmission of the negative effects of the COVID-19 shock. Regarding country heterogeneity, we find that all product vulnerabilities identified in our main results affected negatively exports by richer countries while for poorer countries stronger negative effects on exports were experienced from unskilled and less complex and knowledge-intensive production and reliance on less diversified foreign input providers.

Fourth, examining the country of origin of input providers, we find that stronger reliance on inputs with major suppliers other than China (Germany, Japan, South Korea and the US) actually had a beneficial impact on exports, a finding that points to supplier diversification being an asset during the pandemic.

Our findings have important policy implications by providing insights into which factors need particular attention for resilience to future shocks. Our evidence suggests that the diversification of input suppliers matters since a higher concentration of input providers and strong reliance on China hurt trade as the COVID-19 shock hit. Proposed approaches range from carefully rethinking global production arrangements to revisiting the very strong reliance on a small set of foreign suppliers and the role of localised production (e.g., Javorcik, 2020). Simply reducing imports is not an option as it would result in considerable cost increases for global production (Baldwin et al., 2021; Grossman et al., 2021; OECD, 2021).

Our evidence also suggests that the further deployment of digital tools to improve virtual collaborations and automation can increase resilience to future pandemics since exports of less complex and knowledge-intensive products and that require unskilled labor inputs fared much worse in face of the COVID-19 shock. Adoption of digital technologies and learning can reduce production vulnerabilities by effectively substituting for in-person collaboration in production. Evidence by Barrero et al. (2022) shows the productivity of remote work increased with the COVID-19 experience. Automation of production can also reduce production vulnerabilities but at the risk of potential negative impacts on unskilled employment (that is more easily replaced by machines) that can only be addressed through investments in worker upskilling and alternative models for revenue sharing in the economy (Guellec and Paunov, 2019; Autor et al., 2020).

The main contribution of our study relative to the growing literature on the pandemic's effects on trade is the emphasis on the role of product resilience to understand those effects. We provide empirical evidence to inform two debates: whether reliance on inputs from abroad and China in particular, caused more vulnerabilities and how social distancing measures affected global production and exports. Thereby, our paper adds to the studies of the impacts of COVID-19 on trade and GVCs (e.g., Bonadio et al. 2021; Cerdeiro and Komaromi, 2020; Demir and Javorcik 2020; Espitia et al. 2021; Socrates, 2020; Crozet et al. 2021). Using cross-country-product-month level data, Berthou and Stumpner (2021) show that lockdown measures implemented by exporter and importer countries impacted trade. Bricongne et al. (2021), Pimenta et al. (2021), and Lucio et al. (2021) also show that lockdown stringency in destination markets reduced, respectively, French, Portuguese, and Spanish firms' exports at the onset of the COVID-19 crisis.

Closer to our work, Liu et al. (2021) show better performance in the early phases of the pandemic of Chinese exports of medical products, products with a high share of work from home, high contract intensity, and capital goods while Lafrogne-Joussier et al. (2021) look into one production vulnerability, the reliance on inputs from China, showing that French firms with higher such reliance suffered more input shortages that translated into a decline in their exports through input-output linkages. These two papers differ from ours in that they focus on single countries' exports (China and France) and single or few specific dimensions of how production was affected by COVID-19 while our analysis covers exports by all countries to the 29 largest markets and an encompassing set of product vulnerability dimensions. Differently from these studies, our paper shows where vulnerabilities in global product supply arose in the short-term and helps identify the costs and benefits of building more resilience.

Our study also relates to the literature that studies the responses of trade to other crises and shocks. An important branch focuses on the 2008-2009 global financial crisis and the causes of the ensuing dramatic decline in trade (Ahn et al., 2011; Amiti and Weinstein, 2011; Behrens et al., 2012; Bricongne et al., 2012; Chor and Manova, 2012; Crozet et al., 2020; Levchenko et al., 2010; Eaton et al., 2016a). Another branch studies the effect of natural disasters on trade and GVCs (Gassebner et al., 2010; Barrot and Sauvagnat, 2016; Boehm et al., 2019; Carvalho et al., 2021) while another explores the international transmission of foreign shocks (e.g., Johnson, 2014; Eaton et al., 2016a, 2016b). In addition to examining the unprecedented COVID-19 crisis, our paper differs from these studies by focusing on the drivers of trade resilience. Our identification of concrete vulnerabilities helps to pinpoint factors that need to be considered by policies aimed at building resilience.

The paper is organized as follows. Section 1 presents a conceptual discussion for the hypotheses we test. Section 2 describes the data while Section 3 discusses the empirical approach. Our results are presented in Section 4. Section 5 concludes.

1. Conceptual discussion and testable hypotheses

To guide our empirical analysis, we identify potential vulnerabilities or resilience of exports to the COVID-19 shock within a standard production function framework. Consider exports of Y produced using four inputs unskilled labor (U), skilled labor (S), intermediate inputs (I), capital (K): $Y = f(A, U, S, I, K)$, where A is total factor productivity, capturing everything in the production process related to the effective combination of a set of inputs to produce an output. The COVID-19 shock affected export production through all production factors.

First, the COVID-19 shock reduced overall in-person labor supply due to social distancing to avoid infection and lockdowns imposed by governments to address the shock. This labor supply shock is relevant for all economic activities that are not possible to execute from home, especially in manufacturing production chains that are less susceptible to automation. Given the differential nature of their tasks, this shock affected mostly unskilled labor since highly skilled labor was able to continue to work from home. As highly skilled workers shifted to remote work substituting in-person for virtual exchanges, the COVID-19 shock may have benefited production intensive in such workers in contrast to less complex and knowledge-intensive production processes. This hypothesis is supported by evidence in Barrero et al. (2021) that workers in higher earnings categories experienced productivity gains from remote work during the COVID-19 period. Our first hypothesis to test in the empirical work is as follows:

H1: A larger unskilled labor intensity of production was a source of vulnerabilities in the COVID-19 pandemic.

Second, the COVID-19 shock is expected to affect intermediate inputs and capital due to global disruptions in their production and trade. Thus, products that rely on foreign-produced inputs are likely to be more negatively affected by the pandemic. Moreover, supply chains relying on a poorly diversified portfolio of input suppliers may be at higher risk of disruption and less able to absorb a dramatically adverse shock affecting production or trade from specific origin countries. In the early COVID-19 phase, the disruption of production in China is expected to have greatly hindered the production processes of manufacturing GVCs highly dependent on Chinese imports.[1] Our second hypothesis to test in the empirical work is as follows:

[1] Such high dependence may be due to comparative advantage, specialization, and economies of scale of Chinese suppliers in the production of such inputs.[2] See https://github.com/owid/COVID-19-data/tree/master/public/data.

H2: Exports of intermediate inputs and capital goods relying more heavily on imported intermediates were more vulnerable to the pandemic. Further, downstream production and exports relying strongly on intermediates and capital goods for which either exports are highly concentrated in a few producer countries or the main world supplier is China were more vulnerable to the pandemic.

The COVID-19 shock may have adversely affected productivity due to reduced mobility and the disruption in in-person production activities that were dominant across the economy (Barrero et al., 2021) but less so for more complex and knowledge-intensive products. This is because, for such products, productivity relies more critically on knowledge collaborations that were effectively shifted to virtual exchanges. This also relates to our hypothesis 1 that unskilled-intensive production was more affected by the COVID-19 shock. The exponential growth of virtual online interactions for research and innovation collaborations - critical for productivity - and the wider use of virtual platforms have proven to be highly effective as is illustrated by the surprisingly quick responses to the pandemic, namely the rapid development of vaccines (Paunov and Planes-Satorra, 2021). Our third hypothesis to test in the empirical work is as follows:

H3: The productivity of complex and knowledge-intensive production processes may increase relative to that of less complex and knowledge-intensive processes since the former benefited more from remote work interactions. Hence less complex and knowledge-intensive products were more vulnerable to the pandemic.

2. Data

High-frequency bilateral product level trade data

Our analysis relies on several sources of data. For trade outcomes, we use monthly data on import flows at product level by the major markets of the 27 EU countries, Japan, and the US from January 2018 to December 2020. The specific sources of data are, respectively, Eurostat monthly trade flows for EU countries, the Ministry of Finance for Japan, and the United States International Trade Commission for the US. All datasets are similar in structure and content: they include the country's import flows from all partner countries for each product at a HS 6-digit or 8-digit level providing information on import value (in US dollars) and quantity or weight. We aggregate the data to the importing country-HS4 product-partner country-month-year level concording product codes to the HS 2007 revision. The aggregation to the HS4 level is chosen for comparability across countries, computational feasibility and mirrors the product resilience categories we rely on.

These data are exploited to examine the evolution of export flows by all countries to these major markets - that represented half of global GDP and 28% of global imports pre-COVID-19 - as the pandemic unfolded. Using mirror import data to capture export flows has two advantages. First, import flows are better recorded than export flows, especially by high-income low-corruption countries such as our major markets (e.g., Javorcik and Narciso, 2017). Second, import flows are reported and made public quickly by those high-income countries while high-frequency export flows from all countries are reported with long delays to UN COMTRADE. Summary statistics on the trade data are provided in Appendix Table 1.

COVID-19 incidence data

For COVID-19 incidence, we use the total number of reported COVID-19 deaths per capita per month in each country from the World Health Organization (WHO) Global Health Observatory Repository from December 2019 onward.[2] In robustness tests, we consider two alternative measures of COVID-19 incidence: the number of COVID-19 cases per capita also from the WHO and a measure of stay-at-home requirements imposed by each country each month from the Oxford COVID-19 Government Response Tracker.[3] The latter measure captures the stringency of the economic lockdowns in place and is used in emerging research on COVID-19 impacts (e.g., Bonadio et al., 2021; Chen et al., 2020; Fernandez-Villaverde and Jones, 2020).[4] Summary statistics on the COVID-19 measures are provided in Appendix Table 1.

Defining lag structure of impacts

Exporting involves lags between the departure from the exporting country and arrival to the destination country. Since we rely on import data by major destination countries to study of the impacts of COVID-19 incidence in the exporting country, it is crucial to carefully define the lag structure for the impacts. For example, identification critically relies on understanding if India's exports recorded by the US (as imports) in October 2020 were expedited from India in June, July, August, or September 2020. Previous studies argue that shipment times average 2-3 months (Brincogne et al., 2012). But these times depend on the transportation mode which varies with the type of product. Continuing with the example, we may mistakenly attribute India's September

[2] See https://github.com/owid/COVID-19-data/tree/master/public/data.
[3] See https://www.bsg.ox.ac.uk/research/research-projects/coronavirus-government-response-tracker#data.
[4] Some caveats of the COVID-19 incidence measures we use, deaths and cases per capita, are that they may be underreported due to lack of systematic testing or access to healthcare facilities, or to asymptomatic patients. Deaths of patients due to co-morbid conditions may not be included among COVID-19 deaths in settings with insufficient testing, which further underestimates the fatality rate of the pandemic.

2020 COVID-19 incidence to products already expedited in July 2020. This is supported by evidence from Flaaen et al. (2021) who use daily data from bill of lading information for US imports and Indian exports to show that India's national lockdown announced on March 24, 2020 led to a decline in India's exports to the US recorded in US import data only 5-10 weeks later due to shipping lags.

Consequently, we apply a product-specific origin-destination country lag structure for the COVID-19 incidence variable's impact on trade combining US Census data on HS4 imports by transportation mode in 2015 with searates.com data on shipping days between capital cities as of early 2020 as follows:

(i) For HS4 products whose share of imports by air transport is above 75 percent, a one-month lag is used;

(ii) For the remaining HS4 products, the lag length depends on the number of shipping days between the country pair: one-month for less than 7 shipping days, two-month for 7 to 29 shipping days, three-month for 30 to 59 shipping days, and four-month for more than 60 shipping days.

(iii) For landlocked exporter and/or importer countries, we add the number of days needed to transport goods by road from (or to) the closest port to (or from) the capital using the shortest road distance. This approach uses information contained in Google Maps on travel times using the drive mode and follows Akbar et al. (2018) and Zarate (2021).

Product vulnerability measures

We rely on several data sources to construct proxies for production resilience. First, we use data from US NBER-CES Manufacturing Industry Database on the unskilled labor intensity of production: the ratio of unskilled (blue-collar) employment to capital for each 6-digit 1997 NAICS industry in 2011 (the most recent year available). We map the 1997 NAICS industries into HS4 revision 2007 products using a concordance from Pierce and Schott (2012). Our unskilled intensity measure varies at the HS4 product level.

Second, we rely on OECD's harmonised input-output tables for 2011 to compute sectoral imported input contents following Hummels et al. (2001).[5] We compute the reliance of production on imported inputs as the ratio of imports over the sum of output plus imports minus exports by ISIC 2-digit industry and exporting country. We then map the ISIC 2-digit revision 3 classification to our HS4 revision 2007 products. Using a measure with country variation (from the input-output table) is important to account for the fact that different countries source different inputs. Our imported input reliance measure varies at the exporting country and HS4 product level.

Third, we use export data from UN COMTRADE at the exporting country-HS4-year level combined with the aforementioned OECD harmonized input-output tables to construct measures of (i) the reliance on China as a supplier of inputs for production of each sector and (ii) the concentration (across producer countries) in the exports of intermediates used by a sector. To obtain (i), we calculate for each HS4 product the share of China in the product's world exports in 2015. We average this share by ISIC revision 3 broad sector (the classification used in the input-

[5] OECD input-output tables are available for 63 countries (all 36 OECD countries and a variety of other countries including several developing countries). Since our monthly trade data cover exports for an additional 158 countries with no OECD input-output tables we assign to each of those countries the input-output table from the country that is most similar in terms of three dimensions: level of development captured by GDP per capita, size captured by population and economic structure capture by share of manufacturing value added, all from World Development Indicators. We assign to countries with no input-output table, the table of the country with the lowest aggregate difference across the three dimensions, which we aggregate using inverse-variance weighting.

output tables), after mapping HS4 products to broad sectors. Then, we use each country's input-output table to construct for each given broad sector X the reliance on China as supplier of its inputs as the weighted average across all the broad sectors' average China share, where weights are given by the shares of inputs from each broad sector used for production of broad sector X's output. To obtain (ii), we calculate for each HS4 product the share of its largest exporter in the world in 2015. Then, we use each country's input-output table to construct for each given broad sector X the export concentration of its inputs as the weighted average across all the broad sectors' average share of the largest exporter, where weights are given by the shares of inputs from each broad sector used for production of broad sector X's output. We then map these two measures at the broad sector level into the HS4 level. The resulting measures vary at the exporting country and HS4 product level. Allowing for these two dimensions of variability is important since different countries are likely to source very different inputs.

Fourth, as a proxy for technology, we use product complexity at the HS4 product level defined as the weighted average of the GDP per capita of the countries that export the HS4 product, where weights are given by countries' revealed comparative advantage (RCA) index in that product following Hausmann and Hidalgo (2009, 2011). We compute this RCA (Balassa) index, the ratio between the share of an HS4 product in a country's export portfolio and the share of the same product in world exports, using data from UN COMTRADE and GDP per capita data from the World Development Indicators for 2012.

Finally, as a control variable we use an indicator for COVID-19 medical products from the World Trade Organisation at the HS4 product level.[6]

[6] http://www.wcoomd.org/-/media/wco/public/global/pdf/topics/nomenclature/covid_19/hs-classification-reference_2_1-24_4_20_en.pdf?la=en.

3. Empirical approach

Our empirical specification to test the hypotheses discussed in Section 2 consists in a difference-in-differences specification that estimates the within effect of the COVID-19 shock on bilateral exports to each major market mediated by proxies for production vulnerability or resilience as in:

$$Y_{eipt} = \sum^{v} \beta_v \ covid\_incid_{et-n} * vulnerability_{v,p} + \sum^{v} \varphi_v \, covid\_incid_{et-n} * vulnerability_{v,ep} + \sum \alpha \ covid\_incid_{et-n} * X_p + k_{eip} + \theta_{et} + \pi_{it} + \varepsilon_{eipt} \qquad (1)$$

where Y_{eipt} is the logarithm of the value of exports by country e of HS4 product p to destination market i in month-year t and ε is an independent and identically distributed error term. The coefficients of interest (β_v, φ_v) are those on the interactions between each of the measures of $vulnerability_{v,p}$ at the product level (unskilled labor intensity and complexity) or $vulnerability_{v,ep}$ at the product-exporting country level (reliance on imported inputs, export concentration of inputs, and China export share in inputs) and lagged COVID-19 incidence $covid_{incid_{et-n}}$ is the number of reported COVID-19 deaths per capita per month in each exporting country using the lags defined in Section 2 related to transport mode and shipping times.

By including exporting country-importing country-HS4 product fixed effects k_{eip}, Equation (1) identifies the coefficients based on the within (time-series) variation in bilateral export flows at the product level as the COVID-19 shock unfolds. Other fixed effects also play a crucial role. Exporting country-month-year fixed effects θ_{et} account for changes in economic conditions in the exporting country related or unrelated to the COVID-19 shock that may affect their exports (e.g., exchange rate shocks or any other supply shifters). Importing country-month-year fixed effects π_{it} account for the COVID-19 incidence in the destination markets and any changes in economic conditions that may affect their imports (e.g., exchange rate shocks or any other demand shifters).[7]

To address the possibility that our coefficients of interest might pick up the impact of other product characteristics correlated with product resilience, the vector X_p includes the indicator for COVID-19 medical products whose demand increased due to the COVID-19 shock. We estimate Equation (1) by OLS. Inference is based on robust standard errors clustered by exporting country and the most aggregate product characteristic (unskilled-intensive products) referred to as broad sector. Our findings are robust to clustering by exporting country and HS4 product.

4. Results

Baseline results

The results from estimating the effects of COVID-19 incidence on trade flows depending on product vulnerability are presented in Table 1. We first explore the effect of the shock on trade flows by simplifying Equation (1) to include only the number of reported COVID-19 deaths per capita per month in each exporting country. The estimates in columns (1) and (2) suggest that countries with more COVID-19 deaths reduce more their exports on average across all products over time. This finding is in line with those by Berthou and Stumpner (2021) and Liu et al. (2021) using bilateral product-level trade data and by Bricongne et al. (2021) using French firm-level export data.

Next, we test the hypotheses discussed in Section 1 exploring the heterogeneous effect of the shock on trade flows depending on product resilience or vulnerability focusing on column (7)

[7] Exporting country-month-year fixed effects also account for COVID-19 incidence in levels included in the interaction model while production vulnerabilities in levels are embedded in the panel fixed effects (exporting country-importing country-product).

with all interactions included. Our estimates show that countries with a higher incidence of COVID-19 deaths reduce relatively more their exports of unskilled labor-intensive products. This finding supports our first hypothesis that unskilled labor-intensive production is a source of vulnerabilities during the COVID-19 pandemic due to social distancing, lockdowns, and business closures imposed by governments that disrupted production.

Next, we study the effects of the COVID-19 shock on exports depending on GVC integration. First, we investigate if the effects depend specifically on the reliance of production on intermediate inputs for which China is a dominant supplier. Our estimates show that exports of products that rely more on inputs for which China is a dominant supplier declined more in countries with a higher incidence of the COVID-19 shock. Second, we examine if the effects depend on the reliance on imported intermediate inputs more generally. Our estimates show that exports of products more involved in GVCs were more adversely affected by the COVID-19 shock. Third, we look at whether the effects depend on the concentration of the exports of intermediates inputs used by a sector measured by the share of the largest exporter in the product's world exports in 2015. We do not find a significant additional effect of such export concentration. These findings confirm our second hypothesis on the effect of COVID-19 on trade via global supply chain vulnerability.

Then, we investigate our third hypothesis on the effect of COVID-19 on trade flows depending on the complexity of the exported good. Our estimates reveal that more complex products were more resilient to the COVID-19 shock. This may be a consequence of increased productivity of skilled workers working on such products during the shock despite stay-at-home policies due to an exponential growth of virtual online interactions.

All in all, our main results suggest that the key product vulnerabilities adversely affecting exports during the pandemic were related to the nature of the inputs used, unskilled labor as well as intermediate inputs imported, while more complex products were more resilient to the COVID-19 shock. Our estimates in column (7) of Table 1 imply that countries with higher COVID-19 incidence by its median value (0.66) experience a 1.5 percentage-point larger decline in exports of products at the 90th relative to the 10th percentile of the unskilled labor intensity, corresponding to a decrease by 1,074 million USD in median exports.[8] A similar increase in COVID-19 incidence decreases exports of products with a higher reliance on inputs for which China is a dominant supplier by 1.69 percentage points and exports of products with higher reliance on foreign inputs by 0.81 percentage points which correspond to decreases in median exports of 1,199 and 574 million USD, respectively. Finally, a similar increase in COVID-19 incidence leads to a decrease in exports of products with lower complexity by 1.09 percentage points which corresponds to a 777 million USD decrease in median exports.

Heterogeneity of COVID-19 impacts: products, countries, and time

In this section, we investigate further the role played by the type of products and of exporting country for the impacts of the COVID-19 shock on exports. First, we split our sample into exported final, intermediate, and capital goods following the Broad Economic Categories (BEC) definition of the United Nations and estimate Equation (1) for each subsample. Results are presented in columns (1) to (3) of Table 2. The estimates show that our baseline effects of the

[8] Designating the 10th and 90th percentiles of the unskilled labor intensity measure as *vulnerability_p10* and *vulnerability_p90* and the median of the COVID-19 incidence as $covid\_incid\_med$, this economic magnitude is computed as (β_v * *vulnerability_p90* - β_v * *vulnerability_p10)* * $covid\_incid\_med$. Appendix Table 1 provides the means, standard deviations, 10th and 90th percentiles for all variables.

COVID-19 shock depending on the resilience of products are mostly arising from the effects on intermediate products. We interpret this finding as further evidence on the importance of GVCs as conduits for the propagation of the COVID-19 shock.

In order to understand whether the level of development of the exporting country explains the highly heterogeneous effects of the COVID-19 crisis, we interact our main interaction terms between measures of product vulnerability and COVID incidence separately with an indicator variable for rich countries (high-income countries in the World Bank classification) and an indicator variable for poorer countries (non-high-income). Column (4) of Table 2 shows a statistically stronger impact of the COVID-19 on exports of poorer countries for products that are less complex and that rely intensively on a less diversified portfolio of input suppliers. However, we also identify negative effects of the COVID-19 incidence on rich countries' exports for products that rely more heavily on foreign inputs and on inputs for which China is a dominant supplier.

In the last columns of Table 2, we add controls for the effect of product reliance on inputs for which countries other than China are the main global suppliers. Column (5) shows that exports of products that rely on intermediate inputs from one of the other leading four input suppliers – the Germany, Japan, South Korea and the US – were not negatively but instead were positively affected by the COVID-19 shock. This may be due to the greater stability of supplies from their combined production during the pandemic. The negative impact of reliance on intermediate inputs from China remains significant.

Finally, we investigate the dynamic effects of the COVID-19 shock depending on product vulnerability as the pandemic unfolded throughout 2020. We extend our baseline estimation to include interactions between the three last quarters of 2020 and our measures of product vulnerability interacted with COVID-19 incidence. We plot the estimated coefficients on the interactions with the different quarters in Figure 1. The negative effects of the COVID-19 shock on exported products that rely more on imported inputs, on inputs whose export supply is concentrated, and that are unskilled-intensive are more important in the last quarter of 2020, while the negative effects on exports of products that rely more on inputs for which China is a dominant supplier were concentrated in the second quarter of 2020 when the COVID shock started. This is intuitive and reflects the timing of the initial COVID-19 shock that hit China first and then affected other countries and consequently their inputs.

Robustness tests

In this section we present robustness tests conducted on our baseline results. First, we explore three alternative measures of product vulnerabilities or resilience. Regarding product complexity, we consider the Rauch (1999) differentiated products and the Nunn (2007) input contractability intensity measures that either identify products that are not sold on an organized exchange nor reference-priced or measure the share of intermediate inputs used by a sector that require customized or relationship-specific investments both at the HS4 product level. Additionally, we consider R&D intensity of the sector constructed as the ratio of R&D spending (in million US dollars) from the US National Science Foundation to the size of the industry (total value of shipments) from the U.S. Census Bureau's Annual Survey of Manufactures both for 2015 and converted from NAICS 5-digit sectoral to our HS4 product level. Results are reported in columns (1) to (3) of Table 3. The effect of COVID-19 incidence on exports of differentiated products, high-contractability products and R&D-intensive products is always positive and significant in line with our previous results using product complexity. These findings suggest that exports of more complex and knowledge-intensive products were less vulnerable to the COVID-19 shock.

Second, we use an alternative measure of the reliance of production on inputs from China, the share of production inputs for which China is the dominant supplier. Column (4) of Table 3 shows the results are maintained using this measure.

Third, we account for an important trade policy development occurring over our sample period: the China-US tariff war. While most tariffs were imposed by the US prior to the pandemic, there could be delayed responses and heterogeneous effects across countries as shown by Fajgelbaum et al. (2021). Hence, we add to our specification in column (5) of Table 3 an interaction between an indicator variable for the products subject to increased US tariffs taken from Bown (2021) and COVID-19 incidence. The coefficient on the interaction term is insignificant and all other results are maintained.

Fourth, we carry out additional robustness tests related to the sample period and the COVID-19 measures used. Column (1) of Table 4 shows that our findings are robust to the use of a shorter sample period starting in January 2019. Columns (2) and (3) show that our estimates are robust to the classical way of lagging the COVID-19 incidence measure using one- or two-month lags instead of the specific lags defined in Section 2. The last two columns of Table 4 show robust results when using alternative measures of COVID-19 incidence relying on total cases per capita (column (4)) and stay-at-home requirements (column (5)).

Fifth, we investigate the effects of the pandemic on export quantities (measured by weight) and unit values (defined as values divided by weight). Columns (1) and (2) of Table 5 show that the effects of the COVID-19 shock on export quantities depending on product vulnerability are qualitatively similar to those on export values. However, the effects differ for unit values. The

COVID-19 shock reduces significantly export prices only for products that rely on a less diversified portfolio of input suppliers but increases prices for products whose inputs have China as a dominant supplier. The latter finding hints at the role of supply disruptions due to the impact of COVID-19 in China itself.

Sixth, columns (3) to (5) of Table 5 show that our findings are robust to the exclusion from our sample of China or the US as exporting country and medical products. Unreported estimates available upon request show the results are maintained dropping each destination market at a time.

Lastly, to account for COVID-19 as a demand shock we add to our specification interactions between COVID-19 incidence and two sets of products with divergent demand trends due to the pandemic: home office products whose demand likely increased due to work from home (column (6)) and outdoor activity products such as ski boots whose demand likely decreased due to lockdowns (column (7)).[9] The estimates confirm the demand conjectures and do not change our baseline results.

5. Conclusion

In this study we show that the nature of the inputs used - a higher reliance on unskilled labor, on imported inputs and on inputs for which China is a dominant supplier and less complex and knowledge-intensive products - are the main production vulnerabilities which negatively impacted global exports to the EU, Japan, and US due to the COVID-19 shock in 2020. These product vulnerabilities hit both developing and developed economies.

Our evidence can inform debates on building more resilience to future shocks of similar or different nature than COVID-19. The first finding on the effects of concentration and reliance on

[9] Home office products are defined HS4 8471, 8443, 8525, 8528, 8517, 8518 and 9403 and outdoor products are taken from Lucio et al. (2021).

Chinese imports is about diversification of production inputs showing that low diversification has strong immediate effects. The second, less debated to date in light of resilience, is the vulnerabilities caused by the challenge of organising in-person production (affecting less skilled production). These point to the benefits of wider automation and a more extensive exploration of remote collaborations for resilience to future shocks, in addition to their benefits for productivity (Barrero et al., 2021).

References

Akbar, Prottoy A., Victor Couture, Gilles Duranton, and Adam Storeygard (2018). “Mobility and congestion in urban India,” NBER Working Paper 25218.

Amiti, M., Kong, S.H and D. Weinstein, (2020), “The Effect of the U.S.-China Trade War on U.S. Investment,” NBER Working Paper 27114.

Amiti, M., and D. Weinstein, (2011), “Trade Finance and the Great Trade Collapse,” *American Economic Review Papers & Proceedings*, 101(3), 298–302.

Autor D., Dorn D., Katz L., Patterson C., Van Reenen J., (2020), “The Fall of the Labor Share and the Rise of Superstar Firms. *The Quarterly Journal of Economics* 135(2), 645-709.

Baldwin, R. and S. Evenett (2020), *COVID-19 and Trade Policy: Why Turning Inward Won’t Work*, CEPR Press 2020.

Barrot, J. and J. Sauvagnat, (2016). “Input specificity and the propagation of idiosyncratic shocks in production networks,” *The Quarterly Journal of Economics*, 131(3), 1543-1592.

Behrens, K., Coreos, G., and G. Mion, (2013), “Trade crisis? What trade crisis?,” *Review of Economics and Statistics* 95(2), 702-709.

Berthou, A. and Stumpner, S. (2021), “Trade Under Lockdown”, Mimeo.

Barrero, Jose Maria, Nicholas Bloom, and Steven J. Davis (2021). Why working from home will stick. National Bureau of Economic Research, No. w28731.

Bonadio, B., Huo, Z., Levchenko, A., and N. Pandalai-Nayar, (2021), “Global Supply Chains in the Pandemic” *Journal of International Economics*, 133, 103534.

Boehm, J., Dhingra, S. and J. Morrow, (2019), “The comparative advantage of firms,” CEP discussion paper dp1614.

Boehm, C., A. Flaaen, and N. Pandalai-Nayar, (2019), “Input linkages and the transmission of shocks: firm-level evidence from the 2011 Tōhoku earthquake” *Review of Economics and Statistics*, 101(1): 60-75.

Bown, C. (2021), The US-China Trade War and Phase One Agreement, Peterson Institute for International Economics, Working Paper, 21-2.

Bricongne, J.-C., L. Fontagne, G. Gaulier, D. Taglioni, and V. Vicard, (2012), “Firms and the global crisis: French exports in the turmoil,” *Journal of international Economics* 87(1), 134–146.

Bricongne, J.-C., J. Carluccio, L. Fontagne, G. Gaulier, D. and S. Stumpner (2021), "From Macro to Micro: Heterogeneous Exporters in the Pandemic", mimeo.
Carvalho, V., M. Nirei, Y. Saito, and A. Tahbaz-Salehi, (2021), "Supply chain disruptions: Evidence from the great east japan earthquake," *The Quarterly Journal of Economics* 136(2), 1255–1321.

Cerdeiro, Diego and Andras Komaromi, (2020), "Supply Spillovers During the Pandemic: Evidence from High-Frequency Shipping Data." International Monetary Fund Working Paper Series 284.

Chor, D. and K. Manova, (2012), "Off the cliff and back? Credit conditions and international trade during the global financial crisis," *Journal of International Economics*, 87(1), 117-133.

Cristea, A., (2011), "Buyer–seller relationships in international trade: Evidence from US States' exports and business-class travel," *Journal of International Economics* 84(2), 207–220.

Crozet, M., Demir, B. and B. Javorcik, (2021), "International trade and letters of credit: A double-edged sword in times of crises", *IMF Economic review* forthcoming.

di Giovanni, J, A. Levchenko and I. Mejean (2020), "Foreign Shocks as Granular Fluctuations," NBER Working Paper 28123.

Demir, B. and B. Javorcik, (2020), "Trade finance matters: Evidence from the COVID-19 crisis," *Oxford Review of Economic Policy*, *36*(Supplement_1), S397–S408.

Eaton, J., Kortum, S., Neiman, B., and J. Romalis, (2016a), "Trade and the Global Recession," *American Economic Review*, 106(11), 3401–38.

Eaton, J., Kortum, S. and B. Neiman, (2016b), "Obstfeld and Rogoff's international macro puzzles: a quantitative assessment," *Journal of Economic Dynamics and Control,* 72 (C), 5–23.

Espitia, A., Mattoo, A., Rocha, N., Ruta, M. and D. Winkler (2020). "Pandemic Trade," World Bank mimeo.

Evenett, S. (2009), "Crisis-era Protectionism One Year after the Washington G20 Meeting', ch. 5 in R. Baldwin (ed.), *The Great Trade Collapse: Causes, Consequences and Prospects*, VoxEU.org, 37–45.

Evenett, S. (2020), "Flawed prescription: Export curbs on medical goods won't tackle shortages," in Baldwin, R. and S. Evenett (2020), COVID-19 and Trade Policy: Why Turning Inward Won't Work, CEPR Press 2020.

Fajgelbaum, P., Goldberg, P., Kennedy, P., Khandelwal, A. and D. Taglioni. (2021), "The US-China Trade War and Global Reallocations," NBER Working Paper 29562.

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

Fernández-Villaverde, J., and C. Jones, (2020). "Macroeconomic Outcomes and COVID-19: A Progress Report," NBER Working Paper 28004.

Fujiy, B., Ghose, D., and G. Khanna, (2021). "Production Networks and Firm-level Elasticities of Substitution," mimeo.

Gassebner, M., Keck, A., and R. Teh, (2010), "Shaken, Not Stirred: The Impact of Disasters on International Trade," *Review of International Economics*, *18*(2), 351–368.

Gourinchas, P.-O., Kalemli-Özcan, Ṣebnem, Penciakova, V., and N. Sander, (2020), "COVID-19 and SME Failures," NBER Working Paper 27877.

Guellec, D. and C. Paunov (2017). "Digital innovation and the distribution of income", NBER Working Paper 27877.

Hausmann, R. and C. Hidalgo (2011), "The network structure of economic output," *Journal of Economic Growth*, 16, 309-342.

Hidalgo, C. and R. Hausmann (2009), "The building blocks of economic complexity," *Proceedings of the National Academy of Sciences*, 106, 10570-10575.

Hummels, D., Ishii, J., and K.-M. Yi, (2001), "The Nature and Growth of Vertical Specialization in World Trade," *Journal of International Economics*, 54, 75–96.

Javorcik, B. (2020), "Global supply chains will not be the same in the post-COVID-19 World," in Baldwin, R. and S. Evenett (2020), *COVID-19 and Trade Policy: Why Turning Inward Won't Work*, CEPR Press 2020.

Johnson, R., (2014), "Trade in Intermediate Inputs and Business Cycle Comovement," *American Economic Journal: Macroeconomics*, 6 (4), 39–83.

Hynes, W. et al. (2020), "A Systemic Approach to Dealing with COVID-19 and Future Shocks, OECD New Approaches to Economic Challenges Brief, http://www.oecd.org/naec/projects/resilience/NAEC_Resilience_and_COVID19.pdf

Hovhannisyan, N. and W. Keller, (2015), "International business travel: an engine of innovation?,". *Journal of Economic Growth* 20, 75–104.

Lafrogne-Joussier, R., J.Martin and I. Mejean (2021), "Supply shocks in supply chains: Evidence from the early lockdown in China", First draft, prepared for the 2021 Jacques Polak Annual Research Conference.

Levchenko, A., L. Lewis, and L. Tesar, (2010), "The collapse of international trade during the 2008–09 crisis: in search of the smoking gun," *IMF Economic review*, *58*(2), 214-253.
Liu, X, E. Ornelas, and H, Shi (2021), The Trade Impact of the Covid-19 Pandemic, CESifo WP. 9109 2021.

Mas, A. and E. Moretti, (2009), "Peers at Work." *American Economic Review*, 99 (1): 112-45.

Miroudot, S. (2020), "Resilience versus robustness in global value chains: Some policy implications, VoxEU June 18 2020.

Nunn, N. (2007), "Relationship-specificity, Incomplete Contracts and the Pattern of Trade', *Quarterly Journal of Economics*, 122(2), 569–600.

Pierce, J. and Schott, P. (2012), "A Concordance between Ten-Digit U.S. Harmonized System Codes and SIC/NAICS Product Classes and Industries".

Pimenta, A., Gouveia, C. and J. Amador, (2021). "COVID-19, Lockdowns and International Trade: Evidence from Firm-Level Data," Working Papers w202114, Banco de Portugal, Economics and Research Department.

Rauch, J. (1999), "Networks versus markets in international trade." *Journal of international Economics*, 48 (1): 7-35.

Socrates, M., (2020). "The Effect of Lockdown Policies on International Trade Flows from Developing Countries: Event Study Evidence from Kenya," Working paper, University of Nairobi, Kenya.

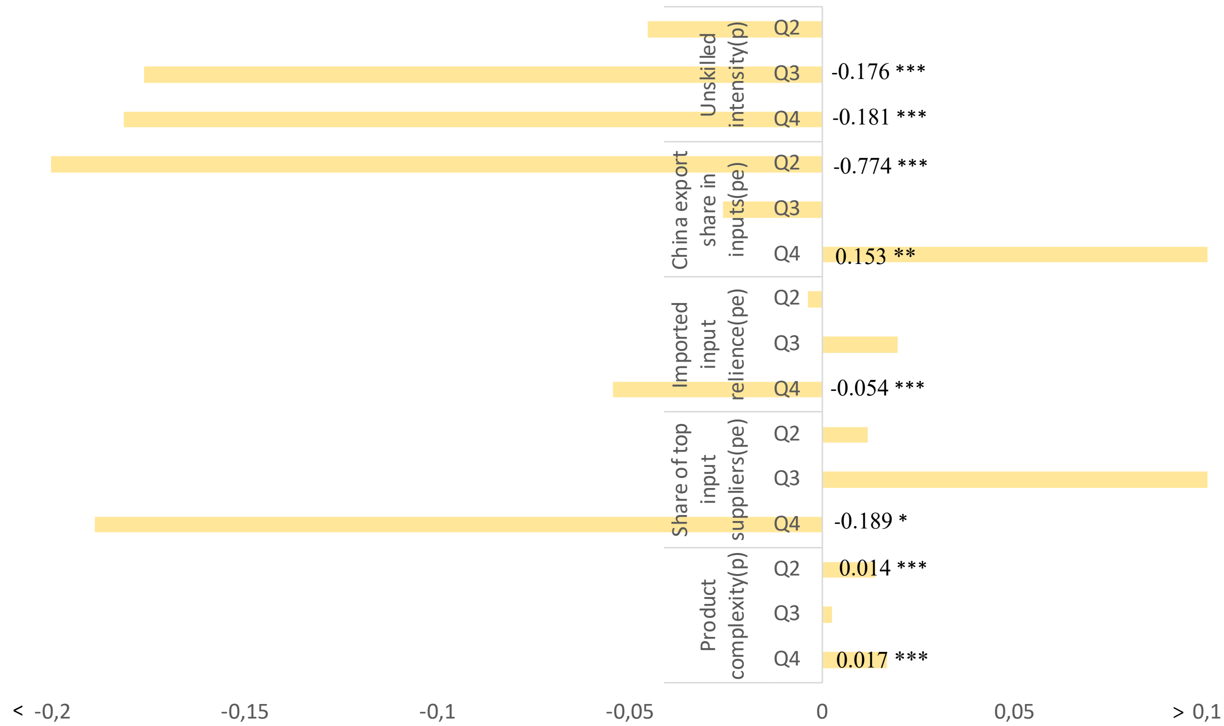
Startz, M., (2018), "The value of face-to-face: Search and contracting problems in Nigerian trade," Stanford University mimeo.

Stelliner, A., Berglund, I and H. Isakson (2020), "How trade can fight the pandemic and contribute to global health, in Baldwin, R. and S. Evenett (2020), COVID-19 and Trade Policy: Why Turning Inward Won't Work, CEPR Press 2020.

World Bank (2020). "COVID-19 Trade Watch," various issues, Washington, DC: World Bank, https://www.worldbank.org/en/topic/trade/brief/trade-watch.

Zarate, R. (2021). "Spatial Misallocation, Informality, and Transit Improvements: Evidence from Mexico City" World Bank mimeo.

Figure 1: Dynamic effects of COVID-19 incidence on exports depending on product resilience



Notes: The figure plots the estimates of the following equation $Y_{eipt} = \sum_4^q \gamma_q \, covid\_incid_{et-n} * X_p * Q_n + k_{eip} + \theta_{et} + \pi_{it} + \varepsilon_{eipt}$. Robust standard errors clustered by exporting country and broad sector used.$***$, $**$, and $*$ indicate significance at the 1, 5 and 10 percent levels respectively.

Table 1: The effect of COVID-19 incidence on exports depending on product resilience

Dependent variable:	Export value by country e of product p to destination market i in time t						
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Death rate(e,t-n)	-0.025***	-0.009**					
	(0.004)	(0.004)					
Death rate(e,t-n) x Unskilled intensity(p)			-0.040***				-0.131***
			(0.007)				(0.030)
Death rate(e,t-n) x China export share in inputs(pe)				-0.098***			-0.185**
				(0.031)			(0.072)
Death rate(e,t-n) x Imported input reliance(pe)					-0.020***		-0.022*
					(0.007)		(0.013)
Death rate(e,t-n) x Share of top input suppliers(pe)						-0.047***	-0,093
						(0.011)	(0.088)
Death rate(e,t-n) x Product complexity(p)							0.014***
							(0.004)
Death rate(e,t-n) x Medical supplies goods(p)			0.103***	0.106***	0.104***	0.105***	0.096***
			(0.011)	(0.011)	(0.011)	(0.011)	(0.011)
Product-exporting country-importing country fixed effects	yes	yes	yes	yes	yes	yes	yes
Exporting-country-time (month-year) fixed effects			yes	yes	yes	yes	yes
Importing-country-time (month-year) fixed effects		yes	yes	yes	yes	yes	yes
Observations	8,624,108	8,624,108	8,624,108	8,624,108	8,624,108	8,624,108	8,624,109
R-squared	0.863	0.866	0.866	0.866	0.866	0.866	0.867

Notes: Robust standard errors clustered by exporting country and broad sector in parentheses. ∗∗∗, ∗∗, and ∗ indicate significance at the 1, 5 and 10 percent levels respectively.

Table 2: The heterogeneous effect of COVID-19 incidence on exports depending on product resilience by product type and country

Dependent variable:	Export value by country e of product p to destination market i in time t				
	Final goods	Intermediates	Capital goods	Rich and poor	
	(1)	(2)	(3)	(4)	(5)
Death rate(e,t-n) x Unskilled intensity(p)	0,042	-0.149***	-0.113**		-0.127***
	(0.062)	(0.028)	(0.045)		(0.029)
Death rate(e,t-n) x China export share in inputs(pe)	-0,100	-0.261***	0,435		-0.174**
	(0.102)	(0.073)	(0.427)		(0.070)
Death rate(e,t-n) x Imported input reliance(pe)	0,019	-0.031*	0,016		-0.044***
	(0.030)	(0.016)	(0.027)		(0.015)
Death rate(e,t-n) x Share of top input suppliers(pe)	-0.583***	-0,047	-0,384		0,047
	(0.174)	(0.091)	(0.407)		(0.089)
Death rate(e,t-n) x Product complexity(p)	0.020***	0.015***	0,009		0,003
	(0.005)	(0.003)	(0.010)		(0.004)
Death rate(e,t-n) x Unskilled intensity(p) x Rich(e)				-0.130***	
				(0.030)	
Death rate(e,t-n) x Unskilled intensity(p) x Poor(e)				-0.169**	
				(0.073)	
Death rate(e,t-n) x China export share in inputs(pe) x Rich(e)				-0.209**	
				(0.082)	
Death rate(e,t-n) x China export share in inputs(pe) x Poor(e)				0,023	
				(0.144)	
Death rate(e,t-n) x Imported input reliance(pe) x Rich(e)				-0.026**	
				(0.013)	
Death rate(e,t-n) x Imported input reliance(pe) x Poor(e)				-0,062	
				(0.078)	
Death rate(e,t-n) x Share of top input suppliers(pe) x Rich(e)				-0,008	
				(0.097)	
Death rate(e,t-n) x Share of top input suppliers(pe) x Poor(e)				-0.677***	
				(0.223)	
Death rate(e,t-n) x Product complexity(p) x Rich(e)				0.012***	
				(0.004)	
Death rate(e,t-n) x Product complexity(p) x Poor(e)				0.034***	
				(0.007)	
Death rate(e,t-n) x Top supplier countries'* export share in inputs(pe)					0.926***
					(0.330)
Control variables	yes	yes	yes	yes	yes
Product-exporting country-importing country fixed effects	yes	yes	yes	yes	yes
Exporting-country-time (month-year) fixed effects	yes	yes	yes	yes	yes
Importing-country-time (month-year) fixed effects	yes	yes	yes	yes	yes
Observations	2,546,142	4,473,547	1,402,921	8,622,105	8 624 108
R-squared	0,88	0,87	0,85	0.866	0,87

Notes: Robust standard errors clustered by exporting country and broad sector in parentheses. ∗∗∗, ∗∗, and ∗ indicate significance at the 1, 5 and 10 percent levels respectively.

Table 3: Alternative product vulnerability measures

Dependent variable	Export value by country e of product p to destination market i in time t				
	(1)	(2)	(3)	(4)	(5)
Death rate(e,t-n) x Differentiated goods(p)	0.057***				
	(0.019)				
Death rate(e,t-n) x Product contractability (p)		0.038***			
		(0.012)			
Death rate(e,t-n) x R&D intensity(p)			0.053**		
			(0.021)		
Death rate(e,t-n) x Unskilled intensity(p)	-0.116***	-0.116***	-0.162***	-0.116***	-0.131***
	(0.029)	(0.029)	(0.032)	(0.030)	(0.030)
Death rate(e,t-n) x China export share in inputs(pe)	-0.500***	-0.289***	-0.352**		-0.184**
	(0.152)	(0.090)	(0.137)		(0.072)
Death rate(e,t-n) x Imported input reliance(pe)	0,001	-0,005	0,027	-0.028**	-0.024*
	(0.015)	(0.014)	(0.024)	(0.013)	(0.013)
Death rate(e,t-n) x Share of top input suppliers(pe)	0.313***	0.236***	0.290***	-0,125	-0,093
	(0.074)	(0.072)	(0.103)	(0.090)	(0.088)
Death rate(e,t-n) x Product complexity(p)				0.012***	0.014***
				(0.003)	(0.004)
Death rate(e,t-n) x China top 1 export share in inputs(pe)				-0.044**	
				(0.018)	
Death rate(e,t-n) x China-US trade war product(p)					-0,003
					(0.008)
Control variables	yes	yes	yes	yes	yes
Product-exporting country-importing country fixed effects	yes	yes	yes	yes	yes
Exporting-country-time (month-year) fixed effects	yes	yes	yes	yes	yes
Importing-country-time (month-year) fixed effects	yes	yes	yes	yes	yes
Observations	8 624 108	8 509 260	1 502 548	8 620 906	8,624,108
R-squared	0,87	0,87	0,86	0,87	0,87

Notes: Robust standard errors clustered by exporting country and broad sector in parentheses. ∗∗∗, ∗∗, and ∗ indicate significance at the 1, 5 and 10 percent levels respectively.

Table 4: Additional robustness tests I

Dependent variable:	Export value by country e of product p to destination market i in time t				
	From 2019	Alternative homogeneous lags		Alternative covid measures	
		t-1	t-2	Cases	Policy
	(1)	(2)	(3)	(4)	(5)
Death rate(e,t-n) x Unskilled intensity(p)	-0.110***				
	(0.027)				
Death rate(e,t-n) x Product complexity(p)	0.015***				
	(0.003)				
Death rate(e,t-n) x China export share in inputs(pe)	-0.160**				
	(0.064)				
Death rate(e,t-n) x Imported input reliance(pe)	-0.019				
	(0.012)				
Death rate(e,t-n) x Share of top input suppliers(pe)	-0.159**				
	(0.080)				
Death rate(e,t-1) x Unskilled intensity(p)		-0.181***			
		(0.030)			
Death rate(e,t-1) x Product complexity(p)		-0.006			
		(0.005)			
Death rate(e,t-1) x China export share in inputs(pe)		-0.244***			
		(0.074)			
Death rate(e,t-1) x Imported input reliance(pe)		-0.045**			
		(0.018)			
Death rate(e,t-1) x Share of top input suppliers(pe)		-0.364***			
		(0.106)			
Death rate(e,t-2) x Unskilled intensity(p)			-0.137***		
			(0.042)		
Death rate(e,t-2) x Product complexity(p)			-0,003		
			(0.005)		
Death rate(e,t-2) x China export share in inputs(pe)			-0.269***		
			(0.067)		
Death rate(e,t-2) x Imported input reliance(pe)			-0.045*		
			(0.026)		
Death rate(e,t-2) x Share of top input suppliers(pe)			-0.448***		
			(0.124)		
Cases(e,t-n) x Unskilled intensity(p)				-0.003***	
				(0.000)	
Cases(e,t-n) x Product complexity(p)				0.0003***	
				(0.000)	
Cases(e,t-n) x China export share in inputs(pe)				0,001	
				(0.001)	
Cases(e,t-n) x Imported input reliance(pe)				-0.001***	
				(0.000)	
Cases(e,t-n) x Share of top input suppliers(pe)				-0,002	
				(0.002)	
Stay at home requirements(e,t-n) x Unskilled intensity(p)					-0.120***
					(0.024)
Stay at home requirements(e,t-n) x Product complexity(p)					0.014***
					(0.002)
Stay at home requirements(e,t-n) x China export share in inputs(pe)					-0.260***
					(0.044)
Stay at home requirements(e,t-n) x Imported input reliance(pe)					-0,010
					(0.008)
Stay at home requirements(e,t-n) x Share of top input suppliers(pe)					-0,097
					(0.084)
Control variables	yes	yes	yes	yes	yes
Product-exporting country-importing country fixed effects	yes	yes	yes	yes	yes
Exporting-country-time (month-year) fixed effects	yes	yes	yes	yes	yes
Importing-country-time (month-year) fixed effects	yes	yes	yes	yes	yes
Observations	5 500 176	9 931 544	9,205,266	8,624,108	8 541 540
R-squared	0,87	0,87	0,87	0,87	0,87

Notes: Robust standard errors clustered by exporting country and broad sector in parentheses. ∗∗∗, ∗∗, and ∗ indicate significance at the 1, 5 and 10 percent levels respectively.

Table 5: Additional robustness tests II

Dependent variables:	Quantity	Unit value	Export value				
		by country e of product p to destination market i in time t					
			Excluding from the sample				
			Chinese exports	US exports	Medical products		
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Death over population (e,t-n) x Unskilled intensity(p)	-0.165***	0,019	-0.131***	-0.131***	-0.140***	-0.110***	-0.120***
	(0.032)	(0.016)	(0.030)	(0.030)	(0.029)	(0.028)	(0.028)
Death over population (e,t-n) x Imported input reliance(pe)	-0,023	-0,004	-0.024*	-0.024*	-0.025**	-0,019	-0.021*
	(0.018)	(0.008)	(0.013)	(0.013)	(0.012)	(0.013)	(0.012)
Death over population (e,t-n) x Share of top input suppliers(pe)	0,124	-0.073*	-0,094	-0,093	-0,098	-0,041	-0,115
	(0.101)	(0.044)	(0.088)	(0.088)	(0.087)	(0.085)	(0.089)
Death over population (e,t-n) x Product complexity(p)	0.011**	0	0.014***	0.014***	0.016***	0.010***	0.017***
	(0.004)	(0.001)	(0.004)	(0.004)	(0.004)	(0.003)	(0.004)
Death over population (e,t-n) x China export share in inputs(pe)	-0.346***	0.135***	-0.182**	-0.185**	-0.215***	-0.142**	-0.237***
	(0.087)	(0.028)	(0.071)	(0.072)	(0.071)	(0.069)	(0.069)
Death rate(e,t-n) x Home office product(p)						0.057***	
						(0.015)	
Death rate(e,t-n) x Outdoor activity product(p)						-0.027***	
						(0.009)	
Death rate(e,t-n) x Product trade elasticity |ϵ|(p)							-0.002***
							(0.000)
Control variables	yes	yes	yes	yes	yes	yes	yes
Hs4-exporting country-importing country fixed effects	yes	yes	yes	yes	yes	yes	yes
Exporting-country-time (month-year) fixed effects	yes	yes	yes	yes	yes	yes	yes
Importing-country-time (month-year) fixed effects	yes	yes	yes	yes	yes	yes	yes
Observations	7,802,279	8,008,145	8,128,252	8,624,108	8,556,547	8 606 945	7,082,358
R-squared	0,89	0,86	0,86	0,87	0,87	0,87	0,87

Notes: Robust standard errors clustered by exporting country and broad sector in parentheses. ∗∗∗, ∗∗, and ∗ indicate significance at the 1, 5 and 10 percent levels respectively.

Appendix

Appendix Table 1. Summary statistics

Characteristics of monthly exports					
Number of exporting countries	181				
Number of HS 4-digit products	1,046				

Key variables	Average	Median	Std. dev.	Perc. 10	Perc. 90
Log exports by exporter-importer-country-product	11.21	11.17	2.41	8.00	14.39
Deaths over population (/100)	0.66	0.12	1.09	0.00	2.30
Product vulnerabilities or resilience in exports					
Unskilled intensity(p)	0.57	0.62	0.10	0.50	0.67
Product complexity(p)	9.79	9.90	0.48	9.12	10.30
China export share in products (pe)	0.18	0.18	0.05	0.10	0.24
Imported input reliance(pe)	0.41	0.34	0.35	0.14	0.69
Share of top input suppliers(pe)	0.36	0.36	0.03	0.33	0.41

Correlation matrix

	Unskilled intensity (p)	Product complexity (p)	China export share in products (pe)	Imported input reliance (pe)	Share of top input suppliers (pe)
Unskilled intensity(p)	1.00				
Product complexity(p)	-0.35	1.00			
China export share in products (pe)	-0.19	-0.14	1.00		
Imported input reliance(pe)	-0.19	0.11	0.15	1.00	
Share of top input suppliers(pe)	0.33	-0.41	0.24	-0.19	1.00

Note: Correlation matrix based on average at HS4-exporting country average of HS4 and export countries included in the estimating sample. The summary statistics for deaths over population are computed over the COVID-19 period only.