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Pandemic Trade

Covid-19, Remote Work and Global Value Chains

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Abstract

This paper studies the trade effects of Covid-19 using monthly disaggregated trade data for 28 countries and multiple trading partners from the beginning of the pandemic to June 2020. Regression results based on a sector-level gravity model show that the negative trade effects induced by Covid-19 shocks varied widely across sectors. Sectors more amenable to remote work contracted less throughout the pandemic. Importantly, participation in global value chains increased traders' vulnerability to shocks suffered by trading partners, but it also reduced their vulnerability to domestic shocks.

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Pandemic Trade:
Covid-19, Remote Work and Global Value Chains

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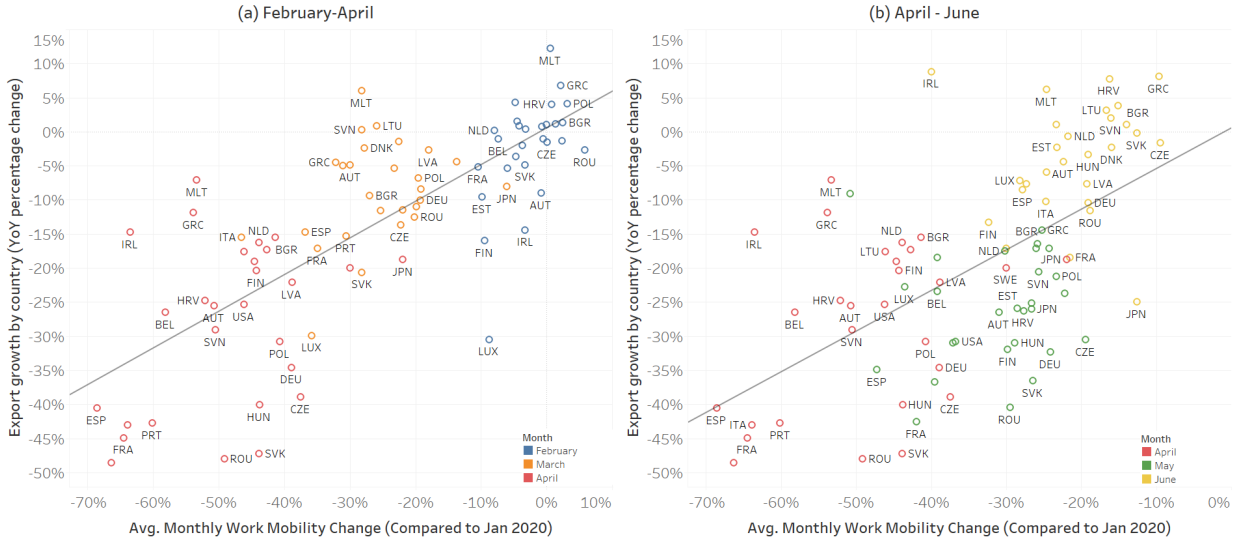
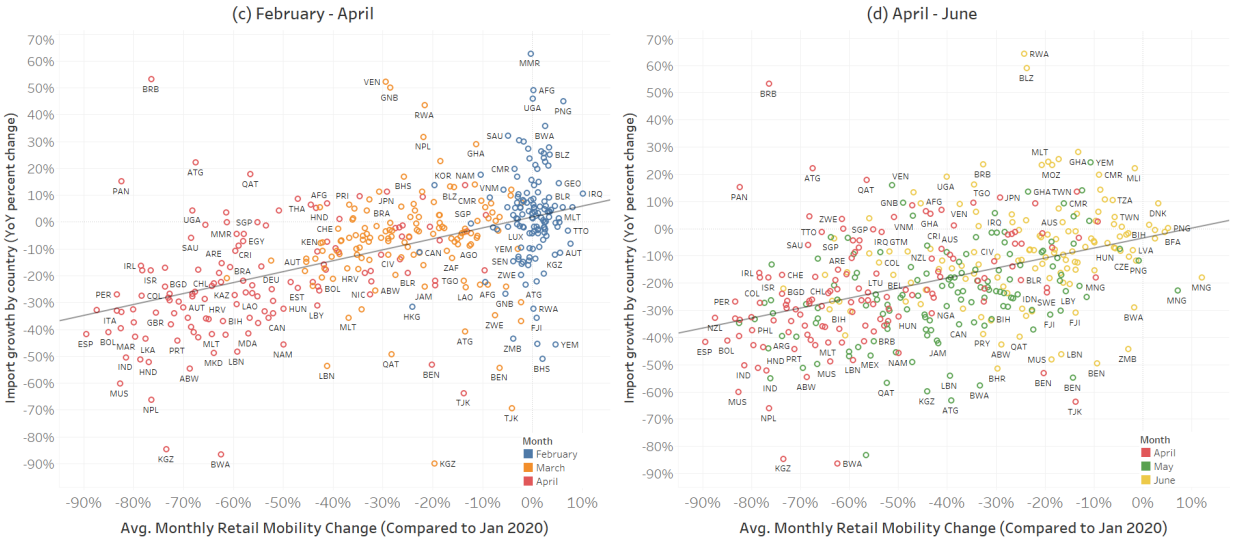
1. Introduction

The Covid-19 pandemic has generated a supply and demand shock across many countries. Production, consumption and trade patterns have been affected both directly and as a result of lockdowns and social distancing measures introduced to reduce the spread of the disease. Factory closings in China, Europe, the United States, and other countries have led to a drop in the supply of exportable goods and to a disruption in global value chains (GVCs). At the same time, consumers and firms have had to curtail their spending in the new environment. This paper studies the near-term impact on trade of these Covid-19 shocks in different countries and sectors.

Global trade declined by approximately 13 percent during the first six months of 2020. In the first three months of the pandemic (February to April 2020), when lockdown policies were implemented in most of the countries in our sample, changes in work and retail mobility — as a consequence of the Covid-19 shock — were correlated with changes in exports and imports, respectively (Figure 1.a and 1.c). The shift over time of the country sample towards the bottom left suggests that both mobility and trade growth declined as the virus advanced. Between the peak of the first wave of Covid-19 in April until June 2020, both mobility and trade improved gradually, as shown by the shift over time of the country sample towards the top right in Panels 1.b and 1.d.

Figure 1: Trade over the first wave of the pandemic, February to June 2020





This paper studies the short-term trade effects of Covid-19. We use bilateral monthly export data for 28 exporting countries (most EU members, the United States and Japan) and multiple trading partners at a detailed sector level between February and June 2020. The goal is to investigate the role of different Covid-19 related shocks and sector characteristics in shaping the trade impacts of the pandemic.

We rely on a simple conceptual framework to organize our thinking on the trade effects of the pandemic. Covid-19 shocks can hit the exporting economy, the importing economy or third countries. Moreover, these shocks can impact trade flows directly or through production linkages in GVCs. While all these shocks and channels work simultaneously, it is helpful to consider them separately.

A shock in the exporting country that reduces mobility and restricts production activities has a negative impact on its exports. But the possibility of remote work can buffer this effect as it allows some production to continue during the pandemic. A shock in the partner country that keeps shops closed and lowers economic activity can also affect trade flows. The direction of the impact depends on the relative strengths of two effects: the contraction in overall demand and the substitution towards imports due to the reduction in domestic production. The effect also depends on product characteristics: for example, the impact on durable goods such as computers and televisions depends on whether consumers postpone purchases in the crisis or buy more to facilitate remote work, education and entertainment. Finally, a supply shock in third countries in direct competition with the exporter could provide a boost to its exports.

Participation in global value chains – either by importing inputs for use in export production or by exporting inputs for use by a trading partner - can mitigate or augment the negative trade effects of Covid-19 related shocks. When the exporting country is itself hit by a supply shock, sectors that rely more on imported inputs are hurt less than those that rely primarily on domestic inputs. But when a supply shock hits countries that are a source of inputs for exporters, the more imported input-dependent sectors are more adversely affected. When a shock disrupts production in the destination country, sectors that export intermediates to other countries are hurt more. From an exporter's perspective, the first channel captures the benefit of GVC diversification in the presence of a domestic shock, while the second and third channels capture the upstream or downstream disruption due to foreign shocks.

Our empirical strategy to identify the trade effects of Covid-19 is based on a sector-level gravity model (e.g. Dai et al. 2014). Instead of controlling for country-level determinants of bilateral trade, we rely on a comprehensive set of fixed effects, as our goal is to identify the role of sector characteristics in mitigating Covid-19 related shocks in the exporting, partner and third countries. Similarly to the large trade literature based on the approach in Rajan and Zingales (1998),[2] we focus on interaction terms between a selected time-varying measure at the country-level (reflecting the Covid-19 shock) and a time-invariant sector measure reflecting the sector's vulnerability to the shock (e.g. amenability to remote work, GVC participation).

The baseline results confirm that the trade effects of the Covid-19 shocks vary across sectors. First, the feasibility of remote work mitigated the negative effects of reduced worker mobility in the exporting country on export growth. We find that sectors with a higher share of occupations that can be performed remotely were less impacted by the pandemic. Second, regression results also show that a decrease in retail mobility in the partner country, such as closure of retail stores, had a smaller negative impact on imports of durable goods in the same month, but a larger negative impact on imported durables in the following month –this is despite the fact that the demand for certain durable goods like computers and home appliances may have increased due to lockdowns. Third, data for the group of 28 exporters in our sample do not support the view that shocks in third countries had a positive impact on exporters that were competing in the same destination markets. As further discussed below, this result may be because all countries in the sample were severely hit by Covid-19 during the period of analysis.

[2] Studies using this framework have assessed the role of financial development (Beck 2003; Manova 2008), factor endowments (Romalis 2004), institutions (Levchenko 2007; Nunn 2007; Costinot 2009), and labor market flexibility (Cuñat and Melitz 2012).

An important issue during the current pandemic has been the relationship between Covid-19 and global value chains, and particularly whether GVCs absorb or transmit Covid-19 shocks (Baldwin and Tomiura, 2020; Javorcik, 2020; Miroudot, 2020). We find that while GVC participation increased an exporter's vulnerability to foreign shocks, it reduced vulnerability to domestic shocks. The disruption of production in input source countries more adversely affected export growth in sectors that relied more strongly on imported inputs from these source countries. Similarly, a disruption of production in an exporter's partner countries more adversely affected its export growth in sectors with high shares of imported inputs. But the negative impact of a disruption in domestic production in exporting countries themselves was mitigated by a sector's higher reliance on imported inputs in export production.

We then perform two robustness tests and extend our analysis in two directions. First, we use growth in industrial production rather than changes in mobility as a measure of the Covid-19 shocks and find that all findings remain unaltered. Second, we estimate the regressions for the sub-periods February to April 2020 and April to June 2020, to separate the two phases of the first wave of Covid-19. As intuition would dictate, we find that the mitigating effects of remote labor mattered more during the more severe lockdown of the first three months. Similarly, during these early months exports were also most affected by shocks in upstream countries. Third, we include China in the sample of exporters. All results are confirmed except that we now find that supply shocks in third countries provided opportunites to expand exports. As a final extension, we use mirror export data, to expand the set of exporters to 64 developed and developing countries. While we find that remoteness plays a smaller role in explaining differences in trade patterns across sectors, perhaps due to the weaker diffusion of internet in developing economies, all results continue to hold.

Our study relates to the growing body of literature on the economic effects of Covid-19 (Baldwin and Weder di Mauro, 2020). In particular, this paper is closely linked to recent studies assessing the impact of Covid-19 on international trade and GVCs, and on supply and demand shocks[3] more broadly. Several organizations have published estimates regarding the potential trade and GDP effects of Covid-19 using computable general equilibrium (CGE) models. While all studies predict a substantial drop in output and international trade flows, results are sensitive to changes in underlying assumptions, such as the length of the lockdown measures.[4] A recent study relies on a newly developed economic disaster model to assess the supply chain effects of different Covid-19 control measures across countries and sectors, emphasizing

[3] For example Rio-Chanona et al. (2020) for the United States.
[4] Such studies include ECB (2020), Maliszewska et al. (2020), and WTO (2020).

the indirect impacts on other countries through supply chain linkages (Guan et al. 2020).[5] Bonadio et al. (2020) calibrate the possible impact of lockdown measures on GDP for a sample of 64 countries, differentiating between foreign and domestic shocks. To identify the contribution of GVCs to the decline in GDP, the study also simulates the effects in a counterfactual world without GVC trade and pure reliance on domestic inputs. Finally, Eppinger et al. (2020) and Gerschel et al. (2020) study the propagation of the productivity slowdown in the Hubei province of China to the global economy, through international trade and global value chains.

Differently from these papers, our study is based on an econometric analysis rather than simulations and to our knowledge this is one of the first papers on trade and Covid-19 that takes this approach. One exception is the work by Hayakawa and Mukunoki (2020). The paper assesses the impact of the numbers of Covid-19 cases and deaths on bilateral export and import growth of machinery goods (finished and intermediates) between January and June 2020 for 26 reporting and 185 partner countries. Their study finds that while Covid-19 did not have a significant demand effect in importing countries, judging by imports of finished machinery products, Covid-19 shocks in supplier countries negatively affected exporters' final machinery exports. Covid-19 cases and deaths in an exporter country are also found to hurt its exports of finished machinery products, but to a lesser extent. A second exception is the contemporaneous and independent work by Fernandes et al. (2020). Similarly, to our paper, they estimate difference-in-differences specifications that explain monthly trade flows by interactions between measures of the Covid-19 pandemic or of measures to contain it and several sector characteristics. Their focus is on measures of trade resilience such as a sector's dependence on China for inputs, a sector's labor intensity of production, and a sector's technological proximity to other sectors.

The remainder of this paper is structured as follows: Section 2 introduces the empirical strategy and describes the data. Section 3 shows the baseline regression results. Robustness tests and extensions are presented in Section 4. Section 5 concludes.

2. Empirical strategy and data

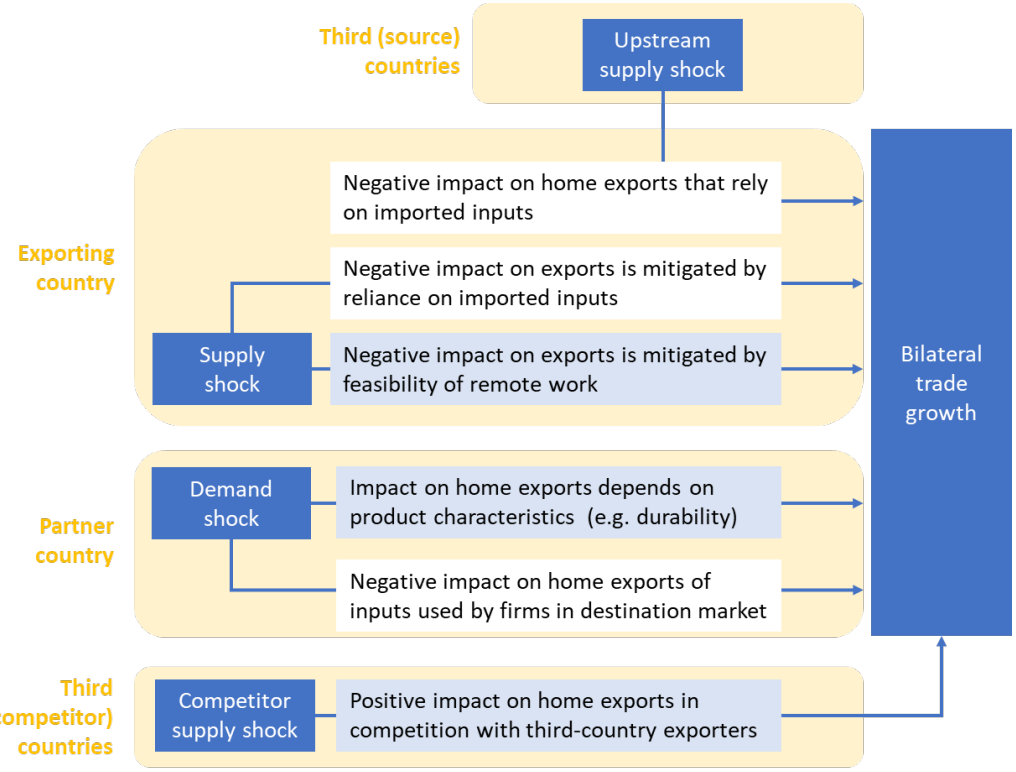
In this section we present a simple framework capturing the linkages between Covid-19 shocks and trade. We then describe the empirical specification and data used in the analysis.

[5] The model differs from CGE models as it assesses short-term economic impacts of disasters over weeks or months, before production and trade have time to adjust, but does not aim to examine the economic cost.

2.1 Trade effects of Covid-19

Covid-19 and the lockdown policies that have been implemented to contain the spread of the coronavirus represent supply and demand shocks across many countries. The impact of these shocks on trade depends on factors that vary at the country and at the sector level. Figure 2 depicts a simplified framework which outlines the various channels through which shocks in the exporting economy, partner country or in third countries affect bilateral trade growth between the exporting and partner country, as well as the role of sectoral characteristics in mitigating or augmenting the effect of such shocks.

Figure 2: A simplified framework of bilateral trade growth



Note: Sector attributes that are hypothesized to influence the relationship between a shock and bilateral trade growth are in italics (expected direction in parentheses).

As a first step, we focus on the production, consumption and competition channels (light blue boxes) and abstract from GVC linkages. Consider a supply shock in the exporting country. Reduced worker mobility – the source of the supply shock – lowers the exporting country's production capacity and thus negatively affects export growth. This negative trade impact is not equal across sectors and depends on sector-specific characteristics. Given the importance of social distancing in limiting the spread of the virus, the efficiency of remote work arrangements is expected to be a key factor in maintaining production

processes in a safe environment. In particular, we hypothesize that the higher the share of occupations in a sector that can be performed remotely – through the use of information and communication technology –the lower the negative impact of the exporting country's supply shock.

Similarly, a demand shock in the partner country can affect bilateral trade through the consumption channel. Declines in retail mobility in the partner country, such as closure of retail stores, reduce the demand for imported consumer goods. This effect varies by type of product. Durable consumer goods tend to be more strongly affected during a crisis as consumers may choose to postpone their purchase when uncertainty is high. As durables are generally ordered by retailers in advance, this effect is likely to be transmitted to imports with a lag. The Covid-19 pandemic may have some offsetting effects. First, the attributes of durable goods are observable through electronic media, increasing the willingness of customers to purchase them online. Second, the demand for durable goods such as computers, televisions or home appliances increases with remote work, education and entertainment.[6] The impact of Covid-19 on trade in durable goods is therefore an empirical question.

Supply shocks in third countries may also have an impact on bilateral trade flows through the competition channel. If Covid-19 leads to mobility restrictions in third countries, firms in the exporting country can take advantage of the production disruption of rivals, and export more to the partner's market. This positive trade effect is expected to be stronger in sectors in which third countries hit by a negative supply shock have a larger global export share and the exporter has the capacity to rapidly scale up production.

Last, we consider the different channels through which reduced productive activity in the exporting, partner or third country could affect production within GVCs (white boxes). The effect of a shock in a country depends on the extent of a sector's reliance on imported inputs, as well as on the geographic location – domestic or foreign – of the shock. When the shock takes place in the exporting country, higher reliance of a sector's exports on imported inputs helps to better withstand disruptions in domestic production, thus supporting export growth. When the shock takes place in the partner country, demand for the exporter's intermediate inputs would decrease relative to demand for final goods as production is

[6] Indeed, Chetty et al. (2020) find that, differently from spending behavior in previous recessions, purchases of durable goods increased during Covid-19, while consumption of in-person (i.e. non-tradable) services such as restaurants remained depressed due to the risk of infection.

disrupted. When the shock takes places in a third source country that is an upstream supplier of inputs, the exporter experiences a production disruption that hurts its exports.[7]

2.2 Empirical strategy

Our empirical strategy is based on the assumption that bilateral trade growth between two countries is affected by supply and demand shocks induced by the health crisis in the exporting country, partner country and in third countries. The negative impact of these shocks is expected to be heterogeneous across sectors, as certain sector characteristics can soften the decline in bilateral export growth induced by the shocks. We estimate difference-in-difference specifications that interact the Covid-19 shocks with sector characteristics. The model is estimated for 28 exporting countries and over 50 trading partners at the ISIC Rev. 3 4-digit level for February to June 2020.[8]

The general estimation equation can be expressed as follows:

$$growth_{ijkt} = \alpha + \beta_1\, exporter\ supply\ shock_{it} * sector\_characteristic_{ik}$$

$$+ \beta_2 partner\ demand\ shock_{jt} * sector\ characteristic_{jk} + \beta_3 third\ country\ supply\ shock_{ikt}$$

$$+ global\ output_{mt} + \gamma_{ijk} + \gamma_{it} + \gamma_{jt} + \gamma_{zt} + \varepsilon_{ijkt}$$

(1)

where $growth_{ijkt}$ denotes bilateral annualized growth of exports from country *i* to partner country *j* in sector *k* at time t. The explanatory variables include the supply shock in the exporting country and the demand shock in the partner country interacted with the relevant sector characteristics, $exporter\ supply\ shock_{it} * sector\_characteristic_{ik}$ and $partner\ demand\ shock_{jt} * sector\_characteristic_{jk}$, and the supply shock in third countries, $third\ country\ supply\ shock_{ikt}$.

We also include a set of controls, namely exporter-partner-sector (γ_{ijk}), exporter-time (γ_{it}), partner-time (γ_{jt}) and sector time (γ_{zt}) fixed effects to account for potentially omitted variables, while ε_{ijkt} is the error

[7] Production disruptions could also have trade effects if firms can switch input suppliers. However, switching input suppliers is difficult in the short term, particularly when inputs are customized in GVCs. We therefore expect that a reshaping of value chains in response to a shock is a longer-term process and is more difficult in the period considered in this paper. For an empirical analysis of longer-term effects of natural disasters on GVCs, see Freund, Mattoo, Mulabdic, Ruta (2020).

[8] In the next section, we use mirror export data to investigate the trade impact of Covid-19 in a larger set of developed and developing countries.

term. Standard errors are clustered at exporter-partner pair-level.[9] The sector-time fixed effects cannot be at a highly disaggregated level due to collinearity with some of the sector characteristics.[10] To account for differences in sectoral output growth over time and minimize the concern of possible omitted variable bias, we construct a global monthly IPI growth variable at the ISIC Rev. 3 2-digit level, $global\ output_{mt}$, as an additional control.[11]

The final specification combines all the channels that have been identified in the conceptual framework:

$$growth_{ijkt} = \underbrace{\alpha + \beta_1\ work\ mobility_{it} * remote_{ik} + \beta_2\ work\ mobility_{it} * gvc_{il}}_{\textit{Exporter supply shock}}$$

$$+ \underbrace{\beta_3 retail\ mobility_{jt} * durable_k + \beta_4 retail\ mobility_{jt} * gvc\ partner_{jl}}_{\textit{Partner demand shock}}$$

$$+ \underbrace{\beta_5\ competition\ shock_{ijkt} + \beta_6\ upstream\ shock_{ilt} + controls}_{\textit{Third country supply shock}}$$

(2)

Here the supply shock in the exporting country is captured by the variable work mobility, $work\ mobility_{it}$, while retail mobility, $retail\ mobility_{jt}$ measures the demand shock in the partner country. Both variables vary at the country-time level and are computed as monthly changes relative to January 2020.[12]

As for sector intensities, the feasibility of performing work remotely in an exporting country is captured by $remote_{ik}$. We expect β_1 to be positive as the greater feasibility to perform remote work in a given sector would shield it from the negative effect of a supply shock in the exporting country. The variable $durable_k$ designates the average percentage of durable (including semi-durable and transport equipment) products within a certain ISIC4-digit sector. The coefficient β_3 has a priori an ambiguous sign as durable goods tend to be more affected during a crisis, but a pandemic may lead to an increase in demand of certain durable

[9] This is the most common approach in a sectoral bilateral gravity trade model setting since there are explanatory determinants of bilateral trade (like distance) that only vary by country-pair. See, e.g., Dai et al. (2014).
[10] Sector-time fixed effects in this model control for unobserved effects affecting aggregated sectors over time. The fixed effects differentiate between GVC-intensive vs. non-intensive sectors where the first includes all sub-sectors in apparel, electronics, machinery and transport.
[11] Monthly output data for a large set of countries are unavailable at the 4-digit ISIC level.
[12] Mobility data are unavailable for 2019 which restricts us from computing annualized mobility changes.

products such as computers for remote working. Moreover, as orders of durable goods can be placed before goods arrive as imports, the impact of the shock on the imports of durables may appear with a lag.

To capture the third-country competition channel, we compute a time-varying third country shock at the exporter-partner-sector-level as follows:

$$competition\ shock_{ijkt} = \sum_{1}^{O} w_{ok} * ipi_{ot}$$

where subscript *o* denotes third country (with o ≠ i, j). *w* is the export share of a third country *o* in total exports of third countries in sector *k* in, $w_{ok} = exp_{ok} / \sum_1^W exp_{ok}$, excluding exporter *i* and partner *j*. This term ensures that industrial production shocks in a third country, ipi_{ot}, have a larger effect on an exporter *i*'s trade growth in a ISIC Rev. 3 4-digit sector the larger the third country's share in world trade. Since mobility data are unavailable for China, we rely on the IPI as shock variable. We expect β_5 to be negative as less robust growth in industrial production in third countries would provide opportunites to competing producers in the exporting country to expand exports in their partner's market.

Three variables are considered to assess the impact of Covid-19 through the GVC channel. The first two are straightforward: gvc_{il} measures an exporter-sector's share of imported inputs in its exports and $gvc\_partner_{jl}$ a partner country-sector's reliance on imported inputs in its total imports. To account for shocks in exporter's source (third) countries, we compute the following upstream shock variable:

$$upstream\ shock_{ilt} = \sum_{1}^{S} \left(\sum_{1}^{N} w_{ilsn} \right) * ipi_{st}$$

where subscript *i* denotes exporting country, *l* output sector, *s* denotes source country and *n* input sector. The variable *ipi* measures the IPI in the source country and *w* is the weight of input sector *n* from source country *s* in all imported inputs used by output sector *l* in exporter country *i.* The equation shows that the larger is an exporter's dependence on imported inputs in a sector (as captured by *w*), the more the upstream shocks in source countries can hurt export growth. Also in this case, we use IPI as our preferred shock measure due to unavailability of mobility data for China.

We expect β_2 to be positive because a higher reliance of a sector's exports on imported inputs shields the sector from a disruption in the domestic economy and supports export growth. We expect β_4 to be negative as a shock in the partner country lowers demand for an exporter's GVC exports. Finally, we

expect the upstream shock variable to be positively associated with export growth in the exporting countries (i.e. a positive β_6). Disruptions in industrial production in source countries are expected to be linked to declines in exports in the exporting country, as exporters face bottlenecks in imported inputs.

2.3 Data

For the estimations we use monthly bilateral trade data for a total of 28[13] exporting countries covering the period from January/February to June 2020, the first phase of the pandemic. Data were collected from the Covid-19 Trade Watch (World Bank, 2020): specific sources of data are, respectively, customs for China, Eurostat for the European Union, Ministry of Finance for Japan, and U.S. International Trade Commission for the United States. Export data are aggregated at the ISIC Rev. 3 4-digit level, which consists of over 140 sectors. Bilateral annualized export growth in a sector ($growth_{ijkt}$) is computed based on export levels for a month in 2020 relative to export levels of the same month in 2019. The estimations exclude mining sectors such as oil and coke from the sample. We also winsorize[14] the export growth data and exclude Serbia as partner country in order to deal with extreme outliers.

To assess the demand and supply shocks that economies experience as a result of Covid-19 we use monthly information from the Google mobility data from the Covid-19 Global Community Reports[15] which are published on a daily basis for 132 countries. The Google mobility growth rate captures peoples' movement trends across different places and is provided relative to the median daily value from the 5-week period from January 3 to February 6, 2020 (the baseline day). We select two components of Google mobility, namely work mobility ($work\ mobility_{it}$) and retail and recreation mobility ($retail\ mobility_{jt}$) to measure, respectively, the supply and demand shocks of the pandemic. Work mobility measures mobility trends for places of work, while retail and recreation mobility capture mobility trends for places like restaurants, cafes, shopping centers, theme parks, museums, libraries, and movie theaters. We compute the mean over all daily measures to obtain monthly Google mobility measures.

Changes in industrial production relative to the previous year are calculated using the industrial production index (IPI) from UNIDO,[16] which is available on a monthly basis for a set of 60 countries.

[13] The 28 exporting countries include all members of the European Union excluding Cyprus, Japan and the United States. While Chinese trade data are also available, the trade data are combined for January and February due to the Chinese New Year. As Google mobility data (our measure of the shock) are not available for China, our baseline regressions do not include China.
[14] Trade growth data at the exporter-partner-sector level exceeding the top (99) percentile and those below the bottom (1) percentile of the distribution are set to the growth rates of these percentiles, respectively.
[15] https://www.google.com/covid19/mobility/
[16] https://stat.unido.org/database/Monthly%20IIP

Industrial production refers to the output of industrial establishments and covers sectors such as mining, manufacturing, electricity, gas and steam and air-conditioning. We use IPI data in other exporting countries (ipi_{ot}) which are weighted using sectoral export shares obtained from 2018 UN Comtrade data to compute the average competition shock in third countries ($competition\ shock_{ijkt}$). We also rely on IPI data to capture supply shocks in source countries (ipi_{st}). Both allow for the inclusion of China for which mobility measures are unavailable. In robustness checks, we use IPI as alternative supply shocks in exporting countries (ipi_{it}) and alternative demand shocks in partner countries (ipi_{jt}).

To capture the potential heterogeneous impact of reduced mobility across sectors, we construct a variable that measures the percent of occupations within an ISIC Rev. 3 4-digit sector that can be performed remotely based on U.S. 2017 O*NET data.[17] In order to obtain a remote labor measure that varies across exporting countries ($remote_{ik}$), we multiply this percentage with a country's internet density defined as individuals using the Internet (as % of population) from the World Development Indicators for 2017. These measures are then indexed to range from 0 to 1. It seems counterintuitive that production-related activities like assembly can be performed remotely. However, the trade data and remote labor index are classified by sectors and not tasks. That is, services tasks that are embodied in goods such as research and development, design or marketing are also classified under goods sectors. Appendix 1 ranks ISIC Rev.3-2 digit sectors by their average remote labor index and shows that remoteness is highest in publishing, printing and reproduction of recorded media, followed by electronics and machinery sectors, while it is lowest in labor-intensive forestry, fishing, agriculture and food production.

To assess the durability of products we calculate the sector's share of durable consumer products, semi-durable consumer products and cars and transport equipment ($durable_k$). Durable, semi-durable and transport products at the HS6-digit level are identified based on the UN BEC classification.[18] Durability measures the percentage of HS-6 products that are classified in each of these three non-overlapping categories within an ISIC Rev. 3 4-digit sector. If an ISIC Rev. 3 4-digit does not contain any products classified as durable, semi-durable or transport products, the share takes the value of 0. In an extension, we examine the role of durable consumer products ($cons\_dur_k$), semi-durable consumer products ($cons\_semi_k$) and transport products ($transp_k$) separately and also include a measure that combines the share of both durable and semi-durable consumer products only ($cons_k$).

[17] Following del Rio-Chanona et al. (2020).

[18] Durable consumer products correspond to BEC sector 61, semi-durable consumer products correspond to BEC sector 62, and transport products correspond to BEC sectors 51 and 522.

GVC participation of a country-sector (gvc_{il}) is measured as the import content of exports (as percent of a sector's exports) for the 28 exporting countries for the year 2015 (latest available). The measure is based on data from the OECD International Input-Output tables and computed following the approach by Borin and Mancini (2019). While the GVC participation measure varies across exporting countries, it is only available at a more aggregate sector level covering 15 TiVA sectors.

To capture the importance of imported inputs for production, we rely on import data from UN Comtrade for 2017 and compute a sector's share of parts and components (as percent of total imports) in partner countries ($gvc\ partner_{jl}$). Parts and components[19] at the HS6-digit product level are determined based on the UN Broad Economic Category (BEC) classification and then further aggregated to the TiVA sector level in order to be consistent with the backward GVC participation measure.[20] We interact the GVC measures with the shock measure in the exporting and partner country to reflect a shock's transmission through the GVC channel. The upstream shock variable ($upstream\ shock_{ilt}$) is computed based on IPI growth and data from the OECD International Input-Output tables to compute weights.[21]

To control for global sector-time trends we use industrial production growth data from UNIDO INDSTAT which are available at the 2-digit ISIC level and cover 60 countries representing more than 90 percent of world GDP and 95 percent of manufacturing value added. Our measure $global\ output_{mt}$ is based on manufacturing value added in constant 2015 USD. The global average is based on the relative contribution of a country (weight) to the world's total manufacturing value-added. The correlation matrix between independent variables is shown in Appendix 2, while the summary statistics are reported in Appendix 3.

3. Regression results

Before assessing the heterogeneous impact that Covid-19-induced shocks could have across different sectors, we examine the relationship between aggregate bilateral export growth and supply shocks both at home and in third countries and demand shocks in trading partners. Results are reported in Table 1.

[19] Parts and components are defined as BEC sectors 111, 121, 21, 22, 42, and 53, as well as the Standard Industrial Classification Sector 65.

[20] We prefer this measure over the imported input share of exports in the partner country because we are mainly interested in a sector's dependence on imported inputs, regardless of whether these are used in the partner country's export or domestic production.

[21] That is, source countries are limited to 64 TiVA countries.

The results suggest that bilateral export growth is positively correlated with both the supply shocks in the exporting country (column (1)) and demand shocks in the partner country (column (2)). Specifically, a 1 percentage point decline in worker mobility relative to January 2020 is associated with a 0.42 percentage point decline in annualized export growth on average (column (1)), while a 1 percentage point decline in retail mobility in the partner countries is linked to a 0.30 percentage point decline on average (column (2)).

Table1: Supply, demand and third-country shocks and bilateral export growth, OLS regression results

VARIABLES	(1) $growth_{ijkt}$	(2) $growth_{ijkt}$	(3) $growth_{ijkt}$	(4) $growth_{ijkt}$	(5) $growth_{ijkt}$	(6) $growth_{ijkt}$	(7) $growth_{ijkt}$
$work\ mobility_{it}$ (supply)	**0.419*** **			**0.439*** **	**0.319*** **		**0.347*** **
	-0.085			-0.086	-0.088		-0.089
$retail\ mobility_{jt}$ (demand)		**0.300*** **		**0.313*** **		**0.299*** **	**0.306*** **
		-0.048		-0.048		-0.048	-0.048
$competition\ shock_{ijkt}$			**-0.337** **		**-0.372** **	**-0.358** **	**-0.390** **
			-0.165		-0.161	-0.165	-0.161
$upstream\ shock_{ilt}$			**2.035** **		**1.634*** **	**2.075** **	**1.485*** **
			-0.843		-0.379	-0.843	-0.376
$global\ output_{mt}$	**1.085*** **	**1.040*** **	**0.915*** **	**1.058*** **	**0.952*** **	**0.878*** **	**0.926*** **
	-0.144	-0.144	-0.155	-0.144	-0.15	-0.154	-0.15
Constant	**0.949*** **	**0.924*** **	**0.984*** **	**1.045*** **	**1.029*** **	**1.071*** **	**1.108*** **
	-0.026	-0.02	-0.077	-0.029	-0.044	-0.078	-0.045
Observations	631,111	631,111	631,111	631,111	631,111	631,111	631,111
R-squared	0.400	0.399	0.400	0.398	0.400	0.399	0.398
Exporter-Time FE	No	Yes	Yes	No	No	Yes	No
Importer-Time FE	Yes	No	Yes	No	Yes	No	No
Exporter-Partner-Sector FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Sector-Time FE	Yes	Yes	Yes	Yes	Yes	Yes	Yes
Cluster	Exporter-Partner	Exporter-Partner	Exporter-Partner	Exporter-Partner	Exporter-Partner	Exporter-Partner	Exporter-Partner

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Note: Exporter-partner-time FEs could not be included due to collinearity with the country shocks. Sector-time fixed effects control for unobserved effects affecting aggregated sectors over time (see footnote 10). The variable $global\ output_{mt}$ additionally controls for global sector-time trends.

By contrast, competition shocks are negatively associated with bilateral export growth (column (3)) which is in line with expectations, because reduced production in third countries could be expected to boost export growth. Last, the coefficient capturing the upstream shock is positive and significant, suggesting that declines in industrial production in an exporter's source countries, weighted by a sector's reliance on imported inputs from these source countries, negatively affected export growth. The findings hold for different combinations of these shocks in columns (4) to (6) and also when all shocks are simultaneously

included in column (7), suggesting that on average, all the transmission shocks had a role in explaining the impact of the pandemic on export growth.

We next move to the sectoral analysis and estimate equation (2) which combines all the different transmission channels identified in the framework in Figure 2. The results using OLS are reported in Table 2. Column 1 assesses the relationship between supply shocks in exporting countries and bilateral export growth through the production and GVC channels. The first interaction term ($work\ mobility_{it}$*$remote_{ik}$) captures the role of remote work in mitigating the negative impact of the supply shock on export growth through the production channel.[22] A positive and statistically significant coefficient at the 1%-level, suggests that a higher percentage of occupations that can be performed remotely in a sector mitigates the negative trade effect of a production shock in exporting countries. For example, in country-sectors such as Hungary's manufacture of pulp, paper and paperboard, where less than one-third of occupations can be performed remotely (country-sectors in the first quartile of the distribution of the remote variable), the negative effect of Covid-19 through decreased work mobility is 19 percentage points larger than for the manufacture of electric motors, generators and transformers in countries such as Japan, where more than two-thirds of production can be done remotely.[23]

The second interaction term presented in column (1) ($work\ mobility_{it}$*gvc_{il}) captures the relationship between the supply shock and export growth through the GVC channel. The estimated coefficient suggests that the trade effect of a negative shock in exporting countries is lower in sectors that rely more strongly on imported inputs for their exports. This supports the hypothesis that importing inputs can help alleviate the impact of domestic supply shocks. We can calculate the impact of reduced mobility for different percentiles of GVC participation in an exporting country and sector. The negative impact of a decrease in mobility for country-sectors in the first quartile of the distribution, where imported inputs account for less than one-quarter of total exports (e.g. Spain manufactures of agricultural and forestry machinery), is 20 percentage points higher than for country-sectors in the third quartile of the distribution

[22] Rather than including work mobility separately in the regression, the production shock in the exporting country is captured by the exporter-time fixed effect.

[23] We cannot compute the total effect of the exporter shock on bilateral export growth accounting for differences in remoteness because equation (2) does not include the exporter shock individually, but controls for it using exporter-time fixed effects. The total effect would be given as follows: (coefficient of exporter shock + β_1*$remote_{ik}$). We can, however, compare the differential impact at two selected points of the distribution in remoteness (β_1*$remote_{ik}$). From Table 1, column (4) we obtain β_1 = 1.587 which is multiplied with the remoteness share at the first quartile of the distribution (Q1=31.4%) and again with remoteness share at the third quartile of the distribution (Q3=43.5%). Taking the interquartile difference yields 1.587*(43.5%-31.4%) = 19.2%-pts.

where shares of imported inputs over exports reach up to 37 percent (e.g. Austria's manufacture of other chemical products).[24]

The results presented in column (2) of Table 2 illustrate the link between the demand shock, captured by decreases in retail mobility, and export growth through the consumption and GVCs channels. For the consumption channel, a positive coefficient for the interaction term ($retail\ mobility_{jt}$*$durable_k$) suggests that the (contemporaneous) negative trade effect of a demand shock in partner countries is smaller for those sectors with larger shares of durable goods. Specifically, for those sectors where all products are classified as durable or semi-durable (e.g. manufactures of parts and accessories for motor vehicles) the negative impact of retail mobility is 41 percentage points smaller compared to those sectors where none of the products are classified as durable or semi-durable (e.g. processing and preserving of fruit and vegetables).[25] To understand whether this effect is driven by a surge in demand for durable goods that are needed during the pandemic or if it reflects a mismatch between the time durables are ordered and delivered, we run equation (2) with a lag in the demand shock. Regression results show that the sign of the interaction term is reversed and strongly significant (Appendix Table 4). These findings are consistent with the view that imports of durable goods were affected with a lag during the pandemic and that their orders eventually declined in response to the Covid-19 demand shock.

Table 2: Supply, demand and third-country shocks and bilateral export growth, the role of sector characteristics, OLS regression results

FRAMEWORK	VARIABLES	(1) $growth_{ijkt}$	(2) $growth_{ijkt}$	(3) $growth_{ijkt}$	(4) $growth_{ijkt}$
Exporter supply shock* sector characteristic	$work\ mobility_{it}$*$remote_{ik}$	**1.509*** **			**1.587*** **
		(0.361)			(0.375)
	$work\ mobility_{it}$*gvc_{il}	**1.293** **			**1.564*** **
		(0.518)			(0.522)
Partner demand shock* sector characteristic	$retail\ mobility_{jt}$*$durable_k$		**0.456*** **		**0.414*** **
			(0.094)		(0.097)
	$retail\ mobility_{jt}$*$gvc\ partner_{jl}$		**-0.215*** **		**-0.234*** **
			(0.074)		(0.074)

[24] We compare the differential impact at the first and third quartile of the distribution in GVC participation ($ß_2$*gvc_{il}). From Table 1, column (4) we obtain $ß_2$ = 1.564 which is multiplied with GVC participation at the first quartile of the distribution (Q1=24.4%) and again with GVC participation at the third quartile of the distribution (Q3=37.0%). Taking the interquartile difference yields 1.564 *(37.0%-24.4%) = 19.7%-pts.

[25] From Table 2, column (4) we obtain $ß_3$ = 0.414 which is multiplied with 0% (for sectors where no underlying products are durable) and again with 100% (for sectors where all underlying products are durable). Taking the difference yields 0.414*(100%-0%) = 41.4%-pts.

Third country supply shock	***competition shock$_{ijkt}$***			-0.089	0.335*
				(0.173)	(0.181)
	upstream shock$_{ilt}$			**2.082****	**2.172****
				(0.890)	(0.891)
	global output$_{mt}$	**1.102*****	**0.839*****	**1.054*****	**0.753*****
		(0.151)	(0.158)	(0.162)	(0.166)
	Constant	**1.013*****	**0.732*****	**0.947*****	**1.243*****
		(0.053)	(0.018)	(0.082)	(0.103)
	Observations	496,295	496,295	496,295	496,295
	R-squared	0.424	0.424	0.424	0.424
	Exporter-Time FE	Yes	Yes	Yes	Yes
	Importer-Time FE	Yes	Yes	Yes	Yes
	Exporter-Partner-Sector FE	Yes	Yes	Yes	Yes
	Sector-Time FE	Yes	Yes	Yes	Yes
	Cluster	Exporter-Partner	Exporter-Partner	Exporter-Partner	Exporter-Partner

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Sector-time fixed effects control for unobserved effects affecting aggregated sectors over time (see footnote 10). The variable $global\ output_{mt}$ additionally controls for global sector-time trends.

The interaction between GVC participation in partner countries and the variable retail mobility ($retail\ mobility_{jt}$*$gvc\ partner_{jl}$) shows that the negative effect on bilateral exports of a shock in the exporters' partner countries is more pronounced in sectors that have a larger share of imported inputs. Specifically, the impact of the demand shock for sector-countries with low shares of imported inputs (1st quartile of the distribution) is almost 12 percentage points smaller than for sector-countries with high shares of imported inputs (3rd quartile of the distribution).[26] These results suggest that buyer firms in partner country-sectors that are hit by the Covid-19 shock import fewer inputs from their suppliers. This result can also be explained by the fact that disruptions in production caused by the pandemic prevent firms in partner countries from satisfying consumer demand for final goods and this translates into higher shares of imports of final goods relative to intermediate inputs from foreign suppliers.

Finally, column (3) presents the impact of a supply shock in third countries on bilateral export growth through the competition and GVC channels. The coefficient capturing the former ($competition\ shock_{ijkt}$) has the expected negative sign but is not statistically significant. A possible explanation for the lack of significance is that the Covid-19 shocks impacted the set of 28 exporters in our sample simultaneously, restricting bilateral trade growth to adjust through the competition channel. We come back to this issue

[26] We compare the differential impact at the first and third quartile of the distribution in the partner's GVC participation (β_4*$gvc\ partner_{il}$). From Table 1, column (4) we obtain β_4 = 0.234 which is multiplied with GVC participation at the first quartile of the distribution (Q1=7.4%) and again with GVC participation at the third quartile of the distribution (Q3=57.7%). Taking the interquartile difference yields 0.234 *(57.7%-7.4%) = 11.8%-pts.

in the next section where we include China in the set of exporters. The coefficient capturing the upstream shock ($upstream\ shock_{jlt}$) is statistically significant and slightly larger, in terms of magnitude, compared to the results presented in Table 1. This result confirms that changes in industrial production in third countries, by affecting availability of intermediate inputs, have an impact on export growth. Specifically, an average decline in the weighted annualized IPI growth in an exporter's source countries by one percentage point is linked to a 2.2 percentage point decline in bilateral annualized export growth, holding all other variables constant.

The last column of Table 2 combines all the shocks and transmission channels in one regression. All the coefficients of interest remain significant and do not vary in terms of their magnitudes. Results therefore confirm that the negative trade effects of Covid-19 were mitigated for sectors with a higher percentage of occupations that can be performed remotely and contemporaneously also for durable goods. The shock in third countries did not translate into into increased exports in the destination markets, at least for firms in the 28 exporters in our sample. In terms of GVC channels, disruption of production in an exporter's source countries more adversely affected its export growth in sectors that rely more strongly on imported inputs from these source countries. Similarly, negative shocks in an exporter's partner countries more adversely affected its export growth in sectors with high shares of parts and components. But the negative impact of a disruption in domestic production in exporting countries themselves was mitigated by a sector's higher reliance on imported inputs used in their exports. Thus, while GVC participation increased an exporter's vulnerability to foreign shocks, it reduced vulnerability to domestic shocks.

Other product characteristics beyond durability can affect how imports respond to Covid-19 demand shocks. In Appendix Table 5, we show the results of a different specification where we focus on the impact of the shock on homogeneous goods. Homogenous goods are those that are traded on an organized exchange, i.e. they are standardized and do not differ substantially across suppliers (Rauch, 1999). One can assume that adjustments on the demand side, such as cancellations of orders, are easier when products are homogenous and hence that these products are more affected during a crisis. The results support this hypothesis, showing that bilateral trade growth in sectors with a higher share of homogeneous products suffers more strongly from a demand shock in partner countries as compared to non-homogeneous products.

Our baseline regressions use export values which can be subject to large price fluctuations during a pandemic. While the regressions already excluded from the sample mining sectors such as oil and coke which are more strongly affected by price fluctuations, we also estimate the model based on export

quantities rather than export values. The country sample is reduced to the EU countries for which export quantities (in kilograms) are readily available, i.e. it excludes Japan and the United States. The results are reported in Appendix Table 6 and broadly support our findings except for the role of an exporter's reliance on imported inputs in a sector which remains positive but loses statistical significance.

4. Robustness tests and extensions

In this section, we present two robustness tests and two extensions. First, we use an alternative measure of the Covid-19 shocks in the exporter and importer country based on industrial production. Second, we study separately the months February to April 2020 to better reflect the period of the global downturn, and the months April to June 2020 where restrictions in most countries were progressively eased. Finally, in our extensions we include China as an exporter and use mirror trade data to expand the sample to 64 developed and developing countries exporters.

Industrial production as an alternative measure of the demand and supply shocks

Results presented in Table 2 could potentially be biased by the presence of measurement error in the work and retail mobility variables, which are used to capture respectively the demand and supply shocks induced by Covid-19. In order to control for this, equation (2) is estimated using growth in industrial production as an alternative proxy for production shocks through the GVC channel in the exporter country and in its trading partners. Interacting GVC-related sector intensities with IPI growth is more closely related to the GVC channel than the broader work and retail mobility measures. The results presented in Table 3 hold, confirming the heterogeneous impact of the demand and supply shocks across sectors.

Table 3: Supply, demand and third-country shocks and bilateral export growth, the role of sector characteristics, OLS regression results, alternative shocks

FRAMEWORK	VARIABLES	(1) $growth_{ijkt}$	(2) $growth_{ijkt}$	(3) $growth_{ijkt}$	(4) $growth_{ijkt}$
Exporter supply shock* sector characteristic	$ipi_{it}*remote_{ik}$	**1.003****			**1.122****
		(0.498)			(0.520)
	$ipi_{it}*gvc_{il}$	**2.060*****			**2.343*****
		(0.668)			(0.677)
Partner demand shock* sector characteristic	$ipi_{jt}*durable_{k}$		**0.499*****		**0.470****
			(0.185)		(0.191)
	$ipi_{jt}*gvc\ partner_{jl}$		**-0.390*****		**-0.394*****
			(0.141)		(0.141)
Third country supply shock	$competition\ shock_{ijkt}$			-0.067	0.187
				(0.175)	(0.182)
	$upstream\ shock_{ilt}$			**1.828****	**2.207****

				(0.877)	(0.886)
	$global\ output_{mt}$	**0.941*** **	**0.755*** **	**0.885*** **	**0.662*** **
		(0.155)	(0.162)	(0.167)	(0.171)
	Constant	**0.818*** **	**0.672*** **	**0.862*** **	**1.032*** **
		(0.034)	(0.017)	(0.081)	(0.095)
	Observations	450,629	450,629	450,629	450,629
	R-squared	0.429	0.429	0.429	0.429
	Exporter-Time FE	Yes	Yes	Yes	Yes
	Importer-Time FE	Yes	Yes	Yes	Yes
	Exporter-Partner-Sector	Yes	Yes	Yes	Yes
	Sector-Time FE	Yes	Yes	Yes	Yes
	Cluster	Exporter-Partner	Exporter-Partner	Exporter-Partner	Exporter-Partner

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Note: Sector-time fixed effects control for unobserved effects affecting aggregated sectors over time (see footnote 10). The variable $global\ output_{mt}$ additionally controls for global sector-time trends.

The availability of production data for years before 2020 also allows us to replicate the analysis for February-June 2019, to assess if our findings are driven by the Covid-19 pandemic. The results, reported in Appendix Table 7, show that sectoral differences related to the possibility of working remotely or the level of dependence on domestically or foreign sourced imported inputs for production did not significantly influence the relationship between the growth of industrial production and bilateral trade in 2019. Similarly, a higher share of durable goods in a sector in partner countries did not significantly influence the link between the growth of industrial production and bilateral trade in the previous year. A significant positive coefficient capturing the shock on demand of final goods relative to intermediates suggests that GVCs are more resilient to negative demand shocks in years when there was no pandemic. The positive and significant coefficient of the competition effect also suggests that during non-pandemic times, the pro-competitive effect of production and trade matters. These results confirm that the differential impact of the supply and demand shocks across sectors is specific feature of the Covid-19 pandemic.

Focusing on the periods of lockdowns and progressive opening

Figure 1 shows the contrast in the behavior of mobility and trade during the period February to April, when lockdown policies were imposed, and for the period April to June when lockdown policies were progressively reversed. The next robustness test examines these two periods separately (Tables 4 and 5). Both tables report the results using the specification that is comparable to Table 2 which covers the full period. Regression results show that, while the direction and significance of the previous findings hold, several variables changed their magnitude. Between February and April 2020, the possibility of remote work mitigated the negative trade effect of a supply shock in exporting countries more strongly, as shown

in columns (1) and (4). Between April and June 2020, by contrast, the possibility of remote labor no longer had a mitigating effect.

The durability of a sector's products mattered less strongly in shaping the negative trade effects from demand shocks in partner countries, as reported in columns (2) and (4), during February and April, whereas its mitigating role mattered much more during April to June. Both results are intuitive. The possibility of remote work increases in importance under more severe lockdowns. Similarly, during a global downturn, consumers withhold their expenditures, including on durable goods, given the uncertainty they are facing.

Regarding the GVC channel, both the positive influence of an exporting country's reliance on imported inputs in buffering domestic shocks and the negative influence of GVC participation in a partner country's sector were smaller between February and April, as reported in columns (1), (2) and (4), while their role was enhanced between April and June. By contrast, the upstream shock showed a magnified effect on bilateral trade growth during the first three months of our time period, as reported in columns (3) and (4), whereas the relationship between the upstream shock and bilateral export growth was no longer significant between April and June. These results imply that shocks in an exporter's source countries represented stronger bottlenecks to export during the early period, whereas shocks in the partner countries were less disruptive. The smaller role of an exporter's reliance on imported inputs in mitigating domestic shocks between February and April could also reflect simultaneous production shocks in key source countries such as China and Germany which made importing inputs less viable. The insignificant upstream shock during April and June, by contrast, could point to reduced bottlenecks in supply as production picked up in China.

Table 4: Supply, demand and third-country shocks and bilateral export growth, the role of sector characteristics, OLS regression results, February to April 2020 only

FRAMEWORK	VARIABLES	(1) $growth_{ijkt}$	(2) $growth_{ijkt}$	(3) $growth_{ijkt}$	(4) $growth_{ijkt}$
Exporter supply sector	$work\ mobility_{it}*remote_{ik}$	**1.616*** **			**1.847*** **
		(0.371)			(0.390)
	$work\ mobility_{it}*gvc_{il}$	**0.911***			**1.204** **
		(0.535)			(0.539)
Partner demand sector	$retail\ mobility_{jt}*durable_{k}$		**0.401*** **		**0.346*** **
			(0.102)		(0.107)
	$retail\ mobility_{jt}*gvc\ partner_{jl}$		**-0.168** **		**-0.178** **
			(0.080)		(0.081)
Third country	$competition\ shock_{ijkt}$			-0.160	0.358*

supply shock				(0.198)	(0.209)
	***upstream shock**$_{ilt}$*			**3.679*** **	**3.883*** **
				(1.058)	(1.067)
	***global output**$_{mt}$*	**1.408*** **	**1.166*** **	**1.275*** **	**1.004*** **
		(0.179)	(0.189)	(0.195)	(0.200)
	Constant	**1.014*** **	**0.760*** **	**1.063*** **	**1.374*** **
		(0.053)	(0.020)	(0.085)	(0.108)
	Observations	292,452	292,452	292,452	292,452
	R-squared	0.521	0.521	0.521	0.521
	Exporter-Time FE	Yes	Yes	Yes	Yes
	Importer-Time FE	Yes	Yes	Yes	Yes
	Exporter-Partner-Sector FE	Yes	Yes	Yes	Yes
	Sector-Time FE	Yes	Yes	Yes	Yes
	Cluster	Exporter-Partner	Exporter-Partner	Exporter-Partner	Exporter-Partner

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Note: Sector-time fixed effects control for unobserved effects affecting aggregated sectors over time (see footnote 10). The variable *global output*$_{mt}$ additionally controls for global sector-time trends.

Table 5: Supply, demand and third-country shocks and bilateral export growth, the role of sector characteristics, OLS regression results, April to June 2020 only

FRAMEWORK	VARIABLES	(1) ***growth***$_{ijkt}$	(2) ***growth***$_{ijkt}$	(3) ***growth***$_{ijkt}$	(4) ***growth***$_{ijkt}$
Exporter supply shock* sector characteristic	***work mobility**$_{it}$*remote**$_{ik}$*	**1.437** **			0.766
		(0.559)			(0.599)
	***work mobility**$_{it}$*gvc**$_{il}$*	**2.719*** **			**2.720*** **
		(0.820)			(0.832)
Partner demand shock* sector characteristic	***retail mobility**$_{jt}$*durable**$_{k}$*		**0.809*** **		**0.740*** **
			(0.143)		(0.147)
	***retail mobility**$_{jt}$*gvc partner**$_{jt}$*		**-0.364*** **		**-0.388*** **
			(0.112)		(0.113)
Third country supply shock	***competition shock**$_{ijkt}$*			-1.213***	-0.594
				(0.361)	(0.382)
	***upstream shock**$_{ilt}$*			0.841	1.211
				(1.154)	(1.164)
	***global output**$_{mt}$*	**0.851*** **	**0.308**	**0.787*** **	**0.215**
		(0.195)	(0.216)	(0.205)	(0.224)
	Constant	**1.092*** **	**0.552*** **	**0.573*** **	**1.004*** **
		(0.103)	(0.034)	(0.149)	(0.207)
	Observations	285,783	285,783	285,783	285,783
	R-squared	0.535	0.535	0.535	0.535
	Exporter-Time FE	Yes	Yes	Yes	Yes
	Importer-Time FE	Yes	Yes	Yes	Yes
	Exporter-Partner-Sector FE	Yes	Yes	Yes	Yes
	Sector-Time FE	Yes	Yes	Yes	Yes
	Cluster	Exporter-Partner	Exporter-Partner	Exporter-Partner	Exporter-Partner

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Note: Sector-time fixed effects control for unobserved effects affecting aggregated sectors over time (see footnote 10). The variable *global output*$_{mt}$ additionally controls for global sector-time trends.

Including China

The baseline results exclude China from the regressions, since Chinese trade data are reported jointly for January and February 2020. In addition, China does not report information feeding the Google mobility data. As a robustness check we combine trade flows data on January-February for our 28 countries and measure Covid-19 related shocks with the industrial production variable to be able to include China as exporter in our regressions. That is, monthly growth rates that were previously computed for February only are now computed for January and February combined. Work mobility changes are replaced with annualized IPI growth in the exporting countries and retail mobility with annualized IPI growth in the partner countries. The results are reported in Table 6.

Table 6: Supply, demand and third-country shocks and bilateral export growth, the role of sector characteristics, including China, OLS regression results

FRAMEWORK	VARIABLES	(1) $growth_{ijkt}$	(2) $growth_{ijkt}$	(3) $growth_{ijkt}$	(4) $growth_{ijkt}$
Exporter supply sector	$ipi_{it}*remote_{ik}$	**1.309*** **			**0.772***
		(0.440)			(0.469)
	$ipi_{it}*gvc_{il}$	**2.104*** **			**2.571*** **
		(0.616)			(0.638)
Partner demand sector	$ipi_{jt}*durable_{k}$		**0.475*** **		**0.382** **
			(0.161)		(0.167)
	$ipi_{jt}*gvc\ partner_{jl}$		**-0.197**		**-0.239***
			(0.122)		(0.127)
Third country supply shock	$competition\ shock_{ijkt}$			**-0.549*** **	-0.244
				(0.141)	(0.158)
	$upstream\ shock_{ilt}$			**1.804** **	**2.400*** **
				(0.727)	(0.789)
	$global\ output_{mt}$	**0.851*** **	**0.710*** **	**0.754*** **	**0.611*** **
		(0.143)	(0.148)	(0.143)	(0.153)
	Constant	**0.840*** **	**0.657*** **	**0.813*** **	**0.971*** **
		(0.030)	(0.018)	(0.069)	(0.085)
	Observations	561,693	510,641	588,245	487,264
	R-squared	0.433	0.433	0.433	0.433
	Exporter-Time FE	Yes	Yes	Yes	Yes
	Importer-Time FE	Yes	Yes	Yes	Yes
	Exporter-Partner-Sector	Yes	Yes	Yes	Yes
	Sector-Time FE	Yes	Yes	Yes	Yes
	Cluster	Exporter-Partner	Exporter-Partner	Exporter-Partner	Exporter-Partner

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Note: Sector-time fixed effects control for unobserved effects affecting aggregated sectors over time (see footnote 10). The variable $global\ output_{mt}$ additionally controls for global sector-time trends.

Interestingly, while the previous findings hold in terms of significance and direction, several differences stand out when comparing the results with results for the original country sample excluding China (Table

3).[27] First, while a higher percentage of occupations that can be performed remotely in a sector still mitigates the negative trade effect of a production shock in exporting countries, the coefficient of 0.77 in column (4) is 0.35 percentage point smaller compared to the original country sample (Table 3) and also shows a lower statistical significance. Second, third-country effects in column (3) have the correct sign and are statistically significant, suggesting that China's exports grew in destination markets as other exporters were affected by Covid-19. This coefficient remains with the right sign but loses significance in column (4). Finally, regarding the GVC channel, the positive role of an exporting country's share of imported inputs in mitigating shocks is 0.2 percentage point larger in the extended country sample including China, whereas the negative role of GVC participation in a partner country's sector is 0.15 percentage point smaller. The upstream shock, however, matters more strongly for bilateral trade growth, consistently with the centrality of China in modern global value chains.

Including developing countries

In a final extension we use mirror trade data, i.e. import data to our 28 countries, to obtain a larger sample of exporting countries. Since the weights used for the computation of the upstream shock variable are based on 64 countries in the TiVA data set, we need to limit the number of exporters to the TiVA sample too. This country sample includes several upper- and lower-middle-income countries and thus allows us to examine whether the previous findings also hold when more middle-income countries are included. The caveat is that the trade data only consider bilateral exports to 26 EU member states, Japan and the United States.

The results reported in Table 7 show that the general findings still hold in the larger country sample. The only exception is the role of remote work in a country and sector which is no longer significant and shows a much smaller coefficient. It appears that in middle-income countries, the possibility of remote work in a sector matters much less in hampering the negative trade effect from shocks, possibly because the type of occupations in a sector cannot be performed remotely. This finding is consistent with the lower role of remote work when we included China to the country sample. Another interesting difference is the size of the upstream shock which becomes smaller when including more middle-income countries. A possible explanation could be the composition of export goods in the larger sample which are likely to be more upstream in the supply chain, implying that a negative shock in an exporter's source countries has a

[27] Appendix 4 presents the comparison. We cannot rule out that the aggregation of January and February data is driving some of these differences.

weaker negative impact on its export growth. The other findings are comparable to the baseline effects reported in Table 2 in terms of sign, size and significance.

Table 7: Supply, demand and third-country shocks and bilateral export growth, the role of sector characteristics, mirror data, OLS regression results

FRAMEWORK	VARIABLES	(1) $growth_{ijkt}$	(2) $growth_{ijkt}$	(3) $growth_{ijkt}$	(4) $growth_{ijkt}$
Exporter supply shock* sector characteristic	$work\ mobility_{it}*remote_{ik}$	**0.074**			**0.044**
		(0.336)			(0.353)
	$work\ mobility_{it}*gvc_{il}$	**1.398*** **			**1.647*** **
		(0.510)			(0.517)
Partner demand sector characteristic	$retail\ mobility_{jt}*durable_{k}$		**0.414*** **		**0.425*** **
			(0.099)		(0.103)
	$retail\ mobility_{jt}*gvc$		**-0.186** **		**-0.214*** **
			(0.072)		(0.074)
Third country supply shock	$competition\ shock_{ijkt}$			-0.012	0.203
				(0.180)	(0.187)
	$upstream\ shock_{ilt}$			**1.835** **	**1.673** *
				(0.865)	(0.870)
	$global\ output_{mt}$	**0.765*** **	**0.502*** **	**0.729*** **	**0.426** **
		(0.160)	(0.172)	(0.171)	(0.179)
	Constant	**0.748*** **	**0.607*** **	**0.802*** **	**0.906*** **
		(0.049)	(0.018)	(0.078)	(0.094)
	Observations	323,998	323,998	323,998	323,998
	R-squared	0.446	0.446	0.446	0.446
	Exporter-Time FE	Yes	Yes	Yes	Yes
	Importer-Time FE	Yes	Yes	Yes	Yes
	Exporter-Partner-Sector FE	Yes	Yes	Yes	Yes
	Sector-Time FE	Yes	Yes	Yes	Yes
	Cluster	Exporter-Partner	Exporter-Partner	Exporter-Partner	Exporter-Partner

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Note: Sector-time fixed effects control for unobserved effects affecting aggregated sectors over time (see footnote 10). The variable $global\ output_{mt}$ additionally controls for global sector-time trends.

5. Conclusions

Using monthly trade data for 28 exporting countries and multiple importers over the January-June 2020 period, this paper investigated how the Covid-19 pandemic impacted international trade. We find strong evidence that sectoral characteristics such as the feasibility of remote work, durability of goods, and integration into global value chains played a large role in mitigating or augmenting the trade effects of Covid-19 shocks. While more work is needed, particularly to include sectoral trade data from a larger set of developing countries, these findings provide relevant policy insights. First, they help identify the sectoral attributes that create vulnerability during a pandemic, providing guidance for sectoral policy

intervention. Second, they show how countries are impacted by domestic and foreign shocks during a global pandemic, which offers insights on strategies for global value chain diversification.

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Appendices

Appendix 1: Remote labor index

ISIC Rev 3.1 d	Sector	Remote Labor Index
2	Forestry, logging and related service activities	0.15
5	Fishing, operation of fish hatcheries and fish farms; service activities incidental to fishing	0.16
16	Manufacture of tobacco products	0.22
15	Manufacture of food products and beverages	0.25
1	Agriculture, hunting and related service activities	0.26
27	Manufacture of basic metals	0.27
34	Manufacture of motor vehicles, trailers and semi-trailers	0.31
21	Manufacture of paper and paper products	0.32
20	Manufacture of wood and of products of wood and cork, except furniture; manufacture of articles of straw and plaiting materials	0.34
25	Manufacture of rubber and plastics products	0.34
28	Manufacture of fabricated metal products, except machinery and equipment	0.34
19	Tanning and dressing of leather; manufacture of luggage, handbags, saddlery, harness and footwear	0.35
17	Manufacture of textiles	0.35
35	Manufacture of other transport equipment	0.35
36	Manufacture of furniture; manufacturing n.e.c.	0.35
24	Manufacture of chemicals and chemical products	0.35
29	Manufacture of machinery and equipment n.e.c.	0.37
18	Manufacture of wearing apparel; dressing and dyeing of fur	0.37
26	Manufacture of other non-metallic mineral products	0.38
31	Manufacture of electrical machinery and apparatus n.e.c.	0.39
30	Manufacture of office, accounting and computing machinery	0.40
33	Manufacture of medical, precision and optical instruments, watches and clocks	0.42
32	Manufacture of radio, television and communication equipment and apparatus	0.45
22	Publishing, printing and reproduction of recorded media	0.54

Source: U.S. 2017 O*NET and WDI (see data description for details).

Appendix 2: Correlation matrix between interaction terms

	$work\ mobility_{it}*remote_{ik}$	$ipi_{it}*gvc_{il}$	$retail\ mobility_{jt}*durable_{k}$	$ipi_{jt}*gvc\ partner_{jl}$	$upstream\ shock_{ilt}$	$competition\ shock_{ijkt}$	$global\ output_{mt}$	$work\ mobility_{it}*gvc_{il}$	$retail\ mobility_{jt}*gvc\ partner_{jl}$
$work\_mobility_{it}*remote_{ik}$	1								
$ipi_{it}*gvc_{il}$	0.53	1							
$retail\_mobility_{jt}*durable_{k}$	0.24	0.16	1						
$ipi_{jt}*gvc\ partner_{jl}$	0.35	0.32	0.01	1					
$upstream\ shock_{ilt}$	0.72	0.72	0.22	0.44	1				
$competition\ shock_{ijkt}$	0.56	0.57	0.07	0.41	0.85	1			
$global\ output_{mt}$	0.37	0.39	0.43	0.11	0.55	0.45	1		
$work\ mobility_{it}*gvc_{il}$	0.82	0.70	0.18	0.34	0.73	0.55	0.34	1	
$retail\ mobility_{jt}*gvc\ partner_{jl}$	0.39	0.30	0.01	0.77	0.41	0.38	0.02	0.37	1

Appendix 3: Summary statistics

Variable	Obs	Mean	Std. Dev.	Min	Max
Dependent variable					
$growth_{ijkt}$	439,807	0.620	3.448	-0.977	30.070
Production and consumption channels					
Mobility changes					
$work\ mobility_{it}$	439,807	-0.257	0.169	-0.686	0.059
$retail\ mobility_{jt}$	439,807	-0.293	0.249	-0.894	0.121
Sector Intensities					
$remote_{ik}$	439,807	0.381	0.096	0.111	0.901
$durable_{k}$	439,807	0.126	0.255	0.000	1.000
Interaction Terms					
$work\ mobility_{it}$* $remote_{ik}$	439,807	-0.098	0.070	-0.598	0.035
$retail\ obility_{jt}$*$durable_{k}$	439,807	-0.036	0.101	-0.894	0.121
GVC channel					
Industrial Production					
ipi_{it}	439,807	-0.119	0.131	-0.479	0.282
ipi_{jt}	439,807	-0.108	0.143	-0.905	0.388
Sector Intensities					
gvc_{il}	439,807	0.310	0.102	0.082	0.713
$gvc\_partner_{jl}$	439,807	0.312	0.282	0.013	1.000
Interaction Terms					
ipi_{it}*gvc_{il}	439,807	-0.037	0.046	-0.316	0.128
ipi_{jt}*$gvc\_partner_{jl}$	439,807	-0.035	0.070	-0.905	0.388
$work\ mobility_{it}$*gvc_{il}	439,807	-0.080	0.060	-0.443	0.022
$retail\ mobility_{jt}$*$gvc\ partner_{jl}$	439,807	-0.092	0.135	-0.892	0.121
Third country shocks					
$competition\ shock_{ijkt}$	439,807	-0.101	0.076	-0.350	0.036
$upstream\_shock_{ilt}$	433,772	-0.097	0.083	-0.284	0.034
Control					
$global\ output_{mt}$	439,807	-0.101	0.087	-0.514	0.008

Appendix 4: Supply, demand and third-country shocks and bilateral export growth, the role of sector characteristics, OLS regression results, one month lag on durable goods

FRAMEWORK	VARIABLES	(1) $growth_{ijkt}$	(2) $growth_{ijkt}$	(3) $growth_{ijkt}$	(4) $growth_{ijkt}$
Exporter supply shock* sector characteristic	$work\ mobility_{it}*remote_{ik}$	0.805			**1.065****
		(0.495)			(0.520)
	$work\ mobility_{it}*gvc_{il}$	**2.955*****			**3.135*****
		(0.774)			(0.779)
Partner demand shock* sector characteristic	$retail\ mobility_{jt-1}*durable_{k}$		**-0.408*****		**-0.404*****
			(0.090)		(0.091)
	$retail\ mobility_{jt}*gvc\ partner_{jl}$		**-0.268*****		**-0.291*****
			(0.101)		(0.101)
Third country supply shock	$competition\ shock_{ijkt}$			-0.063	0.038
				(0.256)	(0.270)
	$upstream\ shock_{ilt}$			**1.899***	**2.389****
				(0.996)	(1.003)
	$global\ output_{mt}$	**0.831*****	**0.857*****	**0.772*****	**0.750*****
		(0.154)	(0.164)	(0.164)	(0.172)
	Constant	0.961***	0.531***	0.793***	1.246***
		(0.089)	(0.024)	(0.113)	(0.163)
	Observations	361,359	361,359	361,359	361,359
	R-squared	0.469	0.469	0.469	0.469
	Exporter-Time FE	Yes	Yes	Yes	Yes
	Importer-Time FE	Yes	Yes	Yes	Yes
	Exporter-Partner-Sector FE	Yes	Yes	Yes	Yes
	Sector-Time FE	Yes	Yes	Yes	Yes
	Cluster	Exporter-Partner	Exporter-Partner	Exporter-Partner	Exporter-Partner

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Sector-time fixed effects control for unobserved effects affecting aggregated sectors over time (see footnote 10). The variable $global\ output_{mt}$ additionally controls for global sector-time trends.

Appendix 5: The role of homogenous goods, OLS regression results

FRAMEWORK	VARIABLES	(1) $growth_{ijkt}$	(2) $growth_{ijkt}$	(3) $growth_{ijkt}$	(4) $growth_{ijkt}$
Exporter supply shock* sector characteristic	$work\ mobility_{it}*remote_{ik}$		**1.077*** **		**1.187*** **
			(0.398)		(0.397)
	$work\ mobility_{it}*gvc_{il}$		**1.285** **		**1.412*** **
			(0.521)		(0.520)
Partner demand shock* sector characteristic	$retail\ mobility_{jt}*homog\_con_{k}$	**-0.402*** **	**-0.321*** **		
		(0.064)	(0.070)		
	$retail\ mobility_{jt}*homog\_lib_{k}$			**-0.336*** **	**-0.252*** **
				(0.060)	(0.065)
	$retail\ mobility_{jt}*gvc\ partner_{jk}$	**-0.199*** **	**-0.221*** **	**-0.194*** **	**-0.222*** **
		(0.073)	(0.074)	(0.073)	(0.074)
Third country supply shock	$competition\ shock_{ijkt}$		0.338*		0.306*
			(0.180)		(0.179)
	$upstream\ shock_{ilt}$		**1.891** **		**1.901** **
			(0.887)		(0.889)
	$global\ output_{mt}$	**0.865*** **	**0.829*** **	**0.912*** **	**0.862*** **
		(0.156)	(0.166)	(0.156)	(0.165)
	Constant	0.696***	1.118***	0.701***	1.142***
		(0.019)	(0.105)	(0.019)	(0.105)
	Observations	496,295	496,295	496,295	496,295
	R-squared	0.424	0.424	0.424	0.424
	Exporter-Time FE	Yes	Yes	Yes	Yes
	Importer-Time FE	Yes	Yes	Yes	Yes
	Exporter-Partner-Sector FE	Yes	Yes	Yes	Yes
	Sector-Time FE	Yes	Yes	Yes	Yes
	Cluster	Exporter-Partner	Exporter-Partner	Exporter-Partner	Exporter-Partner

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Note: Sector-time fixed effects control for unobserved effects affecting aggregated sectors over time (see footnote 10). The variable $global\ output_{mt}$ additionally controls for global sector-time trends. The share of homogenous products traded on an organized exchange in a sector is based on the Rauch classification and serves as inverse measure of a sector's average share of differentiated products. We apply both a more conservative ($homog\_con_{k}$) and a more liberal classification ($homog\_lib_{k}$) of homogenous products.

Appendix 6: Supply, demand and third-country shocks and bilateral export growth based on quantities, the role of sector characteristics, OLS regression results, EU countries

FRAMEWORK	VARIABLES	(1) $growth\_q_{ijkt}$	(2) $growth\_q_{ijkt}$	(3) $growth\_q_{ijkt}$	(4) $growth\_q_{ijkt}$
Exporter supply shock* sector characteristic	$work\ mobility_{it}*remote_{ik}$	**4.927*** **			**5.225*** **
		(1.337)			(1.406)
	$work\ mobility_{it}*gvc_{il}$	0.849			1.358
		(1.782)			(1.797)
Partner demand shock* sector characteristic	$retail\ mobility_{jt}*durable_{k}$		**0.645** **		**0.436**
			(0.325)		(0.336)
	$retail\ mobility_{jt}*gvc\ partner_{jl}$		**-0.723** **		**-0.763*** **
			(0.288)		(0.289)
Third country supply shock	$competition\ shock_{ijkt}$			-0.600	0.366
				(0.604)	(0.637)
	$upstream\ shock_{ilt}$			**5.659***	**5.683***
				(3.115)	(3.149)
	$global\ output_{mt}$	**1.528*** **	**1.021***	**1.258** **	0.789
		(0.566)	(0.594)	(0.602)	(0.620)
	Constant	**2.889*** **	**2.229*** **	**2.795*** **	**3.431*** **
		(0.197)	(0.068)	(0.291)	(0.388)
	Observations	446,472	446,472	446,472	446,472
	R-squared	0.414	0.414	0.414	0.414
	Exporter-Time FE	Yes	Yes	Yes	Yes
	Importer-Time FE	Yes	Yes	Yes	Yes
	Exporter-Partner-Sector FE	Yes	Yes	Yes	Yes
	Sector-Time FE	Yes	Yes	Yes	Yes
	Cluster	Exporter-Partner	Exporter-Partner	Exporter-Partner	Exporter-Partner

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Note: Sector-time fixed effects control for unobserved effects affecting aggregated sectors over time (see footnote 10). The variable $global\ output_{mt}$ additionally controls for global sector-time trends.

Appendix 7: Supply, demand and third shocks and bilateral export growth, the role of sector characteristics, OLS regression results, February to June 2019

FRAMEWORK	VARIABLES	(1) $growth_{ijkt}$	(2) $growth_{ijkt}$	(3) $growth_{ijkt}$	(4) $growth_{ijkt}$
Exporter supply shock* sector characteristic	ipi_{it}*$remote_{ik}$	0.892			0.849
		(1.307)			(1.329)
	ipi_{it}*gvc_{il}	1.372			1.383
		(2.042)			(2.065)
Partner demand shock* sector characteristic	ipi_{jt}*$durable_{k}$		0.247		0.298
			(0.456)		(0.465)
	ipi_{jt}*$gvc\ partner_{jl}$		1.031**		1.010**
			(0.408)		(0.408)
Third country supply shock	$competition\ shock_{ijkt}$			1.545**	1.590**
				(0.744)	(0.756)
	$upstream\ shock_{ilt}$			-2.442	-2.135
				(2.112)	(2.137)
	$global\ output_{mt}$	0.604	0.616	0.564	0.599
		(0.548)	(0.553)	(0.546)	(0.558)
	Constant	0.745***	0.752***	0.742***	0.721***
		(0.017)	(0.010)	(0.014)	(0.022)
	Observations	504,038	504,038	504,038	504,038
	R-squared	0.418	0.418	0.418	0.418
	Exporter-Time FE	Yes	Yes	Yes	Yes
	Importer-Time FE	Yes	Yes	Yes	Yes
	Exporter-Partner-Sector FE	Yes	Yes	Yes	Yes
	Sector-Time FE	gvc_time	gvc_time	gvc_time	gvc_time
	Cluster	Exporter-Partner	Exporter-Partner	Exporter-Partner	Exporter-Partner

Robust standard errors in parentheses. *** p<0.01, ** p<0.05, * p<0.1. Note: Sector-time fixed effects control for unobserved effects affecting aggregated sectors over time (see footnote 10). The variable $global\ output_{mt}$ additionally controls for global sector-time trends.