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Covid-19, trade collapse and GVC linkages: European experience

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Abstract

This paper highlights the role of supply chain linkages for the transmission of Covid-19 induced shocks based on the monthly trade of the European Union Member States during the first wave of Covid-19 pandemic. Using the framework of the gravity model, we find an overall decline of over 20% in trade following the Covid-19 outbreak. Both supply and demand shocks are shown to contribute to this trade decline associated with Covid-19 in the origin and destination country proxied by either infection rate or policy stringency index. While import demand shocks have an immediate effect on trade decline, trade becomes increasingly sensitive to the Covid-19 situation in the origin country over time. Moreover, the results confirm that forward GVC linkages act as a channel for the transmission of (demand) shocks in supply chain trade. Indeed, an increase in the incidence of Covid-19 cases in the destination country leads to a larger decrease in domestic exports of intermediate goods in those destination countries with which a country has stronger forward linkages, i.e. in partners positioned further downstream. We also find the "China effect", with the transmission of the Covid-19 shock from the partner country amplified when the share of supply chain trade with China is higher. On the other hand, we fail to find robust evidence for the transmission of Covid-19-induced shocks via backward linkages.

Keywords: Covid-19, trade, GVC, shock transmission, forward and backward linkages, gravity model, the EU

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1. Introduction

As a result of the Covid-19 pandemic, predictions show the global economy contracting sharply by -4.9 percent in 2020 (IMF, 2020)[6], whilst all regions will suffer double-digit declines in exports and imports (WTO, 2020)[7], much worse than during the 2008-09 global financial crisis (hereinafter GFC). It is projected for the European Union to be among the most affected economies, with a drop in GDP by 8.3 percent in 2020 (European Commission, 2020)[8]. Estimates of the expected recovery of Europe in 2021 are uncertain, with outcomes depending significantly on the duration of the outbreak and the effectiveness of the policy responses, in particular the vaccination rollout. An economic downturn, increased uncertainty and simultaneous supply chain disruptions have been putting tremendous pressure on the reorganisation and reconfiguration of the global value chains (GVC hereafter). Covid-19 has hit at the core of GVC hub regions, including Europe, China, and the US.

The lessons from recent global crises and shocks, such as GFC in 2008 and the Japanese earthquake/tsunami in 2011, showed that companies react by reorienting their sourcing strategies towards more diversification of risk and breaking the value chains into shorter and less complex ones (OECD, 2013). However, the Covid-19 crisis differs from the GFC mainly in that it involves lockdown and social distancing which has led to major GVC disruptions. Trade is likely to fall more steeply in sectors characterized by complex value-chain linkages, particularly in electronics and automotive products. This is closely related to the nature of certain jobs that cannot be sufficiently performed remotely, leading to lower industry output, consequently amplifying trade effects due to supply chain linkages. Using survey data for the US, Dingel and Neiman (2020) estimated an upper bound share of jobs in manufacturing that can be performed remotely at 22%, which helps explain negative trade effects from exporting countries due to lesser export supply as a consequence of imposed measures.

On top of this, as pointed out by Evenett (2020), a troubling trade policy dimension is now coming to light. Over 80 countries have introduced export prohibitions or restrictions as a result of the Covid-19 pandemic, predominantly on medical supplies, pharmaceuticals, and medical equipment, but also additional products, such as foodstuffs and toilet paper (WTO, 2020)[9]. At the same time, politicians' calls for "sovereign" or "national" supply chains and re-thinking of domestic companies' approaches to international outsourcing of production are becoming louder (Serič, Görg, Mösle, and Windisch, 2020). These processes and developments might lead as well to the break of the existing GVCs and their readjustment.

[6] Available at https://www.imf.org/en/Publications/WEO/Issues/2020/06/24/WEOUpdateJune2020
[7] Available at https://www.wto.org/english/news_e/pres20_e/pr855_e.htm
[8] Available at https://ec.europa.eu/info/sites/info/files/economy-finance/ip132_en.pdf
[9] More on this https://www.wto.org/english/tratop_e/covid19_e/export_prohibitions_report_e.pdf

Friedt and Zhang (2020) estimated that GVC contagion effect explains around two-thirds of the total reduction in Chinese exports, thus providing support for the decisive role of GVC participation for the trade response to Covid-19 pandemic situation. In line with this observation, Figure 1 placed later in Section 3.5 illustrates that during the first wave of the pandemic EU member states overall recorded the largest decline in trade with intermediated goods. However, at least at first glance, the differences in trade contraction at the beginning of the second quarter of 2020 between EU member states do not reflect differences in the incidence of Covid-19 cases. As exemplified in Figures 2 and 3 in Section 3.5, despite having relatively fewer Covid-19 cases per capita, the new EU member states experienced above-average import and export contraction. A relevant question is whether this discrepancy can be explained by differences in GVC participation and position among member states. According to World Development Report 2020, the type of GVC participation significantly differs among the EU member states. While most of the old EU member states are specialized in innovative GVCs activities, CEE-11 are mostly specialized in advanced manufacturing and services GVCs with a high share of manufacturing and business services exports and high backward GVC integration. Overall, the old member states occupy a more upstream position in GVCs compared to the new EU member states.

Understanding the severity and nature of trade collapse in EU member states in the wake of the Covid-19 pandemic requires knowledge about the structure of value chains and subsequent level of integration by countries. In this paper, we aim to add to the growing literature on pandemic-induced disruptions to manufacturing activity by empirically assessing how inclusion and position in GVCs determine trade adjustment to Covid-19-induced shocks during the first wave of the pandemic. We augment the gravity model with backward and forward GVC linkages to account for various trade-related transmission mechanisms of the Covid-19 shocks in partner countries.

Our work is closely related to Baldwin and Freeman (2020), Baldwin and Tomiura (2020) and Friedt and Zhang (2020) who investigate the so-called ‘triple pandemic effect’ on trade through the pandemic-induced domestic supply, international demand, and GVC contagion shocks. The transmission role of the GVCs has been addressed also from the perspective of its impact on real economic activity and prices (Meier and Pinto, 2020), output adjustments to cross-sectoral effects of labour supply shocks (Bonadio et al., 2020; McCann and Myers, 2020), and aggregate welfare, through both deaths and reduced gains from trade (Antras et al., 2020). The literature on demand and supply shocks includes Farhi and Baqaee (2020) who study how Covid-19 induced supply and demand shocks affect real economic variables, and Hassan et al. (2020) who identify negative demand shock and supply chain disruptions as one of the prevailing concerns when conducting a firm-level analysis of earnings’ calls.

The rest of the paper is organised as follows. Section 2 discusses transmission mechanisms of Covid-19 shocks through supply chain linkages. Section 3 sets gravity-model-based empirical specifications, discusses methodological issues and presents stylised facts on trade performance and Covid-19 pandemic situation across EU member states. Section 4 shows the estimates and discusses the results of the Covid-19 impact on bilateral trade flows and provides some robustness checks. Section 5 concludes the paper.

2. Background on GVC linkages and transmission of Covid-19 induced shocks

In many countries, several drastic measures have been taken in response to the Covid-19 pandemic, such as lockdowns and social distancing, with direct impact on both the demand and the supply side of the domestic economy and thus on its trade performance. Moreover, due to strong supply chain linkages, the Covid-19 induced shocks spread quickly across countries. Baldwin and Freeman (2020), Baldwin and Tomiura (2020) and Friedt and Zhang (2020) conceptualize this diverse set of effects as the 'triple pandemic effect' on trade through direct supply disruption due to various containment efforts, the supply-chain contagion due to the disruptions of the international flow of intermediate inputs, and the decline in global demand due to reduction in consumer spending and investment delays.

We build upon this classification by further acknowledging that supply and demand shocks transmit through the GVC linkages in both directions via forward and backward linkages, i.e. upstream and downstream, giving rise to complex interplay of the trade effects of Covid-19 pandemic which we summarize in Table 1. Based on their position in GVCs, countries can be classified as more upstream or downstream, each category of countries being subject to different dynamics of shock transmission.

On the supply side, lockdown measures, subsequent closing of local businesses as well as fear of infection result in a labour supply shock. On a domestic level, lockdown-induced labour supply shock is manifested in lower export supply due to lower output. Moreover, labour supply shocks in partner countries affect domestic trade through (see Table 1): (i) lower domestic imports of final consumption goods due to ravaged supply in a partner country, and (ii) reduced imports of intermediates via backward linkages, i.e. supply-chain disruption from foreign upstream suppliers conveyed to domestic downstream customers. For instance, Bonadio et al. (2020) showed that a quarter of the average real GDP downturn due to lockdown-induced labour supply shocks could be atributed to the transmission through global supply chains.

On the demand side, increased uncertainty and declines in household disposable income propagate lower demand for products, especially consumer goods, which means lower import volumes. By analysing text-based measures of the costs, benefits and risks firms associate with the spread of Covid-19 disease in the first quarter of 2020, Hassan et al. (2020) confirmed that collapse of demand and increased uncertainty were among firms' primary concerns. Transmission of demand-side shocks from partner countries come through multiple channels, trade in final goods and supply chain trade (intermediates and capital goods). While the impact on trade in final goods is relatively straightforward, corresponding directly to the decreased exports to partner country which experiences a demand shock (i.e. partner country's demand shock resulting in lower imports will translate directly to lower domestic exports), supply chain trade transmission depends upon the GVC interrelations. In particular, the demand-side shock in a partner country leads to lower demand for intermediates sourced from upstream domestic suppliers through forward GVC linkages, and hence lower exports of intermediates from the domestic market to the partner country. We summarize these potential channels and expected effects of Covid-19 on trade in Table 1.

Table 1: Domestic and transmitted effects of Covid-19 pandemic on the domestic country's trade

	Domestic Covid-19 shock in *i*	**Transmission of Covid-19 shock from partner country *j***		
		Final good trade	*Supply chain trade (intermediates and capital goods)*	
			From downstream customers in *j* to domestic upstream suppliers (via FP_{ij})	From upstream suppliers in *j* to domestic downstream customers (via BP_{ij})
Demand side	IM_i ⇩	EX_i ⇩	EX_i ⇩	
Supply side	EX_i ⇩	IM_i ⇩		IM_i ⇩

Friedt and Zhang (2020) estimated that the impact of GVC contagion explains around 75% of the total reduction in Chinese exports, while the domestic supply shock in China accounts for around 10% to 15% and the international demand shock only explains about 5% to 10%. McCann and Myers (2020) studied the nature of transmission of Covid-19 shock through inter-sectoral supply-chain linkages and found that in particular upstream sectors without direct Covid-19 exposure containment policies can still be affected if their downstream (customer) firms suffer acute revenue losses, while the transmission from upstream suppliers to downstream firms is likely to be smaller. In line with this evidence, we expect that transmission of supply-chain shocks operates primarily from downstream customers to their upstream suppliers. It does so by initially affecting the exports

of the intermediate goods via forward linkages. On the other hand, Meier and Pinto (2020) provide indirect evidence of the transmission of shocks through backward linkages. They found that US sectors with greater exposure to intermediate goods imports from China contracted significantly more than other sectors coupled with their relative input and output price increase. Regarding the direct impact of the Covid-19 crisis, Hayakawa and Mukunoki (2020) found that in the early stage of pandemics, Covid-19 exposure has a significant negative effect on trade in exporting countries but not in importing countries.

3. Conceptual framework, methodology and data

3.1. Gravity model framework

The identified channels of Covid-19 trade effects are tested within a gravity model framework. The gravity model is a workhorse model for testing various determinants of international trade and the effects of trade policy measures. It adopts the logic of Newton's law of universal gravitation for explaining the bilateral trade flows stating that trade between two economic areas will be directly proportional to the product of their market sizes (e.g. GDPs) and inversely proportional to the square of the distance between their centres.

We follow the approach of Anderson and van Wincoop (2003) who had shown that proper specification of the gravity model grounded in the trade theory requires the inclusion of the inward and outward multilateral resistance terms (MRT) which take into consideration how "remote" both regions are from the rest of the world. The main idea is that bilateral trade flows between trading partners "*i*" and "*j*" depend on bilateral trade barriers relative to average trade barriers that both trading partners face with all their trading partners. Their formulation of the structural gravity equation, which is the basis for almost all subsequent papers using gravity models to explain bilateral trade flows, is as follows:

$$trade_{ijt} = \frac{Y_{it}Y_{jt}}{Y_t}\left(\frac{t_{ijt}}{\pi_{it}P_{jt}}\right)^{1-\sigma}, \qquad [1]$$

where Y_{it} and Y_{jt} stand for particular countries' GDP and Y_t for the world aggregate GDP, while t_{ijt} stands for the tariff equivalent of overall trade costs. The elasticity of substitution between goods is represented with σ, while π_{it} and P_{jt} represent multilateral resistance terms (in other words – exporter and importer ease of market access).

By log-linearizing structural gravity eq. [1], we obtain the most common theory-consistent gravity model specification:

$$\ln trade_{ijt} = \ln Y_{it} + \ln Y_{jt} - \ln Y_t + (1-\sigma)\left[\ln t_{ijt} - \ln \Pi_{it} - \ln P_{jt}\right] + \varepsilon_{ij} \; . \qquad [2]$$

3.2. Accounting for transmission of Covid-19 induced shocks via GVC linkages

To account for the role of both the extent of participation in and the position along GVCs in cross-country transmission of Covid-19 shocks we augment eq. [2] with GVC participation indices which measure to what extent are countries involved in a vertically fragmented production and resulting supply chain trade flows. The GVC participation is decomposed in the two indices: forward participation (FP) and backward participation (BP). Forward GVC participation refers to the type of participation where an economy joins the global production by exporting domestically produced inputs to partners who are in charge of downstream production stages, while backward GVC participation is the type of integration where the country participates by importing foreign inputs to produce the goods and services for its export. Backward linkages are measured as foreign value-added (FVA) in domestic exports, while forward ones by the domestic value-added embodied in foreign exports (DVAFX). Hence, the FVA in the exports indicates the country's "downstreamness" in global production chains and the DVAFX indicates "upstreamness".

The GVC indices are calculated using the following equations:

$$FP_{ijt} = \frac{DVAFX_{ijt}}{grossEX_{it}} \cdot 100 \qquad [3]$$

$$BP_{ijt} = \frac{FVA_{ijt}}{grossEX_{it}} \cdot 100 \qquad [4]$$

Where $DVAFX_{ijt}$ n eq. [3] denotes domestic value-added of country *i* embodied in exports of country *j* in a year *t*, and FVA_{ijt} in eq. [4] represents foreign value-added of a country *j* embedded in exports of a country *i*. *G*$rossEX_{it}$ represents gross exports of a country *i* in that same year.

To portray the bilateral GVC position of EU countries we use the log ratio of a country's forward and backward participation as proposed by Koopman, Powers, Wang, & Wei, (2010). The higher the value of the ratio the more upstream position in the GVC a country holds. This measure characterises the relative upstreamness of a country by comparing the importance of forward and backward participation, as opposed to "distance to final demand" based measures, proposed by e.g. Fally (2012) and Antràs et al. (2012), which measure how many stages of production are left before the goods or services produced by an industry reach their final consumers. We adjust the GVC position measure to be country-pair specific by using bilateral participation indices that we specified in eq. [3] and eq. [4] to obtain a bilateral GVC participation index (eq. [5]).

$$GVC_{ijt} = \text{Ln}(1 + FP_{ijt}/100) - \ln(1 + BP_{ijt}/100) \quad [5]$$

To account for the impact of the Covid-19 pandemic situation in domestic and partner countries on bilateral trade both directly and via supply-chain linkages summarized in Table 1 we augment gravity model specification [2] in the following way:

$$\begin{aligned}\ln trade_{ijt} = {} & \beta_0 + \beta_1 covid\_cases\_o_{it} + \beta_2 covid\_cases\_d_{jt} + \beta_3 FP_{ijt} + \beta_4 BP_{ijt} + \beta_5 GVC\_China\_o_{it} + \\ & + \beta_6 FP_{ijt} X covid\_cases\_d_{jt} + \beta_7 BP_{ijt} X covid\_cases\_d_{jt} + \beta_8 GVC\_China\_o_{it} X covid\_cases\_d_{jt} + \\ & + \beta_9 \ln y_{it} + \beta_{10} \ln y_{jt} + X'_{ij}\beta_{11} + \sum \beta_{12.t}\, month_t + \sum \beta_{13.t}\, year_t + \sum \beta_{14.it} year_t\, X reporter_i + \\ & + \sum \beta_{15.jt} year_t\, X partner_j + \sum \beta_{16.ij} country\_pair_{ij} + \varepsilon_{ijt} \end{aligned} \quad [6]$$

Where, $trade_{ijt}$ denotes export and import flows between countries *i* and *j* in time *t*, while *Covid_cases_o* and *covid_cases_d* count the number of infected people per 1000 population in the reporter (origin) and partner (destination) country in *t* to account for domestic and foreign supply and demand Covid-19 induced shocks.[10] As explained above, FP_{ijt} and BP_{ijt} indicate bilateral forward and backward participation based on equations [3] and [4], respectively, while their interaction with the number of infected people per 1000 population in partner country tests the presence of supply-chain transmission of shocks from partner country to domestic exports/imports via both forward and backward linkages. We further include the share of China in the EU member state's trade of intermediate goods ($GVC\_China\_o_{it}$) and its interaction with the Covid-19 cases in partner country to account for "indirect" impact of participation in Chinese GVCs on transmission of shocks from particular partner country. As shown by Meier and Pinto (2020), US sectors with greater exposure to intermediate goods imports from China contracted significantly more than other sectors. Moreover, the response of countries to Covid-19 pandemic varies in terms of the strictness of the measurers. Therefore, we expect that severity of the Covid-19 shock is related as well to the policy response in an affected country. Therefore, we adjust the empirical specification [6] and replace the number of Covid-19 cases with the policy stringency index (*policy_stringency*) to test how the trade effects and transmission of shocks through GVC linkages are related to the stringency of the Covid-19 measures. Regressor *y* represents GDP of reporter and partner country. Vector X' includes country-pair, time-invariant specific variables such as *lnDist* measuring log value of the weighted distance between country *i* and country *j*, and dummy variables indicating whether countries *i* and *j* share a common border (*contig)*, language is spoken by at least 9% of the population in both countries (*comlang_ethno*), have had a common colonizer after 1945 (*comcol*), have had a colonial relationship after 1945 (*col45*), were/are the same country (*smctry*).

[10] For benchmark, simple empirical specification with *covid_period* dummy variable is estimated to test the general drop in trade during the first wave of the Covid-19 pandemic situation. The *covid_period* dummy variable takes value one during the Covid-19 pandemic situation, i.e. from February 2020 on, and zero otherwise.

Specification includes various sets of fixed effects including time-varying reporter and partner fixed effects, country-pair fixed effects and annual and monthly fixed effects.

3.3.Methodological issues

There are certain potential econometric concerns of estimating gravity model in a panel data setting that deserve discussion. The first issue that arises in our estimation is zero trade values that are relatively common in the trade matrix and are dropped from the OLS model due to undefined logarithm value of number zero. Ignoring this issue might result in inefficient and biased estimates. To deal with this issue of zero values we use the Poisson Maximum Likelihood Estimator (PPML) which effectively solves this potential selection bias (Burger et al. 2009). The next issue is a problem of endogeneity (see Baier & Bergstrand, 2007 for discussion). Contrary to exogenous variables, endogenous variables are systematically affected by the changes in other variables within the model. Among the gravity equation variables in our specification, the GVC indices are most likely candidates for endogenous variables. To reduce the risk of endogeneity in our specifications, the FP and BP GVC participation indices are entered in the model in their lagged forms. We also lagged the GDP and Covid-19 variables due to potential simultaneity. Third, following the abovementioned findings from Anderson & van Wincoop (2003) multilateral trade-resistance terms (MRT) are also important when estimating the gravity model. Under MRT we understand a number of different trade barriers that a country faces in trade with all its trading partners, and not just with one particular partner. Without respecting the MRT the only factors that influence the trade between countries i and j are included in the analysis, which is creating a so-called omitted variable bias in the intuitive equation. To control for MRT we use a wide set of fixed effects including time-varying reporter and partner fixed effects, country-pair fixed effects and annual and monthly fixed effects. We implement Poisson pseudolikelihood regression with multiple levels of fixed effects as described by Correia, Guimarães, and Zylkin (2020) which is robust to statistical separation and convergence issues and allows any number and combination of fixed effects and individual slopes based on procedures developed in Correia, Guimarães, and Zylkin (2019). Moreover, the estimations under [6] are obtained through the clustering on the country-pair indicator variable and are therefore robust to cross-sectional heteroscedasticity and serial correlation.

3.4.Data and descriptive statistics

The empirical specification [6] is applied to monthly bilateral trade data of EU member states covering the five-year period, i.e. from June 2015 until September 2020. We focus on the transmission of Covid-19 shocks during the first wave of pandemic for which full dataset is available to us. Gross trade data used in the analysis is obtained from the Comext trade database. It includes monthly intra- and extra-EU export and import flows that are grouped into three product

categories according to their broad economic purpose (BEC classification): intermediates, consumption and capital goods. The data on the nominal GDP of destination/origin countries were taken from World Development Indicators database (The World Bank, 2020), while bilateral distances and a number of country-pair dummy variables from CEPII database (Head, Mayer & Ries, 2010; Head & Mayer, 2014).

Data for the number of affected people and deaths caused by Covid-19 is taken from the European Centre for Disease Prevention and Control. Their data is sourced from health authorities worldwide, comprising from, but not limited to, official reports from countries' ministries of health, public health institutes, World Health Organisation, and other national authorities.

To calculate the GVC indices, we use data from the Eora Multi-Region Input-Output (MRIO) database (henceforth referred to as Eora (see Lenzen et al. (2012) and Lenzen et al. (2013)), which has a considerably broader geographic coverage than the TiVA database. It includes virtually all countries in the world and starts in 1990. Thus, it also provides information on countries without I-O tables based on optimisation algorithms for estimating intra- and interregional transaction matrices for all countries worldwide. Additionally, the robustness check estimations are performed on the TiVA database that excludes non-OECD partner countries from our sample.

3.5.Some stylized facts on EU trade during Covid-19 pandemics

As per the data published by the Comext database, trade between the EU member states and with third countries has decreased notably following the Covid-19 outbreak. A decline in the total intra- and extra-EU exports was led mostly by the decrease in exports of intermediate and capital goods, i.e. supply chain trade, as presented in Figure 1, which plots year on year relative changes in monthly exports of the EU member states. We can observe that the negative trend in exports of intermediate goods started already in the second half of 2019, with the exception of December. With the outbreak of the Covid-19 pandemic, supply chain exports (i.e. exports of intermediate and capital goods) further dropped sharply by over 30% compared to their 2019 levels, reaching the lowest value in April and May 2020, before rebounding to about 90% of the previous year's value by September 2020.

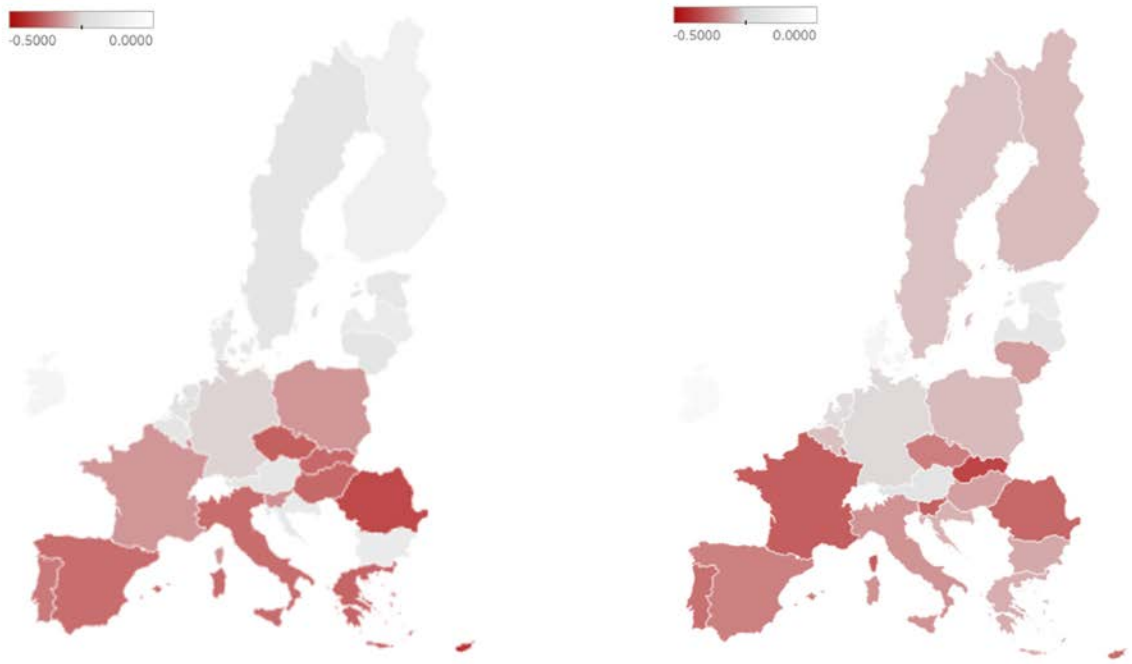
Figure 1: Monthly exports (intra- and extra-EU) of EU-28 according to BEC (indices defined as $Export_t/Export_{t-12}*100$)

Source: Authors' calculations based on the Comext database (Eurostat, 2020).

In Figure 2 we depict relative changes in trade for each European country, comparing the April 2020 values to those in April 2019 to present the trade situation that unfolded at the peak of the first wave of pandemic when the trade collapse was the most apparent. Further division to relative changes to exports (Figure 2a) and relative changes to imports (Figure 2b) aims to portray different initial dynamics that may be dominantly affected by either supply or demand shock. Figure 3 presents cumulative Covid-19 cases per capita for the EU member states in the time span from January through April 2020. Notably, Central and Eastern European Countries (CEECs) had seen a lesser number of cases, while Luxembourg, Spain, and Belgium respectively had the most officially confirmed cases per capita.

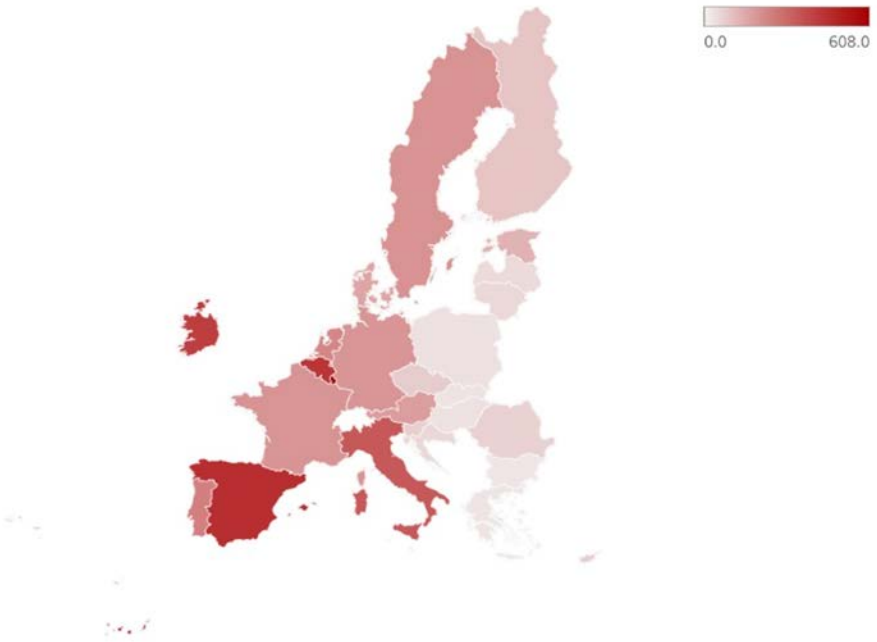
Figure 2: Percentage change in trade in intermediate goods (YoY comparison April 2019-April 2020)

a) Exports **b) Imports**



Source: Authors' calculations based on the Comext database (Eurostat, 2020).

Figure 3: Cumulative cases of Covid-19 per 100,000 inhabitants on a country level (period January-April 2020)



Source: Authors' calculations based on the European CDC data (ECDC, 2020).

We can see that despite having relatively fewer Covid-19 cases per capita, peripheral countries nonetheless experienced a significant import and export contraction. In April, for instance, a CEE country, Slovakia, had an average of 25.50 cases per 100,000 inhabitants, one of the lowest among the member states, yet its trade in April 2020 contracted more than in the average EU country compared to the level for a year ago. The imports decreased by 46.58% on a year-on-year basis while the exports sector experienced a 40.85% reduction. For reference, Spain ranked 2nd among cases per capita and had a sharper decline in intermediate goods trade (37.44 % for imports and approximately 40 % decline in exports). Germany, the largest EU economy, had the 10th highest cases per capita among the EU countries and saw a 25.96 % decline in imports and exports of intermediate goods. An interesting case was Bulgaria, a country with then the lowest number of officially recorded cumulative cases per capita. In Bulgaria, imports fell by almost 32 % while the exports decreased by a much lower amount (16.18 %). While some countries, like Spain and Italy, saw an above-average rise in the number of cases early on, other countries did not experience a surge until later on.

These figures imply remarkable differences in trade contraction between member states, which cannot be directly linked to the severity of the pandemic situation in terms of the number of Covid-19 patients. There is a complex relationship between infection rates, lockdowns and other government-imposed restrictions, and participation in GVCs on the one hand, and trade contraction on the other. We expect that countries that have imposed strict lockdowns for fear of increasing infections and at the same time are heavily involved in GVCs will experience a greater

decline in trade in intermediates. Indeed, the correlation coefficients reported in Table 2 confirm a strong and significant negative correlation between the severity of policies and trade indices, especially for trade in intermediates. The correlation between the year-to-year change in trade and the number of Covid-19 cases per capita also becomes negative and significant with a one-month lag. In addition, the correlation between upstream position in GVCs and imports also tends to be negative, with more upstream positions associated with a higher decline in trade. To explore the Covid-19, GVC position, and trade nexus further, our econometric analysis in the next section focuses on the aspect of shock transmission and supply chain amplification during the period of lockdowns and government-imposed restrictions.

Table 2: Correlation coefficients for trade indices, Covid-19 pandemic indicators and GVC position during Covid-19 period

	EXPORT ($Export_t/Export_{t-12}$*100)				IMPORT ($IMport_t/Import_{t-12}$*100)			
	Total	Intermediate goods	Consumer goods	Capital goods	Total	Intermediate goods	Consumer goods	Capital goods
Covid_cases_o	-0.10	-0.06	-0.08	-0.13*	-0.11	-0.07	-0.08	-0.15**
Covid_cases_o(-1)	-0.22***	-0.17**	-0.19***	-0.20***	-0.20***	-0.22***	-0.13**	-0.11*
Policy_stringency_o	-0.38***	-0.37***	-0.34***	-0.15**	-0.46***	-0.46***	-0.30***	-0.25***
Upstream(-1)	-0.10	-0.09	-0.10	0.02	-0.17**	-0.15**	-0.16 **	-0.04

Note: *** p<0.01, ** p<0.05, * p<0.1

4. Empirical results

4.1 Baseline results for total export s and imports

In this section, we present the results for the transmission channels discussed in section 2 and summarized in Table 1. First, we focus on total imports and exports. In Tables 3 and 4 we present results based on the per capita number of Covid-19 cases for total exports and imports, respectively, while in Table 4 we alternatively consider the policy stringency index. As expected, the results confirm the general drop of approximately 21 % in total exports and 24 % in total imports during the pandemic time, i.e. from February to September 2020, as indicated with the significantly negative coefficient for the *covid_period* dummy variable (Tables 3 and 4, column 1). Furthermore, there is a highly significant, negative impact of per capita number of Covid-19 cases both in origin and destination country on imports and exports indicating the presence of both supply and demand shocks.

The impact of Covid-19 incidence strengthens with one-month lag in particular for the domestic number of cases. The exports decrease by more than 1 % if number of domestic Covid-19 cases increases by 10 per 1000 population in a previous month (Tab. 3, column 3), while the same increase in the Covid-19 incidence in partner country reduces domestic exports by 0.3 %. Introducing Covid-19 as a lagged variable is important as many of the effects of an increased number of cases have a time component (i.e. a government imposes stricter measures and lockdowns after the spike). The response of exports to a one-month-lagged Covid-19 count in the origin country is bigger than in the destination country. This shift might be attributed to the fact that less stringent measures were imposed at the beginning of the pandemic. Once more stringent measures were imposed by governments, there was a labour supply shortage and production halted, resulting in a lower export supply as response to lagged number of Covid-19 cases. Similarly, after lockdown measures were lifted output increases, which was reflected in increased exports in the next month's statistics. On the other hand, the impact of an increase in the number of Covid-19 cases in the destination country is not elevated that significantly with elapsed time, suggesting that demand induced shocks through contraction of partner country's imports play an immediate role in transmission. Similar conclusions emerge for imports, with the impact of Covid-19 cases in the origin and destination countries becoming stronger for the lagged Covid-19 variable (columns 2 - 3 in Table 4) and more so for the domestic country.

Comparing regression coefficients of interaction terms between GVC indices, accounting for forward and backward linkages, and Covid-19 cases in a partner country, we observe that forward participation interaction plays a statistically significant role and is more prominent and instant when it comes to exports (Table 3). Strong bilateral forward linkages reinforce the negative impact of the Covid-19 cases in the destination country on home exports implying the transmission of the Covid-19 induced shocks from foreign downstream customers to more upstream domestic suppliers. We expect this channel to be particularly relevant for the supply-chain exports, which we test on the disaggregated trade flows according to broad economic purpose in the next step.

The impact of forward participation for transmission of Covid-19 related shocks can be explained through the GVC composition. With higher bilateral forward participation, the country has a larger share of its domestic value added relative to its gross exports embodied in exports of a particular partner country. Since the home country's exports are reliant on the exports of a partner country, the decrease in exports of a partner country, and hence its demand for intermediate goods from the domestic country, will have an amplified effect on the home country's exports. Consequentially with the elapsed time, this channel leads to a higher contraction of imports as well confirmed by significantly negative interaction term in case of considering lagged Covid-19 cases in import specification (column 6 in Table 4). On the other hand, we have not found any empirical support

for transmission of Covid-19 induced supply shocks through the backward linkages from foreign upstream suppliers to domestic downstream customers.

In addition, the evidence shows that the extent of the involvement in Chinese GVCs is associated with higher exposure to Covid-19 shock in partner countries. Namely, the higher share of supply chain trade with China measured by *GVC_China_o* amplifies the transmission of Covid-19 shocks from the partner country resulting in lower domestic exports. This is indicated by significant and negative interaction term *covid_cases_d#GVC_China_o* (columns 5-6 in Table 3). The traditional regressors in the gravity model specifications, e.g. distance and various country-pair dummy variables, all have the expected sign and are mostly highly significant in all specifications.

Table 3: Poisson pseudolikelihood estimates of gravity model for total exports of EU-28 member states (Oct 2015-Sept 2020)

	(1)	(2)	(3)	(4)	(5)	(6)
	EXPORTS	EXPORTS	EXPORTS	EXPORTS	EXPORTS	EXPORTS
	total	total	total	total	total	total
			Lagged Covid-19 variables			Lagged Covid-19 variables
Covid_period	-0.235***					
	[0.021]					
Covid_cases_o		-0.025***	-0.107***	-0.020***	-0.022***	-0.098***
		[0.005]	[0.009]	[0.005]	[0.006]	[0.010]
Covid_cases_d		-0.026***	-0.031***	-0.016***	0.028*	0.020
		[0.005]	[0.007]	[0.005]	[0.017]	[0.020]
FP(-1)				0.011	0.008	0.008
				[0.011]	[0.010]	[0.010]
Covid_cases_d				-0.012***	-0.011***	-0.020***
# FP(-1)				[0.004]	[0.004]	[0.004]
BP(-1)				0.003	0.005	0.005
				[0.007]	[0.007]	[0.007]
Covid_cases_d				0.000	-0.000	0.005
# BP(-1)				[0.003]	[0.003]	[0.004]
Covid_cases_d					-0.009**	-0.010**
#GVC_China_o(-1)					[0.004]	[0.005]
lndistw	-1.086***	-1.091***				

	[0.073]	[0.072]				
contig	0.180**	0.179**				
	[0.074]	[0.074]				
comlang_ethno	0.102	0.101				
	[0.124]	[0.124]				
comcol	1.876***	1.858***				
	[0.148]	[0.148]				
col45	1.013***	0.998***				
	[0.128]	[0.129]				
smctry	0.018	0.014				
	[0.145]	[0.145]				
Constant	28.575***	28.599***	20.818***	20.792***	20.796***	20.800***
	[0.545]	[0.543]	[0.001]	[0.027]	[0.026]	[0.025]
Monthly FE	yes	yes	yes	yes	yes	yes
Annual FE	yes	yes	yes	yes	yes	yes
Reporter-year FE	yes	yes	yes	yes	yes	yes
Partner-year FE	yes	yes	yes	yes	yes	yes
Country-pair FE	no	no	yes	yes	yes	yes
Observations	326,700	275,907	359,607	296,562	281,886	282,064
Pseudo R^2	0,962	0.962	0.993	0.993	0.993	0.993

Note: Robust standard errors in brackets, adjusted for country-pair clusters. *** p<0.01, ** p<0.05, * p<0.1

Table 4: Poisson pseudolikelihood estimates of gravity model for total imports of EU-28 member states (Oct 2015-Sept 2020)

	(1) IMPORTS total	(2) IMPORTS total	(3) IMPORTS total	(4) IMPORTS total	(5) IMPORTS total	(6) IMPORTS total
			Lagged Covid-19 variables			Lagged Covid-19 variables
Covid_period	-0.274***					
	[0.029]					

Covid_cases_o		-0.019***	-0.086***	-0.015***	-0.017***	-0.077***
		[0.005]	[0.010]	[0.005]	[0.006]	[0.010]
Covid_cases_d		-0.038***	-0.053***	-0.029***	0.011	-0.009
		[0.007]	[0.008]	[0.007]	[0.025]	[0.031]
FP(-1)				-0.001	-0.005	-0.004
				[0.011]	[0.011]	[0.011]
Covid_cases_d				-0.006	-0.005	-0.018***
# FP(-1)				[0.005]	[0.005]	[0.004]
BP(-1)				-0.001	0.001	0.001
				[0.004]	[0.005]	[0.005]
Covid_cases_d				-0.002	-0.003	0.001
# BP(-1)				[0.004]	[0.004]	[0.004]
Covid_cases_d					-0.008	-0.007
#GVC_China_o(-1)					[0.006]	[0.007]
lndistw	-0.809***	-0.817***				
	[0.105]	[0.105]				
contig	0.371***	0.367***				
	[0.082]	[0.082]				
comlang_ethno	0.130	0.128				
	[0.144]	[0.144]				
comcol	1.775***	1.748***				
	[0.220]	[0.222]				
col45	0.604***	0.603***				
	[0.132]	[0.133]				
smctry	-0.139	-0.143				
	[0.187]	[0.186]				
Constant	26.509***	26.553***	20.829***	20.834***	20.839***	20.842***
	[0.785]	[0.783]	[0.001]	[0.026]	[0.027]	[0.027]
Monthly FE	yes	yes	yes	yes	yes	yes
Annual FE	yes	yes	yes	yes	yes	yes
Reporter-year FE	yes	yes	yes	yes	yes	yes
Partner-year FE	yes	yes	yes	yes	yes	yes
Country-pair FE	no	no	yes	yes	yes	yes
Observations	326,700	275,907	352,504	293,325	278,577	278,752
Pseudo R^2	0.947	0.945	0,991	0.991	0.990	0.991

Note: Robust standard errors in brackets, adjusted for country-pair clusters. *** p<0.01, ** p<0.05, * p<0.1

In Table 5, we replace the number of Covid-19 cases with the index of policy stringency in reporter and partner countries to assess how the lockdown and other measures contribute to the disruption of trade flows. We find significant, negative effects of policy stringency in both the reporting and partner countries for bilateral exports and imports. The impact of the lockdown and other policy measures in the partner country on lower exports and imports is built up through the share of the supply-chain trade with China. However, no transmission is found through either forward or backward linkages with the partner country, suggesting that trade and supply chain linkages have not been the primary target of Covid-19 measures.

Table 5: Poisson pseudolikelihood estimates of gravity model for total trade of EU-28 member states (Oct 2015-Sept 2020)

	(1) EXPORTS total	(2) EXPORTS total	(3) EXPORTS total	(4) EXPORTS total	(5) IMPORTS total	(6) IMPORTS total	(7) IMPORTS total	(8) IMPORTS total
				Lagged Covid-19 variables				Lagged Covid-19 variables
policy_stringency_o	-0.002***	-0.002***	-0.002***	-0.003***	-0.002***	-0.002***	-0.001***	-0.001*
	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.000]	[0.001]
policy_stringency_d	-0.003***	-0.003***	-0.001	0.002*	-0.004***	-0.004***	-0.000	0.000
	[0.000]	[0.000]	[0.001]	[0.001]	[0.000]	[0.000]	[0.001]	[0.001]
FP(-1)		0.011	0.008	0.007		-0.002	-0.006	-0.005
		[0.011]	[0.010]	[0.010]		[0.011]	[0.011]	[0.011]
policy_stringency_d		-0.000	-0.000	-0.000		0.000	0.000	-0.000
# FP(-1)		[0.000]	[0.000]	[0.000]		[0.000]	[0.000]	[0.000]
BP(-1)		0.003	0.005	0.005		-0.001	0.001	0.001
		[0.007]	[0.007]	[0.007]		[0.004]	[0.005]	[0.005]
policy_stringency_d		0.000	0.000	0.000		-0.000	-0.000	0.000
# BP(-1)		[0.000]	[0.000]	[0.000]		[0.000]	[0.000]	[0.000]
policy_stringency_d			-0.000**	-0.000***			-0.001**	-0.001***
#GVC_China_o(-1)			[0.000]	[0.000]			[0.000]	[0.000]
Constant	20.842***	20.820***	20.824***	20.810***	20.853***	20.862***	20.868***	20.856***
	[0.001]	[0.027]	[0.025]	[0.026]	[0.002]	[0.027]	[0.027]	[0.027]

Monthly FE	yes	yes	yes	yes	yes	yes	yes	yes
Annual FE	yes	yes	yes	yes	yes	yes	yes	yes
Reporter-year FE	yes	yes	yes	yes	yes	yes	yes	yes
Partner-year FE	yes	yes	yes	yes	yes	yes	yes	yes
Country-pair FE	yes	yes	yes	yes	yes	yes	yes	yes
Observations	355,059	295,410	280,734	281,040	348,072	292,098	277,359	277,669
Pseudo R^2	0.993	0.993	0.993	0.993	0.991	0.991	0.991	0.991

Note: Robust standard errors in brackets, adjusted for country-pair clusters. *** p<0.01, ** p<0.05, * p<0.1

4.2 Accounting for the supply-chain trade

We further analyse the trade effects by breaking down the exports and imports using the broad economic purpose classification in Tables 6 and 7, respectively to address the supply-chain trade effects. Here, we observe the difference among the intermediate, consumer and capital goods. Overall, exports of consumer goods seem to be least affected by Covid-19 incidence at home and in partner country over the course of the first wave of Covid-19 pandemic and capital goods the most. The negative impact of Covid-19 cases per capita persists up to two months and is strongest with one-month lag. As expected, the interaction term between Covid-19 cases in a destination country and forward GVC participation exhibits significant impact only for the exports of intermediate goods providing further support for the supply chain transmission of Covid-19 induced shocks through forward GVC linkages (see columns from 1 through 3 in Table 6). This implies that an increase in the incidence of Covid-19 cases induces a bigger decline of supply chain exports of intermediates to those destinations with which a country has stronger forward linkages, i.e. to partner positioned further downstream. In other words, an increase in bilateral forward participation amplifies the effect of Covid-19 cases in the destination country on the decrease in exports of intermediate goods to that destination country.

Table 6: Poisson pseudolikelihood estimates of gravity model for EU-28 exports according to BEC categories (Oct 2015-Sept 2020)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
VARIABLES	EXPORTS	EXPORTS	EXPORTS	EXPORTS	EXPORTS	EXPORTS	EXPORTS	EXPORTS	EXPORTS
	Intermediate goods	Intermediate goods	Intermediate goods	Consumer goods	Consumer goods	Consumer goods	Capital goods	Capital goods	Capital goods

		One period lagged Covid-19 variables	Two period lagged Covid-19 variables		One period lagged Covid-19 variables	Two period lagged Covid-19 variables		One period lagged Covid-19 variables	Two period lagged Covid-19 variables
Covid_cases_o	-0.017***	-0.085***	-0.057***	-0.016***	-0.066***	-0.038***	-0.028***	-0.140***	-0.064***
	[0.005]	[0.010]	[0.009]	[0.005]	[0.008]	[0.007]	[0.009]	[0.014]	[0.011]
Covid_cases_d	-0.017***	-0.033***	-0.010*	-0.014***	-0.024***	0.001	-0.024***	-0.020**	0.001
	[0.005]	[0.007]	[0.006]	[0.005]	[0.005]	[0.005]	[0.008]	[0.009]	[0.007]
FP(-1)	0.012	0.013	0.012	0.003	0.003	0.002	0.003	0.003	0.003
	[0.012]	[0.012]	[0.012]	[0.019]	[0.019]	[0.019]	[0.029]	[0.029]	[0.029]
Covid_cases_d # FP(-1)	-0.014***	-0.027***	-0.012***	-0.005	-0.006*	0.002	-0.003	-0.006	-0.002
	[0.004]	[0.005]	[0.003]	[0.004]	[0.004]	[0.003]	[0.004]	[0.005]	[0.005]
BP(-1)	-0.006	-0.006	-0.006	0.003	0.003	0.003	0.036***	0.036***	0.036***
	[0.009]	[0.009]	[0.009]	[0.015]	[0.015]	[0.015]	[0.010]	[0.010]	[0.010]
Covid_cases_d # BP(-1)	0.002	0.008**	0.003	0.001	0.001	-0.002	-0.004	-0.001	0.001
	[0.004]	[0.004]	[0.003]	[0.003]	[0.003]	[0.002]	[0.003]	[0.004]	[0.005]
Constant	20.135***	20.138***	20.134***	19.433***	19.436***	19.431***	19.055***	19.059***	19.052***
	[0.034]	[0.034]	[0.034]	[0.058]	[0.058]	[0.058]	[0.051]	[0.051]	[0.051]
Monthly FE	yes	yes	yes	yes	yes	yes	yes	yes	yes
Annual FE	yes	yes	yes	yes	yes	yes	yes	yes	yes
Reporter-year FE	yes	yes	yes	yes	yes	yes	yes	yes	yes
Partner-year FE	yes	yes	yes	yes	yes	yes	yes	yes	yes
Country-pair FE	yes	yes	yes	yes	yes	yes	yes	yes	yes
Observations	294,666	294,838	295,010	293,622	293,793	293,964	292,269	292,439	292,611
Pseudo R^2	0.991	0.991	0.991	0.992	0.993	0.992	0.976	0.976	0.976

Note: Robust standard errors in brackets, adjusted for country-pair clusters. *** p<0.01, ** p<0.05, * p<0.1

Table 7: Poisson pseudolikelihood estimates of gravity model for EU-28 imports according to BEC categories (Oct 2015-Sept 2020)

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
VARIABLES	IMPORTS	IMPORTS	IMPORTS	IMPORTS	IMPORTS	IMPORTS	IMPORTS	IMPORTS	IMPORTS
	Intermediate goods	Intermediate goods	Intermediate goods	Consumer goods	Consumer goods	Consumer goods	Capital goods	Capital goods	Capital goods
		One period lagged	Two period		One period lagged	Two period		One period lagged	Two period

		Covid-19 variables	lagged Covid-19 variables		Covid-19 variables	lagged Covid-19 variables		Covid-19 variables	lagged Covid-19 variables
Covid_cases_o	-0.021***	-0.094***	-0.084***	-0.003	-0.025*	-0.015	-0.016**	-0.050***	-0.022
	[0.006]	[0.010]	[0.009]	[0.006]	[0.014]	[0.014]	[0.008]	[0.015]	[0.015]
Covid_cases_d	-0.028***	-0.035***	-0.016*	-0.024***	-0.039***	-0.009	-0.045***	-0.076***	-0.027
	[0.008]	[0.009]	[0.009]	[0.006]	[0.009]	[0.009]	[0.014]	[0.021]	[0.017]
FP(-1)	-0.005	-0.004	-0.005	0.011	0.011	0.011	-0.017	-0.017	-0.018
	[0.013]	[0.013]	[0.013]	[0.018]	[0.018]	[0.018]	[0.025]	[0.025]	[0.025]
Covid_cases_d # FP(-1)	-0.002	-0.017***	-0.002	-0.003	-0.007	0.000	-0.013**	-0.021***	-0.001
	[0.005]	[0.004]	[0.004]	[0.005]	[0.005]	[0.004]	[0.006]	[0.006]	[0.005]
BP(-1)	-0.003	-0.003	-0.003	-0.007	-0.007	-0.007	0.006	0.006	0.006
	[0.006]	[0.006]	[0.006]	[0.009]	[0.009]	[0.009]	[0.009]	[0.009]	[0.009]
Covid_cases_d # BP(-1)	-0.005	-0.002	-0.005	-0.002	-0.003	-0.004	0.008	0.014*	0.005
	[0.004]	[0.004]	[0.004]	[0.004]	[0.004]	[0.004]	[0.007]	[0.008]	[0.007]
Constant	20.186***	20.189***	20.186***	19.504***	19.505***	19.502***	19.450***	19.452***	19.448***
	[0.033]	[0.033]	[0.033]	[0.041]	[0.041]	[0.041]	[0.061]	[0.061]	[0.061]
Monthly FE	yes	yes	yes	yes	yes	yes	yes	yes	yes
Annual FE	yes	yes	yes	yes	yes	yes	yes	yes	yes
Reporter-year FE	yes	yes	yes	yes	yes	yes	yes	yes	yes
Partner-year FE	yes	yes	yes	yes	yes	yes	yes	yes	yes
Country-pair FE	yes	yes	yes	yes	yes	yes	yes	yes	yes
Observations	284,709	284,976	285,141	281,499	281,720	281,934	270,327	270,465	270,623
Pseudo R^2	0.986	0.986	0.986	0.992	0.992	0.992	0.983	0.983	0.983

Note: Robust standard errors in brackets, adjusted for country-pair clusters. *** p<0.01, ** p<0.05, * p<0.1

In Table 7 we present the import breakdown by the product category. Observing the import trade flows, the role of forward linkages as a channel for Covid-19 induced shocks is further confirmed (columns 2, 7 and 8) for intermediate and capital goods, with changes to intermediate goods being on a lower scale and later than for the exports. This follows our notion that the decline in imports through forward linkages comes after the decline in exports, since producers do not need the intermediate inputs because they need to reduce output. Again, there is no evidence of the amplification effect of backward linkages for the Covid19 effect of the destination country on imports, but surprisingly the interaction actually becomes positive at the 10% confidence level for the capital goods category.

4.3 Robustness checks

Table 8 reports regression results using a different approach to the country's GVC involvement. Here we use the upstreamness index that measures a country's bilateral GVC position based on the forward and backward participation values. Results are in support of conclusions following from baseline results presented in Tables 6 and 7 on importance of forward linkages for the transmission of the Covid-19 shocks from partner countries to domestic country's exports of intermediate goods. Namely, a significantly negative interaction term between upstreamness and Covid-19 cases in partner country for this type of exports (column 1) indicates that the adverse impact of the seriousness of destination country's pandemic situation is larger the more upstream is the position of the country in trade relations with the particular partner country, i.e. higher the forward relative to backward participation. Moreover, such kind of shock transmission becomes significant in this specification also in case of imports of capital goods. While the bilateral forward linkages channel is relevant for exports of intermediate goods and imports of capital goods, exports of the other two categories, i.e. consumer and capital goods, are more responsive to the Covid-19 cases in destination market when the country is more intensively involved in supply chain trade with China.

Table 8: Poisson pseudolikelihood estimates of gravity model for EU-28 trade according to BEC categories

	(1)	(2)	(3)	(4)	(5)	(5)
VARIABLES	EXPORTS	EXPORTS	EXPORTS	IMPORTS	IMPORTS	IMPORTS
	Intermediate goods	Consumer goods	Capital goods	Intermediate goods	Consumer goods	Capital goods
Covid_cases_o(-1)	-0.096***	-0.070***	-0.145***	-0.105***	-0.030**	-0.053***
	[0.010]	[0.008]	[0.014]	[0.009]	[0.014]	[0.014]
Covid_cases_d(-1)	-0.027	0.008	0.020	-0.023	-0.022	-0.076
	[0.025]	[0.019]	[0.024]	[0.035]	[0.029]	[0.060]
Upstream(-1)	0.501	-0.539	-3.565***	0.003	0.706	-1.049
	[0.961]	[1.219]	[1.139]	[0.561]	[0.821]	[1.022]
Covid_cases_d(-1)	-1.332***	-0.181	-0.075	-0.178	0.100	-1.729***
# Upstream(-1)	[0.464]	[0.372]	[0.375]	[0.474]	[0.376]	[0.660]
Covid_cases_d(-1)	-0.005	-0.008*	-0.010**	-0.007	-0.007	-0.003
#GVC_China_o(-1)	[0.006]	[0.004]	[0.005]	[0.009]	[0.007]	[0.014]
Constant	20.155***	19.450***	19.131***	20.177***	19.515***	19.421***

	[0.005]	[0.005]	[0.006]	[0.003]	[0.005]	[0.012]
Monthly FE	yes	yes	yes	yes	yes	yes
Annual FE	yes	yes	yes	yes	yes	yes
Reporter-year FE	yes	yes	yes	yes	yes	yes
Partner-year FE	yes	yes	yes	yes	yes	yes
Country-pair FE	yes	yes	yes	yes	yes	yes
Observations	280,129	279,000	277,802	270,407	267,032	255,830
Pseudo R^2	0.991	0.992	0.976	0.986	0.992	0.983

Note: Robust standard errors in brackets, adjusted for country-pair clusters. *** p<0.01, ** p<0.05, * p<0.1

We perform second robustness check using the data from the OECD TiVA database to calculate the corresponding GVC indices (see Table 9) which limits our sample to OECD partner countries. The GVC indices are constructed in the same way as based on Eora dataset in previous specifications, but the difference is that here we use values of the GVC indices for 2015 given the non-availability of the TiVA data for more recent years. Results confirm our previous findings on GVC contagion effect through forward linkages. In fact in this specification, the transmission of shocks through forward linkages turn into significant for both export and imports of intermediate and consumer goods with one month lagged values of Covid-19 cases in partner countries. Furthermore, using the TiVA trade data, we get a statistically significant effect of backward linkages in transmitting the supply chain shocks from partner countries resulting in a sharper drop in trade with capital goods. Through these linkages, we provide indication that the supply side shocks/disruptions are transmitted from foreign upstream suppliers to downstream domestic importers. A country's reliance on foreign value added in exports will cause its imports and exports of capital goods to decrease following the increase in Covid- 19 cases in partner countries. However, the interaction term with backward participation is of the opposite sign for the exports of intermediate goods suggesting that certain reorientation of exports of intermediate goods towards traditionally more upstream positioned partners took place during the pandemic period.

Table 9: Poisson pseudolikelihood estimates of gravity model for EU-28 trade according to BEC categories based on TiVA data

	(1)	(2)	(3)	(4)	(5)	(6)
VARIABLES	EXPORTS	EXPORTS	EXPORTS	IMPORTS	IMPORTS	IMPORTS
	Intermediate goods	Consumer goods	Capital goods	Intermediate goods	Consumer goods	Capital goods

Covid_cases_o(-1)	-0.070***	-0.055***	-0.127***	-0.067***	-0.004	-0.040***
	[0.010]	[0.008]	[0.014]	[0.008]	[0.013]	[0.012]
Covid_cases_d(-1)	-0.010	-0.015**	-0.004	-0.021**	-0.029***	-0.021
	[0.008]	[0.006]	[0.008]	[0.009]	[0.009]	[0.017]
Covid_cases_d(-1)	-0.052***	-0.018***	-0.007	-0.034***	-0.023***	-0.017
# FP_TiVA2015	[0.008]	[0.006]	[0.011]	[0.010]	[0.008]	[0.011]
Covid_cases_d(-1)	0.007***	0.002	-0.008***	-0.003	0.001	-0.009***
# BP_TiVA2015	[0.002]	[0.002]	[0.002]	[0.003]	[0.003]	[0.003]
Constant	20.298***	19.614***	19.350***	20.282***	19.566***	19.416***
	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]	[0.001]
Monthly FE	yes	yes	yes	yes	yes	yes
Annual FE	yes	yes	yes	yes	yes	yes
Reporter-year FE	yes	yes	yes	yes	yes	yes
Partner-year FE	yes	yes	yes	yes	yes	yes
Country-pair FE	yes	yes	yes	yes	yes	yes
Observations	101,628	101,628	101,508	101,448	101,508	101,268
r2_p	0.993	0.994	0.976	0.990	0.993	0.980

Note: Robust standard errors in brackets, adjusted for country-pair clusters. *** p<0.01, ** p<0.05, * p<0.1

5. Concluding remarks

Although several months have already passed since the beginning of the Covid-19 outbreak in Europe, uncertainty regarding the future of international trade and supply chain reorganisation remains. In this paper, we performed gravity model analysis of final goods trade and supply chain trade of EU member states during the first wave of Covid-19 pandemic to identify the transmission channels of the shocks caused by the pandemic. To account for various mechanisms we distinguish demand and supply shocks as of either domestic or partner country origin. We further characterize the latter on the basis of the country's GVC position, thus accommodating for a possibility of transmission through forward and backward linkages. We argue that the identified transmission channels of demand shocks and forward linkages play an important role in the supply chain trade. Results show that an increase in the incidence of Covid-19 cases induces a steeper decline of supply chain exports of intermediates in those destinations with which a country has stronger forward linkages, i.e. in partners positioned further downstream. Furthermore, a decrease in exports of inputs is followed by a contraction in imports. Although our study demonstrates some of the important GVC trade dynamics during the Covid-19 pandemic, we are aware that certain

outcomes remain unexplained. This may be attributed to the limitations of the existing model as well as to the current unavailability of important data. We, therefore, leave possible extensions of the model for future work as some of our findings may have long-lasting effects such as reshaping of the supply chains, whilst others will only be temporary. As some of the findings suggest, identifying the proper cause is important in explaining the trade dynamics, especially in a complex environment of GVCs. Thus, they should be recognised by policymakers, as the policies ought to address right causes for optimal outcomes, whether those concern demand or supply side.

References

Anderson, J.E., van Wincoop, E. (2003). "Gravity with Gravitas: A Solution to the Border Puzzle," *The American Economic Review*, 93(1), pp.170-192.

Antras, P., Chor, D., Fally, T. & Hillberry, R. (2012). Measuring the Upstreamness of Production and Trade Flows. American Economic Review, American Economic Association, vol. 102(3), pages 412-16, May.

Antras, P., Redding, S.J., and Rossi-Hansberg, E. (2020). "Globalization and pandemics," *Covid Economics* 49, 1-84. https://cepr.org/sites/default/files/CovidEconomics49.pdf#Paper1

Baier, S. L., and Bergstrand, J. H. (2007). "Do free trade agreements actually increase members' international trade?," *Journal of international Economics*, 71(1), 72-95.

Baldwin, R., and Freeman, R. (2020). "Supply chain contagion waves: Thinking ahead on manufacturing 'contagion and reinfection' from the covid concussion". Retrieved from: https://voxeu.org/article/covidconcussion-and-supply-chain-contagion-waves, 2020.

Baldwin, R., and Tomiura, E. (2020). "Thinking ahead about the trade impact of covid-19." Economics in the Time of COVID-19, 59, 2020.

Bonadio, B., Huo, Z., Levchenko, A. A., & Pandalai-Nayar, N. (2020). *Global supply chains in the pandemic* (No. w27224). National Bureau of Economic Research.

Burger, M., van Oort, F., and Linders., G-J. (2009). "On The Specification of The Gravity Model of Trade: Zeros, Excess Zeros and Zero-inflated Estimation," *Spatial Economic Analysis, (4)*2, 167-190.

Correia, S., Guimarães, P., & Zylkin, T. (2019). "Verifying the existence of maximum likelihood estimates for generalized linear models". arXiv preprint arXiv:1903.01633.

Correia, S., Guimarães, P., & Zylkin, T. (2020). "Fast Poisson estimation with high-dimensional fixed effects," *The Stata Journal*, 20(1), 95-115.

Dingel, J., and Neiman, B. (2020). "How many jobs can be done at home?," *Journal of Public Economics*, vol 189.

European Centre for Disease Prevention and Control (ECDC) (2020). Retrieved from: https://www.ecdc.europa.eu/en/publications-data/download-todays-data-geographic-distribution-covid-19-cases-worldwide

Eurostat (2020). Comext trade database. Retrieved from: http://epp.eurostat.ec.europa.eu/newxtweb/

Evenett, S. (2020). "Sickening thy neighbour: Export restraints on medical supplies during a pandemic". Retrieved from: https://voxeu.org/article/export-restraints-medical-supplies-during-pandemic

Fally, T. (2012). Has production become more fragmented? International vs domestic perspective, VoxEU Policy Brief, retrieved from: https://voxeu.org/article/has-production-become-more-fragmented-international-vs-domestic-perspectives

Farhi, E., & Baqaee, D. R. (2020). "Supply and Demand in Disaggregated Keynesian Economies with an Application to the Covid-19 Crisis" CEPR Discussion Paper DP14743.

Friedt, F. L., and Zhang, K. (2020). "The triple effect of Covid-19 on Chinese exports: First evidence of the export supply, import demand and GVC contagion effects," *Covid Economics* 53, 72-109. https://cepr.org/sites/default/files/CovidEconomics53.pdf#Paper1

Hassan, T. A., Hollander, S., van Lent, L., Tahoun, A. (2020). "Firm-level Exposure to Epidemic Diseases: Covid-19, SARS, and H1N1", NBER Working Paper No. 26971.

Hayakawa, K., and Mukunoki, H. (2020). "Impacts of covid-19 on international trade: evidence from the first quarter of 2020", IDE Discussion Paper Vol. 791.

Head, K., Mayer, T. & Ries, J. (2010). "The erosion of colonial trade linkages after independence", *Journal of International Economics*, 81(1):1-14.

Head, K. and T. Mayer, (2014). "Gravity Equations: Toolkit, Cookbook, Workhorse." *Handbook of International Economics*, Vol. 4,eds. Gopinath, Helpman, and Rogoff, Elsevier.

Koopman, R., Powers, W., Wang, Z., & Wei, S.-J. (2010). Give Credit Where Credit Is Due: Tracing Value Added in Global Production Chains: National Bureau of Economic Research, Inc.

Lenzen M., Kanemoto K., Moran D. & Geschke A. (2012). Mapping the structure of the world economy. Environmental Science & Technology, 46(15) pp 8374–8381. doi: 10.1021/es300171x

Lenzen, M., Moran, D., Kanemoto, K. & Geschke, A. (2013). Building Eora: A Global Multi-regional Input-Output Database at High Country and Sector Resolution. Economic Systems Research, 25:1, 20-49, doi:10.1080/09535314.2013.769938

McCann, F., and Myers, S. (2020). "COVID-19 and the transmission of shocks through domestic supply chains," Financial Stability Notes Vol. 2020 No. 3, Central Bank of Ireland.

Meier, M., and Pinto, E. (2020). "Covid-19 supply chain disruptions", *Covid Economics* 48, 139-170. https://cepr.org/sites/default/files/CovidEconomics48.pdf#Paper4

OECD (2013). Interconnected economies: Benefiting from Global Value Chains. Synthesis Report, OECD. https://www.oecd.org/mcm/C-MIN(2013)15-ENG.pdf

OECD (2020). "Trade in value added", *OECD Statistics on Trade in Value Added* (database), retrieved from: https://doi.org/10.1787/data-00648-en

Serič, A., Görg, H., Mösle, S., and Windisch, M. (2020). "Managing COVID-19: How the pandemic disrupts global value chains," *UNIDO's Department of Policy Research and Statistics.* Retrieved from: https://iap.unido.org/articles/managing-covid-19-how-pandemic-disrupts-global-value-chains
the Pandemic," NBER Working Paper No. 27224.

World Bank (2020). "World Development Report 2020," World Bank Publications, The World Bank, number 32437, June.