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Deutsches Institut für Entwicklungspolitik

German Development Institute

Discussion Paper 21/2020

Cling Together, Swing Together

The Contagious Effects of COVID-19 on Developing Countries through Global Value Chains

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Bonn 2020

Discussion Paper / Deutsches Institut für Entwicklungspolitik
ISSN (Print) 1860-0441
ISSN (Online) 2512-8698

Die Deutsche Nationalbibliothek verzeichnet diese Publikation in der Deutschen Nationalbibliografie; detaillierte bibliografische Daten sind im Internet über http://dnb.d-nb.de abrufbar.
The Deutsche Nationalbibliothek lists this publication in the Deutsche Nationalbibliografie; detailed bibliographic data is available on the Internet at http://dnb.d-nb.de.

ISBN 978-3-96021-133-4 (printed edition)

DOI:10.23661/dp21.2020

Printed on eco-friendly, certified paper

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Published with financial support from the Federal Ministry for Economic Cooperation and Development (BMZ)

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Abstract

This paper aims at estimating the economic vulnerability of developing countries to disruptions in global value chains (GVCs) due to the COVID-19 pandemic. It uses data on trade in value-added for a sample of 12 developing countries in sub-Saharan Africa, Asia and Latin America to assess their dependence on demand and supply from the three main hubs China, Europe, and North America. Using first estimates on COVID-19-induced changes in production and sectoral final demand, we obtain an early projection of the GDP effect during the lockdowns that runs through trade in GVCs. Our estimates reveal that adverse demand-side effects reduce GDP by up to 5.4 per cent, and that collapsing foreign supply is responsible for a drop in GDP of a similar magnitude. Overall, we confirm conjecture that the countries most affected are those highly integrated into GVCs (Southeast Asian countries). We argue, however, that these countries also benefit from a well-diversified portfolio of foreign suppliers, leading to a cushioning of economic downswing from adverse supply-side spillovers, because COVID-19 stroke major hubs at different times during the first wave in early 2020. Moreover, despite expected hazardous home market effects, sub-Saharan Africa's GDP appears to be comparatively less affected though GVCs due to a lack of intensive supply- and demand-side dependencies.

Key words: COVID-19, global value chains, input-output analysis, international trade, supply- and demand-side dependency, shock spillover

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Abbreviations

ACP	African, Caribbean and Pacific
ASEAN	Association of Southeast Asian Nations
COVID	coronavirus disease
EORA	Eora Global Value Chain Database
EU	European Union
FRED	Federal Reserve Economic Data
GDP	gross domestic product
GVC	global value chain
ICIO	inter-country input-output
ILO	International Labour Organization
ISIC	International Standard Industrial Classification of All Economic Activities
NAFTA	North American Free Trade Agreement
NBS	National Bureau of Statistics of China
OECD	Organisation for Economic Cooperation and Development
TiVA	trade in value-added
UK	United Kingdom
UNIDO	United Nations Industrial Development Organization
US	United States
USD	United States dollar
WIOD	World Input-Output Database
WTO	World Trade Organization

1 Introduction

The entire world has been hit hard by the consequences of the COVID-19 pandemic and the political, social, and economic measures to contain it. While the long-term effects of the disease still remain unpredictable, some countries are currently being affected more strongly by it, and there is considerable heterogeneity in underlying causal chains. For instance, healthcare systems in developing countries are generally less prepared to cope with increasing numbers of infections. Moreover, adding to the immediate adverse economic consequences due to countries' own lockdowns, many developing countries are increasingly facing additional hazards in the highly interconnected global economy stemming from their integration into global value chains (GVCs). More specifically, despite the positive developmental effects associated with participation in GVCs in normal times (see, for example, Kummritz, Taglioni, & Winkler, 2017; Pahl & Timmer, 2020; World Bank, 2020), the pandemic has transformed this channel into a menace.

In this paper, we explore the economic vulnerability of developing countries to COVID-19-induced demand and supply shocks occurring in the key hubs of GVCs. Using global input-output tables, we map countries' value-added to final demand in specific consumer markets (as in Johnson & Noguera, 2017) and to the production within specific value chains (in accordance with Los, Timmer, & de Vries, 2015; Pahl, Timmer, Gouma, & Woltjer, 2019; and Timmer, Los, Stehrer, & De Vries, 2013). This allows us to provide first estimates on potential effects of the demand and supply shock on gross domestic product (GDP), running through trade in GVCs. As the nature of the COVID-19 crisis is different to previous global economic crises insofar as sectors of household consumption are affected very heterogeneously due to social distancing measures, and that some supply chains may be fully interrupted for certain periods of time, the expected hazardous effects from this inflicted on developing countries remain an empirical puzzle. A key characteristic of GVCs is that firms are linked to other producers (of intermediate goods) and consumers through production networks spanning multiple countries. A *demand* shock in a specific consumer market therefore affects all (foreign) upstream suppliers delivering to this market, which goes well beyond a country's direct trade partners (in the spirit of Bems, Johnson, & Yi, 2011; and Johnson & Noguera, 2017). Furthermore, a shock to a specific key input *supplier* can cause major bottlenecks in production, which goes well beyond directly linked firms, but which can disrupt production along the entire value chain. Both types of shocks are currently looming large due to COVID-19-related lockdowns in many places around the world, in particular in the major demand and supply hubs China, Europe and North America.

Starting from a local concentration on China, COVID-19 initially put a strain on the production capacities of a crucial link – but yet only one in a number of links – in international production networks. With the disease's evolution from epidemic to pandemic proportions, however, disruptions are now also being felt across the board, from simple to complex GVCs due to COVID-19 containment policies in manufacturing hubs like the European Union (EU) and North America, leading to even more far-reaching repercussions via trade-based contagion links (Baldwin & Freeman, 2020b; Seric, Gorg, Mosle, & Windisch, 2020). While first analyses are available on the repercussions for trade in value-added (Baldwin, 2020; Baldwin & Freeman, 2020a; Bonadio, Huo, Levchenko, & Pandalai-Nayar, 2020; Guan et al., 2020), we still lack a detailed understanding of how the pandemic transmits through GVCs – especially in developing countries.

We implement our analysis using a new set of global input-output tables from Pahl et al. (2019), constructed for country-specific analyses of a set of lower-income countries in the world economy. These data are constructed using highly country-specific sources. In particular, the time series of national input-output tables are built up from national supply and use tables or social accounting matrices; from production data (value-added, gross output) with high sectoral detail and yearly variation; information on national accounts, such as final consumption; as well as detailed trade data. The construction strictly follows the methodologies of the World Input-Output Database (WIOD; Timmer, Dietzenbacher, Los, Stehrer, & De Vries, 2015) and can therefore be used in conjunction for global analyses. This dataset aims to represent developing countries from all world regions, while adhering to high demands in terms of data requirements for the construction of a global input-output database. For the purpose of providing an initial view of the effects of the COVID-19 crisis running through GVCs, our sample in this paper consists of all 12 low- and middle-income countries in the major emerging regions Africa, Asia, and Latin America available in that database. To identify the adverse effects of final demand contractions in hubs on developing countries, we combine these input-output data with estimates of final demand changes at the sector level and COVID-19-induced cuts in industrial production. While precise pandemic-induced economic effects are still uncertain, we provide a ballpark figure for the potential size of the trade-induced shocks to developing countries due to the ongoing crisis.

With regard to the demand shock, we find that there are stark differences across the 12 developing countries, particularly in terms of the importance of hub markets for their own production and with regard to the sectors that they deliver to. In Bangladesh, for example, 6.1 (2.7) per cent of GDP depends on final demand in Europe (North America), of which more than 90 per cent stem from final demand for textiles. In Vietnam, an even greater share, namely 8.1 (9.4) per cent of GDP, depends on final demand in Europe (North America). At the same time, however, the Vietnamese export sector is more diversified, with only roughly one-quarter to one-third of the value-added being concentrated in the production of one final demand sector at maximum. Combining these dependencies with estimated changes in final demand by sector and region, we find, for instance, that 4.5 per cent of Bangladesh's GDP are at risk alone through the demand shock and demand shifts in Europe during the starkest time of the lockdown. One per cent of GDP is at risk due to the demand collapse in North America. For Vietnam, overall 3 per cent of GDP are at risk through GVCs, almost equally due to the declining demand from Europe and North America. Sub-Saharan African countries are much more dependent on their home markets and, as such, are less affected by changes in final demand in the major hubs.

On the supply-side, we take into consideration that shocks to supply within a value chain both upstream and downstream may cause the entire value chain to break down. We therefore assume for our projections that – in sectoral production for which more than a threshold share of inputs from a particular region (directly or indirectly) is needed – these inputs cannot be substituted for by inputs from other regions; the production thus has to stand still if the required inputs are missing. The resulting shock analysis reveals that not only a lockdown in China may cause bottlenecks in production: for example, while impressive shares of Vietnamese (7.5 per cent), Indonesian (8.7 per cent), and Malaysian (11.1 per cent) GDPs are generated in GVCs in which China is a key supplier (that is, generates more than 5 per cent of inputs in value-added terms), this holds true for only 0.4 per cent of GDP in Bangladesh. Southeast Asian countries, however, not only rely heavily on Chinese intermediates but to a similar extent also on European ones, suggesting a well-

diversified portfolio of suppliers. With this, this latter group of countries seems to benefit from the temporal differences in economic lockdown across the major GVC-hubs. On the other hand, sub-Saharan African countries mainly require domestic inputs for value-added production, which makes them comparatively more resilient to foreign bottlenecks in the input supply. By assuming zero substitutability of firms, both in terms of key markets and in terms of sourcing regions, our estimations represent a short-term indication of the economic effects of lockdown due to the pandemic.

Our results inform the debate on COVID-19-related shocks by documenting not only the dependencies through trade in GVCs but also what is at stake through this channel during the lockdowns in the major hubs. This, however, is not to hide the fact that the countries most affected through trade in GVCs are not necessarily the ones overall hit hardest by the pandemic. Yet, during the recovery, those with strong linkages in GVCs need to consider both supply and demand at home, as well as in their GVC-linked partner countries. The results of this exercise do not only contribute to our understanding of the impacts of the current pandemic and potential future global demand or supply shocks but will also make a contribution to the discourse about the potential role of supply chains in a post-COVID world. The pandemic and the asymmetric structure of its impacts show that, in order to diversify risks, a simple detachment from direct links with China – as is currently being discussed (Seric & Winkler, 2020) – is not productive. Rather, diversification both with respect to sectoral specialisation patterns, and to the regional dispersion of input suppliers, appears promising if the gains from an international division of labour are to be reaped and at the same time contagious cross-border spillovers cushioned.

The remainder of the paper is structured as follows: Section 2 provides a brief review of the trade effects of the COVID-19 pandemic and discusses the literature on how GVCs have been affected by previous crises. Section 3 presents the method used to compute the sector-regional demand and supply dependencies through analysing the value-added trade of the developing countries in the sample and the respective data. In Section 4, we present the estimations of the shock for developing countries through the decreasing demand downstream in GVCs. Section 5 then discusses the impact through the contraction of supply upstream in the value chains and Section 6 concludes.

2 Related literature

In addition to the threats inflicted by the pandemic on individual physical and mental well-being, wide-spread long-term effects are expected to arise from the decline in economic output and trade. As regards the latter, the pandemic spread of COVID-19 is disrupting international trade in an unprecedented manner (Baldwin, 2020; WTO [World Trade Organization], 2020). In 2020, global merchandise trade is expected to fall by between 13 and 32 per cent due to the pandemic. Almost all world regions will be hit by double-digit declines in trade volumes, with exports from North America and Asia expected to be affected most intensely. A glimmer of hope comes from a predicted global trade recovery of up to 24 per cent in 2021 (Bekkers, Keck, Koopman, & Nee, 2020).

While it is important to understand the effects on gross trade flows in (final) goods and services, it is also essential to study the effects of the pandemic that run through GVCs as much of world's production is organised in such production chains. In this context, latest

figures on total manufacturing output in major hub-regions testify to declines during the first quarter of 2020 ranging from 2.4 per cent in North America to more than 14 per cent in China (UNIDO [United Nations Industrial Development Organization], 2020), potentially causing ongoing disruptions in GVCs. Moreover, according to the WTO (2020), trade is likely to decline more strongly in sectors with complex value chains such as electronics and automotive products. Based on the OECD's (Organisation for Economic Cooperation and Development) inter-country input-output (ICIO) tables, Baldwin and Freeman (2020a) have computed larger countries' total direct and indirect exposure of each nation's manufacturing sector to the manufacturing sector of other nations. While their findings, namely that "supply disruption in the United States, Germany, China, Korea, and Japan will have large effects on consumers and firms in all the major economies" (Baldwin & Freeman, 2020a), are highly relevant for understanding the trade-based contagion effects throughout supply chains, their evidence leaves us in the dark when it comes to the question of how less developed countries might be affected by these value chain effects.

Our paper is closely related to the studies by Bonadio et al. (2020) and Guan et al. (2020). Both of these works simulate the potential contagion effects through GVCs for various lockdown scenarios. Both studies, however, focus on the effects stemming from breakdowns on the supply-side, analysing hypothetical lockdown measures. In contrast to these papers, we also consider shifts in and shocks to final demand, using actual economic data on disruptions both of supply and sectoral demand. Furthermore, on the supply-side, Bonadio et al. (2020) and Guan et al. (2020) compute their figures on the basis of a general equilibrium model, implying substitutability between inputs. We, in contrast, study the complete breakdown of GVCs that have a strong dependence on production from countries in lockdown. Thus our approach speaks more to short-run effects, as we will highlight in the next section.

The world has seen various pandemic spreads of infectious diseases before COVID-19. Among them, the Spanish Flu ranks as the most prominent and devastating example, costing up to 50 million lives between 1918 and 1920. Due to much less developed trade ties between countries and geographical fragmentation of production processes than today, however, the economic consequences of the Spanish Flu arguably had little in common with the dynamics surfacing within the context of COVID-19. In contrast, while the 2008-2009 Great Trade Collapse emerging in the wake of the global financial crisis is only partial similar to the ongoing pandemic in terms of cause, in as far as that collapse had hardly any effect on supply, it does hold important implications for the consequences of developing countries' participation in the global trading system in particular. Echoed by, for example, Bems, Johnson and Yi (2013) and Eaton, Kortum, Neiman and Romalis (2016), most academic commentators generally name the drop in aggregated expenditure in trade-intensive durables and capital goods as the origin of the massive plunge of international trade in 2008-2009. In line with this view, empirical evidence by Berkman et al. (2012) attests that food exporters in developing countries escaped relatively unscathed from the trade collapse whereas open developing countries in particular are generally found to have suffered from declining exports. Adding to the descriptive analysis provided in Baldwin (2009), whose findings point towards a "severe, sudden and synchronized" negative trend in goods trade across nearly all product categories between mid-2008 and early 2009 but with a skewness towards commodities (especially in minerals and oil). Meyn and Kennan (2009) observe a severe aggravation of price volatility in selected commodities. In the absence of a balanced cushioning mechanism, not only were the developing countries hardest hit whose export performance relied on only a small range of products but, in

particular, also those dependent on particular commodities, among them most of the African, Caribbean and Pacific (ACP) countries. In a similar vein, empirical evidence by Camanho da Costa Neto and Romeu (2011) of sectoral export patterns across Latin American countries during the financial crisis suggests that diversification of export activities across industries rather than sectoral concentration significantly helped to cushion countries' declines in exports.

A number of studies have paid special attention to the role of GVCs during the financial crisis. Here, one of the empirical insights brought forward in the widely acclaimed article by Levchenko, Lewis and Tesar (2010) is that trade (imports and exports alike) in sectors categorised as intermediates declined disproportionally stronger than in other sectors. As processed sectoral inputs cross borders multiple times in the production of final goods organised in GVCs, the authors' findings could be read as being in support of a widespread (at least partial) explanation for the overshooting of the global trade relative to global GDP decline during the financial crisis. While some empirical evidence underpinning this perception exists (see, for instance, Anderton & Tewolde, 2011; Nagengast & Stehrer, 2016), it is far from being generally accepted, and likewise challenged (for instance, Bems et al., 2011; Bénassy-Quéré, Decreux, Fontagné, & Khoudour-Casteras, 2009). Analysing the impact of the global financial crisis on global apparel value chains, Gereffi and Frederick (2010) find that the massive decline in global demand for apparel has led to a surge in unemployment across the industry's supply chain, borne mainly by those located in developing countries.

The trade effects on developing countries associated with the global financial crisis have revived research not only on their international linkages but also on the spillover mechanisms of global trade hubs; at the same time, however, the evidence that emerges is inconsistent. For example, while the positive nexus between income and import demand already resonates in Forbes (2001; 2004), Bems, Johnson and Yi (2010) explicitly emphasise the impact of US and EU demand shocks on cross-border linkages of intermediate goods. More specifically, employing a global input-output framework, their empirical findings suggest that declines in demand induced by the financial crisis in both hubs largely came at the cost of falling exports in North American Free Trade Agreement (NAFTA) integration partners and Emerging Europe. Accounting for international production networks, Cheewatrakoolpong and Manprasert (2014) find that the severity of the adverse effects arising from the financial crisis in developing countries was significantly linked to US export dependency. Moreover, while Yamamoto (2014) emphasises that US spillover shocks generally account for around 50 per cent of Asian production fluctuation owing to financial and trade linkages, the author finds that both types of linkages posed a considerable negative impact on production in Asian economies during the financial crisis, yet with a larger impact by the former. By contrast, Rose and Spiegel (2010) as well as Pentecôte and Rondeau (2015) attribute only secondary importance to trade linkages for the adverse spillover effects during the financial crisis. In fact, based on their empirical analysis, Rose and Spiegel (2010) reject that there was a positive nexus between economic exposure to the United States and financial crisis contagion. Similarly, empirical findings in Pentecôte and Rondeau (2015) suggest that stronger trade linkages with the United States may have even helped to mitigate output loss in developing countries during the financial crisis.

A related and growing strand of literature analyses transmission channels and spillover effects explicitly arising from China.[1] For example, addressing the implications of China's pre-COVID-19 growth slowdown for the exports of its ASEAN (Association of Southeast Asian Nations) -5 neighbours, Dizioli, Guajardo, Klyuev, Mano and Raissi (2016) find that both generally closer trade ties to and commodity export dependency on China translated into declining growth rates of between 0.2 and 0.5 percentage points, respectively, resultant from China's growth falling by 1 per cent. Similar insights are provided in input-output analysis for the years 2002-2006 by Escaith (2009) who notes that China had notably already increased its role as an exporter of manufacturing intermediates prior to the global financial crisis, thus making it a major exporter of adverse supply shocks in global value chains. Given their concentration on GVC-integration in manufacturing sectors and their dependency on imported manufacturing inputs, both Malaysia and Thailand are linked to China's economic performance to a special degree. Emphasising China's impact on commodity prices given its role in world trade as well as sub-Saharan Africa's ever closer cooperation with China, particularly in terms of trade, Anderson, Kriljenko, Drummond, Espaillat, and Muir (2015) provide evidence confirming that the degree of spillover effects arising from an output drop in China heavily depends on whether sub-Saharan countries are importers or exporters of commodities.

Accounting for the direct as well as rebounding second-round trade effects and in an input-output framework, Andritzky, Kassner and Reuter (2019) show that a final demand shock occurring in China does less harm to the global economy than shocks originating in the European Union or the United States because of the latter two's comparatively larger share of imports of final goods. Unsurprisingly, with close trade ties in mind, a Chinese final demand shock will generally affect the output of its Asian neighbours the strongest in negative terms, outpacing the effect of economic turmoil caused by Europe or the United States. In more depth, however, the authors demonstrate that demand shocks to investment specifically in primary and secondary sectors – that is, allegedly import-intensive sectors of China – have an even stronger spillover elasticity than broad-based final demand shocks. The latter finding attracts particular attention in view of China's gradual transition of replacing investment and exports as drivers of its economic growth by consumption. In a recent paper, Cao, Jin and Zhao (2020) compare the spillover effects of import fluctuations in China and the United States and find that Europe and Asia would be the regions most negatively affected through import declines in the two countries, with a larger amount stemming from falling US imports.

It is well beyond question that the ongoing pandemic already poses the greatest challenge to the world community since the 1930's Great Depression. For this reason, it is all the more important to assess whether well-documented insights from previous crises, or even non-crisis times, can be transferred to the current context.

1 In a similar vein, previous literature has analysed the disrupting effect of regionally concentrated natural disasters on GVCs, most prominently the 2011 Japan earthquake (see Boehm, Flaaen, & Pandalai-Nayar, 2019; Carvalho, Nirei, Saito, & Tahbaz-Salehi, 2016; Park, Hong, & Roh, 2013).

3 Method and data

To study GVC-induced demand and supply shocks on developing countries, we map individual countries' value-added to demand for and production of specific value chains. In accordance with Los et al. (2015) and Timmer et al. (2013), we define a value chain by the finalised products, that is, by the final industrial grouping and the country of completion, for example, textiles finalised in Bangladesh. To trace each country's contribution to this value chain, we need to find the output and value-added associated with the production of textiles finalised in Bangladesh. In the last stage of production, output and value-added is by definition generated in the textiles sector in Bangladesh. Yet, textiles production requires intermediate inputs, such as cotton from the agricultural sector. This will generate output and value-added in the agricultural sector, which can be in Bangladesh or in any other country from which the intermediate is imported. Those first-tier agricultural intermediates may in turn require intermediate inputs themselves, which again generates output and value-added in a specific country-industry, depending on the source of those second-tier intermediates. Hence, to identify the complete characterisation of a value chain, we trace the entire chain of intermediate suppliers across both countries and industries.

To do so, we make use of the global system of input-output relationships. We define a column vector **F** for final demand for finalised products grouped by industry (such as textiles) and country of completion (for instance, Bangladesh). With **A** being a matrix of intermediate input coefficients, we can trace the contributions to the production of **F** making use of the well-known Leontief-inverse $(\mathbf{I}-\mathbf{A})^{-1}$, where **I** is an identity matrix. The expression $(\mathbf{I}-\mathbf{A})^{-1}\mathbf{F}$ then describes the output generated in any country-industry to produce the vector of final demand **F**.[2] Multiplying by a matrix **V** of value-added to gross output ratios for each country-industry on the diagonal, we further obtain the value-added by each country-industry (vector VA) generated in the production of **F**. That is,

$$(1)\ \mathrm{VA} = \mathbf{V}(\mathbf{I}-\mathbf{A})^{-1}\mathbf{F}.$$

By appropriate definition of **F**, we obtain value-added generated in a specific country-industry related to finalisation of a specific product or to final demand by consumers in a specific region or country. For example, setting all elements to zero in **F** except those for Chinese consumers, we obtain value-added generated in any country-industry associated with final demand in China. In a similar vein, setting all elements to zero except those finalised in China consumed anywhere in the world, we obtain value-added in any country-industry associated with production for goods finalised in China.

We obtain each country's demand dependencies by calculating that country's share of GDP that is generated in the production of final goods consumed in the three world regions Europe (EU27 plus Switzerland and the United Kingdom), North America (United States and Canada), and China. To estimate the size of the demand-side effect of the COVID-19 pandemic, we combine these demand dependencies with estimations of the sectoral differences in the downturn in final demand. For Europe, we obtain sectoral retail consumption data from Eurostat (2020). For the sectoral demand effects in the United States,

2 $(\mathbf{I}-\mathbf{A})^{-1}$ is a geometric series. That is, $(\mathbf{I}-\mathbf{A})^{-1}\mathbf{F}$ can be written as $(\mathbf{AF}+\mathbf{A^2F}+\mathbf{A^3F}+\cdots)$. **AF** then describes the first-tier intermediate use, $\mathbf{A^2F}$ the second-tier use, and so on. Therefore $(\mathbf{I}-\mathbf{A})^{-1}\mathbf{F}$ gives the output in any country-industry in the system that participates in production of **F**. For details, see Miller & Blair (2009).

we rely on estimates by Coibion, Gorodnichenko and Weber (2020). These authors use household survey data in the United States and exploit regional variation in the exposure to COVID-19 and measures to contain it to estimate the effect on different categories of consumption goods by household. The survey was held in April, and thus during the time when the US economy was hit the hardest by the pandemic. For China, we use data from the National Bureau of Statistics China (NBS [National Statistical Bureau of China], 2020b). The sectoral classifications differ slightly between the three sources. However, all the information can be straightforwardly mapped with the ISIC (International Standard Industrial Classification of All Economic Activities) Rev. 4 categories in the TiVA (Trade in value-added) data (see Table A1 in the Appendix for the respective mappings).[3]

For interpretation of our demand-side results, we would like to highlight the following two main points. Firstly, the observed shock in final demand is uniform across products within relatively broad sector groupings by final market. For example, textiles consumed in Europe that are finished in Bangladesh experience the same shock to final demand as textiles consumed in Europe that are finished in Italy. This is a matter of aggregation, as we do not observe these demand shocks at high disaggregation, that is, by finalising country for example. Secondly, the demand shock is assumed to have no effect on the way value chains were set up: if demand for textiles finalised in Bangladesh falls, all upstream suppliers lose income in a proportionate manner; the analysis does not, for example, account for potential redirection of upstream intermediates into other value chains. Such dynamics could potentially mitigate the effects for producers further upstream in the value chains, at least in value chains with relatively less specific intermediate inputs.

We obtain each country's supply-side dependency by calculating each country's share of GDP generated in GVCs that are dependent on one of the three hubs. We define a GVC as dependent on a specific hub if that hub generates at least 5 per cent of value-added in production of the respective final good (defined by country of completion and sector grouping).[4] Admittedly, this is an ad-hoc threshold to provide a first ballpark figure of potential effects stemming from disrupted GVCs. Yet, identifying when a GVC is disrupted is not straightforward, and boils down to the substitutability of the respective hub in a GVC. With full substitutability, there would be no disruption and production shocks in one hub would not have any negative effects on other producers in the same value chain. Instead, they would potentially lead to an increase in GDP outside the hub as production stages are taken over by new producers outside the hub. In an input-output-based approach related to ours, Giammetti (2020) assumes, for example, that Brexit induces import substitution within Europe away from the United Kingdom to other European trading partners. This substitution across locations would mitigate the negative effects of Brexit. In model-based approaches, one would additionally consider substitution between varieties of intermediate inputs, as well as between factors of production and intermediates. Bonadio et al. (2020) provide a

3 Mostly for reasons of exposure, our analysis concentrated on those ISIC Rev. 4 categories for which final demand in the three hubs meaningfully contributed to GDP in the set of developing countries. Table A2 in the Appendix shows the shares of value-added generated by final demand in the three hubs, shading those that are ignored in the analysis.

4 There were 50 countries of completion and 28 sectors, and therefore $50 \, x \, 28 = 1400$ value chains. By definition, the value-added shares of all countries that participate in the GVC added up to expenditure for the respective final product (see equation (1)).

recent model-based analysis of the supply-shock running through the COVID-19 crisis. One might argue that such substitution patterns occur in the longer run but are potentially less likely in the short run. Our approach of using a threshold of dependence that leads to a disruption of a GVC therefore needs to be carefully interpreted as a short-run ballpark figure if substitution of relatively important suppliers in GVCs (defined by the threshold) is not possible.[5] We would further like to stress that our supply-side approach accounts for upstream as well as downstream dependencies, in contrast to supply-side applications that focus only on upstream dependencies via imported intermediates (such as Baldwin & Freeman, 2020a). For example, let us assume that Ethiopia exports cotton to China where the cotton is processed and then exported to Europe as a textiles product. Ethiopian agriculture does not require any Chinese inputs, but its production is nonetheless dependent on Chinese producers located further downstream. By decomposing the value chain by its final product, we trace all participants in that chain, independent of their relative position. However – as in the demand-side analysis – we also assume that upstream (and downstream) suppliers do not redirect their output into other value chains.

To capture the effects of the supply shock, we use data on the drop in percentage of industrial production in the three hubs Europe, North America, and China in the month of the largest drop during the first months of 2020.[6] The months with the largest drop were February for China, and April for Europe and North America. China was the first country globally to be affected by COVID-19, and the first to implement a drastic lockdown, with other countries around the globe following in staggered sequence as the disease emerged and spread, with the resulting effects on industrial production.

For both the demand- and supply-side shocks, our estimations of the effects refer to the time that the pandemic – and the measures to contain it – restrained the economies most. All three hubs initially recovered quite substantially after one to two months with regard to both their final demand and their industrial production. All estimates thus refer to this time frame and can be read as projections of what were to happen if the economic effects of the lockdown due to the pandemic prevailed or returned during a future wave.

To implement the method described above to be applied to estimate both the demand and the supply shock, we need information on the global system of input-output relationships (depicted in **A**); information on value-added to gross output ratios (**V**); and a vector of final demand (**F**). In particular, to obtain **A**, one needs to turn to global input-output tables, which describe the supply and use relationships between producers within and across countries. Global input-output tables are constructed combining a large amount of information on value-added, gross output, trade flows (intermediates, final goods), and final demand categories. As this is a highly data-intensive exercise, a major bottleneck to studying the involvement of developing countries is the relatively poor coverage of less developed countries, in particular in sub-Saharan Africa. Some attempts have been made to bridge this gap. The construction of the EORA Global Value Chain database (Lenzen, Moran, Kanemoto, & Geschke, 2013) has taken a global approach covering a large amount of countries since the 1990s but naturally has to make a compromise with respect to a clear

5 In further analysis, we also used a threshold of 10 percent. The results were naturally considerably smaller in magnitude but the cross-country pattern was qualitatively similar (results available upon request).

6 For Europe, we used data from the European Union, for North America from the United States. The data came from the respective national statistical bureaus.

anchoring in official statistics and simplifying assumptions. As a country-specific alternative, we use the data compiled by Pahl et al. (2019), which extend the original World Input-Output Database (WIOD) (Dietzenbacher, Los, Stehrer, Timmer, & De Vries, 2013; Timmer et al., 2015). The WIOD covers the EU 27 plus Norway, Switzerland and the United Kingdom; United States and Canada; China, India, Indonesia, Japan, Taiwan and South Korea; Brazil and Mexico; Russia, Turkey and Australia; and an aggregate for the rest of the world. The construction in Pahl et al. (2019) closely follows the approach laid out in the construction of the WIOD but adds seven new developing countries for the period 2000 to 2014 to the existing WIOD. The new countries are: Ethiopia, Kenya, Senegal, South Africa, Bangladesh, Malaysia and Vietnam.

This country-specific (rather than a global) approach allows for a number of improvements, which are particularly important when studying the value-added or income effects related to GVCs. As is easy to see from equation (1), value-added to gross output ratios in **V** are crucial to obtain a country's value-added in global production. An advantage of using data from Pahl et al. (2019) is the yearly variation in the input data between 2000 and 2014 in those ratios for each of the sectors and industries covered, as opposed to keeping these ratios constant with, say, 2000 values in the year 2014. Secondly, the construction in Pahl et al. (2019) provides a careful treatment of trade flows (for example, re-exports; missing trade flows; classification by use category), which is paramount to depicting the cross-country relationships in **A**. Moreover, to obtain the domestic supply and use relations in **A**, the data are built up from national supply and use tables or official input-output tables, and as such are highly country-specific. Lastly, **F** is consistent with national accounts, and split between household consumption, government consumption, gross fixed capital formation and inventories. This allows for the clean identification of the reductions in final demand that stem from household consumption (as depicted in the retail survey of Eurostat, 2020, the household survey by Coibion et al., 2020, and the data from NBS, 2020b).

Using this dataset, we choose all 12 low and middle-income countries in the three major developing world regions: 4 countries in Sub-Saharan Africa (Ethiopia, Kenya, Senegal, South Africa); 6 in East and Southeast Asia (Bangladesh, China, India, Indonesia, Malaysia, Vietnam); and 2 in Latin America (Brazil, Mexico). The choice of countries in Pahl et al. (2019) was guided by obtaining a first overview of developing countries from the major world regions, while meeting the high data demands necessary for the data construction. We base the estimates on the final year in that dataset, that is, 2014.

4 Demand-side vulnerability

To study demand-side-related GDP effects for developing countries arising from the pandemic, we use the value-added trade data to compute how much of value-added in each of the developing countries in the sample depends on final demand in the various different regions in the world. Table 1 presents these results aggregated across sectors, where rows show individual developing countries. The first six columns list separate world regions, while the last column lists developing countries' home markets. The values then depict how much of value-added in each country depends on final demand in each of these regions.[7]

7 These numbers are related to the export-to-GDP ratio, but not equal to it. Differences arise in different shares of domestic value-added to gross exports across the countries.

Table 1: Demand-side dependency by region (as a percentage of GDP)

	Europe	North America	China	East Asia	Other emerging countries	Rest of world	Home market
Bangladesh	6.1	2.7	0.2	0.4	0.7	2.6	87.2
China	3.2	3.6	-	2.1	2.1	7.7	81.3
India	2.1	1.7	0.9	0.5	0.8	7.3	86.7
Indonesia	2.3	2.6	2.4	3.3	1.7	7.0	80.7
Malaysia	4.7	4.8	5.3	6.5	4.9	24.1	49.7
Vietnam	8.1	9.4	5.3	6.0	3.6	15.5	52.1
Ethiopia	2.5	0.5	0.9	0.5	0.5	8.6	86.5
Kenya	3.0	0.7	0.2	0.2	0.5	14.8	80.6
Senegal	2.3	0.3	0.3	0.4	0.4	12.5	83.9
South Africa	4.7	2.5	2.6	1.5	2.0	13.9	72.8
Brazil	1.7	1.4	1.5	0.7	0.9	3.6	90.3
Mexico	1.4	13.8	0.6	0.5	0.6	2.1	81.0

Notes: Figures for 2014. GDP as the sum of value-added in 2014 USD. "Europe" refers to all 28 member countries of the European Union as of 2014 plus Switzerland; "North America" refers to the United States and Canada. Each country's home market is included in the home market region such that columns add up to 100, except for rounding.
Source: Authors' calculations, based on method and data from Pahl et al. (2019)

As shown in Table 1, Vietnam and Malaysia are most strongly dependent on foreign demand, with only around 50 per cent of domestic value-added dependent on final demand in their home markets. For other countries, GDP dependence on foreign demand ranges between 27 (South Africa) to below 10 per cent (Brazil). At the same time, for example, Bangladesh's GDP is relatively strongly dependent on demand from Europe, at 6.1 per cent; and Mexico, unsurprisingly, on demand from North America, at 13.8 per cent. Hence, we would expect these countries to be most strongly affected by the economic downturn and plummeting demand in Europe and the United States. Considering regional differences, value-added in Asian countries is on average more dependent on foreign final demand than that in African countries.[8]

However, economic lockdown measures do not lead to a homogeneous decrease in demand across all sectors. Social distancing measures affect the sectors much more strongly that require direct personal interaction, besides the differentiated demand reductions due to an overall plunge in income.[9] Developing countries participating in GVCs for which final demand collapsed comparatively more are therefore likely to be more vulnerable to COVID-19-induced demand shocks through global production links. To reveal these sectoral dependencies, we show how much of the value-added in each developing country that

8 For Latin America, the sample is quite small and particular, with Brazil as a large country with a large home market and Mexico, with a strong dependence on US final demand, which are not necessarily representative of other countries in the region, but which, on the other hand, make for interesting contrasts in this respect.

9 The declining demand may also be due to people's concerns rather than political measures, see Chetty, Friedman, Hendren, & Stepner (2020) and Goolsbee & Syverson (2020). We do not differentiate between various different drivers of demand downturns but viewed them jointly as a result of the pandemic.

depends on final demand in the foreign region (as shown in Table 1) arises from demand in individual sectors. Table 2 presents corresponding findings, where the values depicted represent shares in per cent of total value-added in a developing country that depends on final demand in the respective foreign region, stemming from final demand in a given sector. While Table 2 is not exhaustive, it shows the most important end markets by sector grouping for the sample set of countries. The dependencies displayed reveal quite stark differences between developing countries and regions in terms of how much of domestic production for foreign demand is concentrated in production for specific sectors.[10] For Bangladesh, 94.1 per cent of its value-added embedded in European final demand is for textile goods, and this value is 94.9 per cent of its production for North American final demand. Other countries, such as Vietnam, are much more diversified: for all of Vietnamese production consumed in Europe, only 24.2 per cent are for textiles whereas 26.4 per cent are for the electronics sector and 14.9 per cent go into the consumption of food. If the consumption of textiles breaks down in Europe more than in other manufacturing sectors – as has now happened during the COVID-19 pandemic (ILO [International Labour Organization], 2020) – Bangladesh is thus likely to be relatively more affected by this than a more diversified country such as Vietnam.

10 Note that the value-added in the source country may be in other sectors, as long as they supply the respective sector of final demand. Conversely, production in a certain sector in a source country need not be for final demand in that sector in another country (or domestically).

Table 2: Demand-side dependency by product group (as a percentage of GDP generated in respective region)													
		Asia						**Sub-Saharan Africa**				**Latin America**	
		Bangladesh	**China**	**India**	**Indonesia**	**Malaysia**	**Vietnam**	**Ethiopia**	**Kenya**	**Senegal**	**South Africa**	**Mexico**	**Brazil**
Europe													
Agriculture, forestry and fishing	A	0.0	0.7	2.7	2.4	1.7	4.7	48.5	66.0	40.9	8.5	2.8	4.1
Food, beverages, tobacco	C10t12	3.1	4.0	7.4	14.3	8.8	14.9	27.0	20.4	18.9	9.6	8.3	25.6
Textiles	C13t15	94.1	13.5	20.1	13.2	4.1	24.2	3.1	1.5	2.5	1.9	1.8	3.3
Coke and refined petroleum	C19	0.0	1.1	2.1	3.5	2.7	0.7	0.2	0.5	2.3	4.6	8.6	3.4
Pharmaceuticals	C21	0.1	1.3	1.1	1.5	0.9	0.4	0.4	0.2	0.8	0.8	3.4	1.4
Computer, and electronics	C26	0.1	15.9	1.9	7.1	18.6	26.4	0.5	0.4	1.5	3.0	5.2	1.6
Electrical equipment	C27	0.0	6.0	1.3	2.1	3.4	1.5	0.5	0.1	1.9	1.8	1.6	1.3
Machinery	C28	0.1	6.0	2.8	2.1	4.7	1.4	0.8	0.3	3.3	10.0	4.1	2.7
Furniture; other manufacturing	C31t33	0.1	6.4	3.2	5.8	6.1	6.6	0.9	0.8	3.0	3.7	4.9	3.4
Sum		*97.7*	*54.9*	*42.5*	*52.0*	*50.9*	*80.7*	*82.0*	*90.3*	*75.0*	*43.8*	*40.8*	*46.8*
North America													
Agriculture, forestry and fishing	A	0.1	0.3	2.0	0.8	0.5	5.1	7.7	11.6	2.7	2.2	4.9	1.8
Food, beverages, tobacco	C10t12	1.3	3.2	7.4	13.0	6.0	11.6	33.2	8.7	8.6	5.6	7.0	11.0
Textiles	C13t15	94.9	16.1	22.5	26.5	5.2	37.8	10.8	57.4	9.3	2.7	3.4	4.5
Coke and refined petroleum	C19	0.0	0.8	2.3	2.2	1.8	1.0	1.2	0.8	3.4	5.0	4.8	4.7
Pharmaceuticals	C21	0.0	0.8	1.5	0.6	0.7	0.2	1.3	0.6	1.6	1.1	0.4	1.5
Computer, and electronics	C26	0.2	18.5	2.1	6.0	20.6	11.4	1.6	1.2	4.5	3.9	6.3	2.3
Electrical equipment	C27	0.0	5.4	1.1	1.4	3.6	1.1	0.6	0.3	1.7	1.8	3.5	1.9
Machinery	C28	0.1	6.0	3.0	2.0	3.8	1.5	1.2	0.7	3.8	7.6	5.8	5.3
Furniture; other manufacturing	C31t33	0.6	6.9	6.0	7.1	7.0	10.7	3.4	2.0	21.7	4.3	4.4	5.3
Sum		*97.3*	*58.1*	*48.0*	*59.7*	*49.2*	*80.3*	*61.1*	*83.2*	*57.4*	*34.2*	*40.3*	*38.3*

Table 2 (cont.): Demand-side dependency by product group (as percentage of GDP generated in respective region)													
China													
Agriculture, forestry and fishing	A	8.6		2.4	3.0	2.5	8.7	6.9	6.3	3.9	2.4	2.0	4.6
Food, beverages, tobacco	C10t12	3.7		6.5	11.7	7.2	20.8	19.8	10.0	17.9	4.3	4.8	19.4
Textiles	C13t15	48.6		4.6	3.6	1.7	6.5	4.1	4.4	3.0	1.5	1.5	3.3
Coke and refined petroleum	C19	0.3		0.7	2.0	1.4	1.0	0.2	0.8	0.6	1.6	1.2	0.9
Pharmaceuticals	C21	0.4		0.5	0.5	0.4	0.2	0.8	0.8	0.7	0.4	0.7	1.0
Computer, and electronics	C26	1.7		3.3	3.7	13.2	9.9	0.9	5.2	5.1	3.2	5.3	1.5
Electrical equipment	C27	1.2		2.5	3.5	4.0	2.9	1.3	3.3	3.4	3.6	4.2	2.1
Machinery	C28	2.6		5.1	5.0	6.8	4.0	2.7	5.5	7.1	6.9	7.3	4.1
Furniture; other manufacturing	C31t33	1.3		1.0	1.2	0.9	1.3	0.6	1.4	1.7	0.6	3.9	0.6
Sum		*68.2*		*26.7*	*34.2*	*38.1*	*55.4*	*37.3*	*37.8*	*43.3*	*24.5*	*30.9*	*37.6*

Notes: Figures for 2014. Shaded cells indicate 10 per cent or more in respective region. List of industries is not exhaustive but only shows industries for which we obtained demand shock figures (see Table 3). “Europe” refers to all 27 member countries of the European Union plus Switzerland and the United Kingdom; “North America” refers to the United States and Canada.

Source: Authors’ calculations, based on method and data in Pahl et al. (2019)

In order to provide a ballpark figure for the adverse effects inflicted on sample developing countries by the demand slumps in Europe, the United States, and China due to the COVID-19 pandemic, we combine the above results with data on how much final demand fell by sector. Table 3 shows the collapse in demand by ISIC sector and region, using the sectoral mapping provided by Appendix table A1.

Table 3: Sectoral downturns in final demand (in per cent)

Sectors	ISIC4	Europe	North America	China
Agriculture, forestry and fishing	A	-1.4	-14.7	-11.3
Food, beverages, tobacco	C10t12	-1.4	-14.7	-11.3
Textiles	C13t15	-77.8	-35.7	-48.9
Coke and refined petroleum	C19	-43.2	-28.2	-37.5
Pharmaceuticals	C21	-12.4	-20.5	-33.0
Computer, and electronics	C26	-41.5	-9.5	-28.6
Electrical equipment	C27	-34.8	-9.5	-28.6
Machinery	C28	-34.8	-9.5	-40.4
Furniture; other manufacturing	C31t33	-34.8	-22.0	-66.5

Notes: "Europe" refers to all 27 member countries of the European Union plus Switzerland and the United Kingdom; "North America" refers to the United States and Canada.
Source: Coibion et al. (2020), Eurostat (2020), NBS (2020b)

The numbers shown in Table 3 indicate sizable heterogeneity across regions in terms of sectoral demand slumps. Textiles demand, for example, dropped by about 78 per cent in Europe but only by about 36 per cent in North America. Countries highly dependent on textiles consumed in Europe are thus likely to experience a relatively more severe shock in GDP than those dependent on textiles consumption in North America.

What does this imply for those developing countries located upstream in GVCs? To get a first impression about the dimensions of what the demand slumps could imply, we assume that each sectoral downturn was passed proportionally through the value chain, thus affecting value-added in the supplying countries to the same extent.[11] This produces an approximation to the loss of value-added in each developing country through its contribution to the respective final demand sectors. Table 4 shows these results.

11 This assumes that the demand shock is uniform across varieties of final goods within sectoral aggregation (for example, final good varieties from different countries), and that the production function remains unchanged (that is, cost shares remain constant); see also Pahl et al. (2019).

Table 4: Demand-induced value-added effect (as a percentage of GDP)			
	Europe	**North America**	**China**
Bangladesh	-4.46	-0.93	-0.06
China	-0.52	-0.31	-
India	-0.37	-0.20	-0.04
Indonesia	-0.36	-0.36	-0.13
Malaysia	-0.38	-0.25	-0.21
Vietnam	-1.78	-1.75	-0.45
Ethiopia	-0.10	-0.05	-0.05
Kenya	-0.09	-0.17	-0.01
Senegal	-0.11	-0.03	-0.02
South Africa	-0.25	-0.12	-0.08
Brazil	-0.09	-0.08	-0.08
Mexico	-0.10	-0.73	-0.02

Notes: Figures for 2014. "GDP" is the sum of value-added in 2014 USD. "Europe" refers to all 27 member countries of the European Union plus Switzerland and the United Kingdom; "North America" refers to the United States and Canada.

Source: Authors' calculations, based on Table 2 (including all sectors) and demand-side estimates as shown in Table 3

As Table 4 illustrates, the likely contribution of demand downturns further downstream in GVCs to an overall decrease in GDP differs significantly across the countries in our sample. The countries that we found to be dependent more on foreign markets – and among those the ones specialised in sectors with forecasted sharpest demand decreases – were expected to suffer from comparatively stronger drops in own GDP through this channel. For example, our estimations suggest that Bangladesh's GDP is experiencing a drop of about 4.5 per cent due only to falling demand in Europe and 0.9 per cent in North America. This effect is mainly because of the sharp decline in demand for textiles. Overall, Vietnam is even more dependent on foreign demand, although in different sectors, and might expect a decline of about 1.8 per cent through declining final demand in Europe and North America, respectively. Despite its comparable reliance on production in value chains for Chinese final demand rather than that in Europe or North America, it is not so much affected by declining demand in China. The reason is that Vietnam produces comparatively even more in value chains for China where final demand has not plummeted so much (food and agriculture) as in those in which it still produces significant shares for European and North American final demand (textiles, and computer and electronics). By contrast, countries in sub-Saharan Africa are much less integrated into the world economy and therefore only experience minor economic effects through GVCs.

5 Supply-side vulnerability

With the role for some of the poorest developing countries in GVCs remains restricted to the supply of commodities to be processed abroad, others have managed to become important pillars further downstream in value chains – for example, in the assembly of final goods (World Bank, 2020). As such, the maintenance of output capacities in developing countries for both commodity exporters as well as downstream assemblers often relies on

intermediate inputs from foreign sources. We would like to emphasise that this dependency can consequently be critical for production in GVCs. Analogously to Table 1 and for an aggregation across sectors, Table 5 presents how much of value-added in each developing country in our sample depends on critical inputs from the three hubs. Values indicate the share of value-added in the row country (as per cent of GDP) generated in value chains with a minimum supply-side contribution of 5 per cent at any stage in the production process according to the column regions. Defining a threshold contribution implies that substituting existing supply-side relations appears fairly difficult (at least in the short run) and, with this, unlikely. This emphasises the displayed dependencies.

Table 5: Supply-side dependency (as a percentage of GDP)

	Europe	North America	China
Bangladesh	0.6	0.1	0.4
China	5.4	1.9	93.2
India	7.1	1.1	2.6
Indonesia	7.7	1.5	8.7
Malaysia	13.4	3.8	11.1
Vietnam	8.4	2.8	7.5
Ethiopia	2.6	0.4	1.4
Kenya	5.8	0.3	4.5
Senegal	3.3	0.2	1.8
South Africa	8.5	2.2	5.8
Brazil	5.4	1.7	3.4
Mexico	7.6		2.5

Notes: Shares indicate value-added in row country generated in value chains with contributions of 5 per cent or more of column region. “Europe” refers to all 28 member countries of the European Union as of 2014 plus Switzerland; “North America” refers to the United States and Canada. Row countries are included in the respective column.

Source: Authors’ calculations, based on Pahl et al. (2019) and method as described in the main text

Table 5 reveals that the dependency of developing countries is far from being homogeneous with respect to supplying countries: indeed, geographical proximity appears to be a salient determinant (see also Baldwin & Lopez-Gonzalez, 2015; Johnson & Noguera, 2017). For example, while Mexico generates nearly 50 per cent of domestic value-added through value chains which depend on inputs from the United States and/or Canada, Indonesia (8.7 per cent), Malaysia (11.1 per cent), and Vietnam (7.5 per cent) exhibit natural dependencies on China. At the same time, however, all three are not exclusively tied to Chinese inputs. Instead, their value-added appears to depend equally on European inputs, suggesting a well-diversified portfolio of suppliers. In view of the uneven temporal distribution of production bottlenecks across major GVC-hubs induced by COVID-19 that is still affecting Europe and North America while Chinese production capacities started to be ramped up again in the late spring of 2020, Southeast Asian countries do not seem to have to bear the full impact of supply shortages at the same time. Instead, it appears that their supply-side diversification at least partly contributes to a cushioning of the adverse spillover effects originating in major hubs. What is more, depending on both its duration and extent, Southeast Asian countries not only benefit disproportionally from Chinese economic recovery; at the same time, their supply-side diversification potentially allows them to partly circumvent adverse effects originating in Europe if Chinese supply growth outbalances declines in Europe.

Bangladesh constitutes an exceptional case in Asia as the country shows extraordinarily little dependence on inputs from any of the major hub regions. In sharp contrast to the country's deep integration into GVCs through significant demand-side dependencies especially vis-à-vis the European textile industries (see Table 1), Bangladesh's limited supply-side dependence makes it a natural candidate for low vulnerability in terms of foreign supply-side shocks arising from COVID-19-induced bottlenecks. In other words, without ignoring Bangladesh's high degree of vulnerability due to its obvious concentration on both sector (textiles) and downstream destination (Europe), and the country's domestic supply difficulties due to high future infection rates and economic lockdowns, the country is exposed to surprisingly little vulnerability due to COVID-19-induced supply constraints in the three major global economic hubs.[12]

Similarly, pronounced "shock-resilience" towards adverse supply-side spillovers from global GVC-hubs can be found for three sub-Saharan countries, namely Kenya, Senegal, and to a lesser extent, Ethiopia, where in all cases the most important value chains seem to depend primarily on domestic sources. The above-mentioned sectoral assessment already provides a partial explanation for this finding as all three reveal a sharp concentration in value-added generation in "agriculture, forestry and fishery" for example, which is characterised by limited international production fragmentation (see, for example, Johnson & Noguera, 2017).

Table 6: Decline in industrial production (in per cent)

	Europe	North America	China
Decline in industrial production	-27	-16.6	-28.7

Note: Figures refer to April in Europe and North America, and February in China.
Source: Eurostat (2020) for Europe, FRED [Federal Reserve Economic Data] (2020) for North America, NBS (2020a) for China

Underpinning our a priori findings, we use data from the national statistical bureaus of the European Union, the United States, and China. The peaks in industrial production declines since the outbreak of the pandemic amount to 27 per cent (Europe in April), 16.6 per cent (United States in April) and 28.7 per cent (China in February). These numbers are shown in Table 6. Assuming, for simplicity, that sectoral export activities were hit proportionally, this implies that the same share of value-added that uses more than 5 per cent of Chinese inputs as overall intermediates cannot produce anymore for this time span. As the above numbers suggest, the stricter lockdowns in Europe and China resulted in a larger production drop than in North America. Thus, being integrated into GVCs dependent on those hubs has a more severe effect on the developing countries' own production. A back-of-the-envelope calculation can give a rough estimate of what effect this will have on GDPs in our sample developing countries, given the results presented in Table 5. Table 7 shows the results of this exercise. Resulting from its enormous supply-side dependency on the United States, 11 per cent of Mexico's GDP are at risk. While Bangladesh's GDP may drop by a slight 0.3 per cent following adverse supply-shocks originating across the three major hubs, the GDPs of Indonesia (-4.8 per cent), Malaysia (-7.4 per cent), Vietnam (-5.0 per cent) are threatened

12 Bangladesh does rely on imports from countries other than the hubs, particularly India. While initially, agricultural production in India did not plummet as much as other Indian sectors, the overall effects of past and potential future lockdown measures in India for developing countries is beyond the scope of this paper. This would be an important extension of our work.

by a ten-times larger decline due to supply bottlenecks abroad. By contrast, Ethiopia, Kenya, and Senegal are estimated to experience a comparatively mild economic downswing of between 1.2 and 3 per cent, provoked by adverse supply-side spillovers in GVCs. While a larger fraction of Mexico's GDP is at stake in total numbers due to adverse supply-side spillovers from its NAFTA fellow integration partners, Southeast Asian countries especially are assigned a significant global importance in GVCs. The relatively more pronounced critical reliance on inputs from Europe and China also exposes these countries to the detrimental effect of the stronger production declines in these hubs, compared to the lockdown in North America. In this context, however, despite considerable shortages in intermediate supply due to economic lockdown across the two major hubs, one might hypothesise that Southeast Asia might not have to bear the full costs of accompanying GDP declines. In actual fact, the staggered structure of COVID-19-induced supply-shocks across hubs could well provide a remedy: as China already left behind its economic lockdown in March, economic output was expected to ramp up shortly after. As a result, adverse supply-side spillovers inflicted on Southeast Asia and originating in Europe could thus be (more than) outbalanced by already increased Chinese supply.

Table 7: Supply-induced value-added effect (as a percentage of GDP)

	Europe	North America	China
Bangladesh	-0.2	0.0	-0.1
China	-1.5	-0.3	-
India	-1.9	-0.2	-0.8
Indonesia	-2.1	-0.2	-2.5
Malaysia	-3.6	-0.6	-3.2
Vietnam	-2.3	-0.5	-2.2
Ethiopia	-0.7	-0.1	-0.4
Kenya	-1.6	0.0	-1.3
Senegal	-0.9	0.0	-0.5
South Africa	-2.3	-0.4	-1.7
Brazil	-1.5	-0.3	-1.0
Mexico	-2.0	-8.2	-0.7

Notes: Shares indicate value-added in row country associated with supply drop column region (in value chains with contributions of 5 per cent or more of column region). "Europe" refers to all 27 member countries of the European Union plus Switzerland and the United Kingdom; "North America" refers to the United States and Canada. "Supply drop" refers to the estimated decline in industrial production as described in the main text.

Source: Authors' calculations, based on Pahl et al. (2019) and estimates on industrial production (Eurostat, 2020; FRED, 2020; NBS, 2020)

6 Discussion and outlook

Since international trade and trade policy are both part of the problem and part of the solution of many of the current challenges in light of the pandemic (Bown, 2020; Evenett, 2020; Evenett & Freeman, 2020; González, 2020), it is key to acquire a deeper understanding of how GVCs are affected by COVID-19. In this paper, we have documented the GVC-related vulnerabilities of a set of 12 developing and emerging economies, showing dependencies through demand and supply linkages. Confirming conjecture, we find that the

most integrated economies tend to suffer most through those channels and we document that the highly integrated Southeast Asian economies have substantial shares of GDP at risk. By contrast, countries in sub-Saharan Africa are much more dependent on their home markets and show comparatively little supply integration with key hubs in GVCs, namely China, Europe and North America. They are thus potentially less affected via this channel. For these countries, disruptions in supply and demand in the home market are the most pressing issue. Yet, for the highly integrated countries, the findings suggest that mitigating economic effects requires both a focus on the recovery of home-market supply and demand, as well as a focus on trade in GVCs.

This relates to the discussion on whether the recovery from economic crises is easier for countries that are highly embedded in GVCs. Brakman and van Marrewijk (2019) study recovery from the 2008-2009 financial crisis in relation to participation in GVCs, finding that countries with stronger linkages in GVCs recovered more slowly from the crisis. At the same time, integration into diverse GVCs can also have the advantage of risk diversification.

In our results, we show that countries like Vietnam tend to be relatively diversified from both a demand and a supply perspective. Given that the current economic crisis may play out very differently across end markets as well as supplier countries, such diversification may prove beneficial. Mexico, on the other hand, is highly dependent on the United States and Canada. Even though both demand and supply shocks were not as stark in North America as in Europe or China, if the economic crisis in this region continues for much longer than in other regions, Mexico will find its own recovery to be much slower. This dependence has also, for example, led to only minor growth in jobs in Mexico as expenditure growth has already been relatively slow in North America since 2000 compared to more dynamic countries in Asia (see Pahl et al., 2019). Countries that are mostly dependent on their home market demand and supply may face a similar problem in the recovery process if, for instance, demand growth is weak in the home market but is already picking up in the three hubs.

Discussions about diversification might also become important in relation to adjustments to GVCs. At least for a subset of products, the current crisis has revealed the strong dependence on a few, key suppliers often located in China. In the past, many lead firms in GVCs have indeed turned to fewer key suppliers in strategic locations, coinciding with the rise of China as a major hub in world manufacturing production (Gereffi, 2014; Haraguchi, Cheng & Smeets, 2017). One might hypothesise that the current crisis would cause lead firms to reorganise their GVCs to mitigate risks by reducing dependence on single – that is, Chinese – suppliers. Kilic and Marin (mimeo) argue that uncertainty in the global economy (for example, due to trade tensions or pandemics) in combination with falling prices of automation (for instance, due to falling interest rates and prices for robots) reduces the cost advantage of offshoring for developing nations (see also Seric & Winkler, 2020). Such developments might be further fuelled by the demands of policymakers, calling for renationalisation of key industries. This would not only dispute China's role in global manufacturing production but also make it harder for other developing countries to develop through participation in GVCs. Yet, reshoring to home countries also means that value chains are dependent on single suppliers, which similarly will not protect against disruptions in production. Risks such as that of a pandemic may hit any country alike, and many equally, even though somewhat consecutively. Our results show that the impacts of this for

developing countries through GVCs may differ significantly depending on the character of their integration in these chains.

Javorcik (2020) points out that lead firms may need to show to shareholders that their supply chains are resilient to such shocks in the future. This might offer opportunities for to date less popular investment locations outside of China if countries can show that they are well equipped to address future disruptions. Diversification on the input-side may be one important determinant for this. Miroudot (2020) indeed argues that more complex value chains are in fact better equipped to mitigate disruptions, as they can adjust more easily by using a larger network of diversified suppliers in multiple countries.

For some developing countries, in contrast, commodities make up a larger share of exports and value-added than for the ones included in the sample of the present study. Analysing the effects of falling commodity prices by including countries exemplary of this would be an interesting extension of the analysis in order to achieve an even more comprehensive picture of the effects of the pandemic on developing countries through GVCs. Also, tourism as a final demand category of central importance for many developing countries is not included in this paper, but would deserve particular attention. Another interesting avenue for future research would be to study how well firms also manage to substitute within GVCs of physical goods, in order to cushion the effects of collapsing value chains. This is something that the partial equilibrium analysis in this paper cannot do, which means that it is restricted to the short-term perspective.

How smooth a rebound from the COVID-19-induced economic breakdown in the mid- to long term will be for developing countries, however, also depends on a global environment allowing for trade in GVCs. The complex web of GVCs highlights how detrimental pandemic-related trade restrictions can be, especially in times of crisis. Export restrictions of one country are restrictions on the imports of another, aggravating the effects of such measures, above all for developing countries that depend on imports in order to be integrated into GVCs. The analysis of the upstream and downstream vulnerability of GVCs to demand and supply shocks underlines the importance of diversifying the reliance of developing countries on demand and supply and, in particular, of diversifying their own inputs further up the supply chains.

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Appendix

Table A1: Sectoral mapping

ISIC Rev 4 Classification	Europe: sectoral classification in Eurostat (2020)	North America: sectoral classification in Coibion et al. (2020)	China: sectoral classification in NBS (2020b)
Agriculture, forestry and fishing	Food, drinks, tobacco	Food	Grain and oil, foodstuffs, beverages, tobacco
Food, beverages, tobacco	Food, drinks, tobacco	Food	Grain and oil, foodstuffs, bseverage, tobacco
Textiles	Textiles, clothes, footwear	Clothing, footwear, personal care	Garments, footwear, hats, knitwear
Coke and refined petroleum	Automotive fuel	Gasoline	Petroleum and related products
Pharmaceuticals	Pharmaceutical and medical goods	Medical	Traditional Chinese and Western medicine
Computer, and electronics	Computer equipment, books	Durable goods	Communication appliances
Electrical equipment	Electrical goods and furniture	Durable goods	Communication appliances
Machinery	Electrical goods and furniture	Durable goods	Cultural and office appliances
Furniture; other manufacturing	Electrical goods and furniture	Furniture, jewellery, small appliances and other small durable goods	Furniture

Notes: Column 1 lists the sectors of final demand used in this study. Columns 2-4 list the sectors from the classifications in Eurostat (2020), Coibion et al. (2020) and NBS (2020b) that we map with the respective ISIC Rev. 4 sector.

Source: Authors

Table A2: Shares of value-added generated by final demand in three hubs

Shares		Bangladesh	Brazil	China	Ethiopia	Indonesia	India	Kenya	Mexico	Malaysia	Senegal	Vietnam	South Africa
Agriculture	A	0.3	5.4	0.8	42.8	2.9	3.4	57.8	8.1	3.1	43.9	8.6	10.6
Mining	B	0.0	0.3	0.4	0.1	0.1	0.1	0.0	1.0	0.1	0.1	0.1	0.8
Food	C10t12	2.7	32.2	5.9	33.1	20.5	10.8	19.2	12.4	15.5	23.2	22.4	14.7
Textiles	C13t15	94.9	6.1	24.8	5.5	23.3	26.8	13.0	5.6	7.6	4.1	38.6	4.1
Wood	C16	0.0	0.1	0.4	0.5	0.3	0.5	0.1	0.1	0.2	0.1	0.3	0.1
Paper	C17	0.0	0.5	0.5	0.2	0.4	0.3	0.1	0.6	0.3	0.1	0.1	0.4
Printing	C18	0.0	0.1	0.1	0.0	0.1	0.1	0.0	0.1	0.1	0.0	0.0	0.1
Coke and refined petroleum	C19	0.0	4.9	1.5	0.4	4.0	2.8	0.6	8.8	4.1	2.9	1.3	8.0
Chemicals	C20	0.0	2.3	1.9	0.5	1.9	2.5	0.3	2.7	2.6	0.8	0.5	2.8
Pharmaceuticals	C21	0.1	1.6	1.2	0.6	0.9	1.3	0.2	0.9	1.0	0.6	0.3	1.1
Rubber	C22	0.1	0.5	1.8	0.2	1.4	1.1	0.1	1.2	4.4	0.3	0.9	0.7
Non-metallic mineral products	C23	0.2	0.2	0.8	0.1	0.4	0.2	0.1	0.2	0.3	0.1	0.3	0.3
Basic metals	C24	0.0	0.2	0.9	0.0	0.1	0.2	0.0	0.1	0.2	0.1	0.1	0.4
Fabricated metal products	C25	0.0	0.6	1.6	0.1	0.4	0.5	0.1	0.7	0.4	0.5	0.3	1.0
Computer	C26	0.0	1.0	8.7	0.3	3.5	1.1	0.3	5.6	8.0	0.9	2.2	2.0
Electrical equipment	C27	0.0	0.9	5.1	0.2	1.3	0.7	0.1	2.4	2.8	0.5	0.6	1.6
Machinery	C28	0.0	0.3	1.0	0.1	0.2	0.3	0.1	0.5	0.4	0.3	0.3	0.7
Automotives	C29	0.1	3.1	4.6	0.7	3.5	3.9	0.4	10.7	4.6	1.3	2.1	12.1
Transport equipment	C30	0.5	0.5	1.1	0.1	0.6	0.6	0.1	1.2	0.9	0.4	0.5	1.1
Furniture; other manufacturing	C31t33	0.2	1.7	9.1	1.0	6.2	4.5	0.9	3.4	6.2	4.9	9.3	4.4
Electricity	DtE	0.0	2.2	1.3	0.4	1.6	1.3	0.3	2.4	2.2	1.8	0.7	4.2
Construction	F	0.0	0.3	0.3	0.1	0.2	0.3	0.1	0.1	0.3	0.4	0.1	0.4
Wholesale & retail, food & restaurants	GnI	0.3	11.4	7.1	6.8	8.8	7.4	2.8	10.3	9.7	4.7	3.1	8.2
Transportation & storage; telecomm.	HnJ61	0.1	4.1	3.8	0.8	3.3	3.1	0.5	4.7	4.4	1.6	1.2	4.3
Business services	JtNexJ61	0.2	9.5	8.2	2.0	6.1	9.3	1.2	5.6	9.7	2.9	2.5	7.1
Public services	OtQ	0.2	6.7	4.8	2.4	5.2	5.5	1.0	8.4	7.5	2.5	2.5	6.4
Other services	RtT	0.1	3.1	2.3	1.0	2.4	11.5	0.5	2.3	3.2	0.9	1.0	2.4

Notes: Figures for 2014. Shares are all value-added generated in respective country by delivering to final demand in three hubs by consumption by sector aggregate.
Source: Authors' calculations, based on data in Pahl et al. (2019)

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