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The Globalization Conundrum Post COVID19: Internalizing the Risks of the Supply Chain

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Abstract

In 2020, US and European firms have undertaken financial risk that they can ill-afford to carry, stemming from their supply chain networks. Many have gradually deluded themselves into thinking their risk was reasonable, while other firms have made production sourcing decisions with little idea of the true magnitude of their risks. However, the rising risk was an inevitable consequence of the economy's multinational firms spreading the supply chain further away from its home base. For the purposes of this paper, we consider risk associated with a transaction to be excessive when the domestic multinational is likely to incur a loss that will seriously compromise its production and sales, and possibly force the firm into bankruptcy.

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I. INTRODUCTION

The formation of a global supply chain in the past two decades has created both losers and winners. The formation of these supply chains affected the location of imported inputs, as industry supply shifted from developed country markets into developing country suppliers. The resulting "production shifting-in effect" of the development of a supply chain was functioning uninterrupted until the Covid-19 pandemic.

Historically, the big winner of the shift in production globally was the PRC - where the development of the supply chain was accompanied by a large amount of foreign direct investment. (Pelzman, 2016). As a result of the Covid-19 pandemic and the apparent risks of depending on a single major supplier – the PRC - there have been alternative candidates to substitute for the PRC. The latest such competition comes from Vietnam which has recently adopted the EU-Vietnam Free Trade Agreement (EVFTA), in the hopes to secure customers in the European market after the Covid-19 pandemic, and substitute for the PRC.[1]

The policy debate about the outcome of the Covid-19 pandemic has included all the latest predictions focusing on the dire impact on the global market.[2] What most of these predictions have missed is that the market will adjust once it appropriately internalizes the impact of supply side socks across the multi-stage production process. This paper shows that the industrial structure resulting from the "production shifting-in effect" of the establishing of a global supply chain, may

[1] Once the agreement takes effect, 71 per cent of Vietnam's exports to the EU will become duty-free, as will 65 per cent of EU exports to Vietnam. Of the remaining tariffs, up to 99 per cent will be phased out by Hanoi over 10 years and by Brussels over seven years. (EVFTA text)

[2] The most prolific of these predictions comes from the standard cast of characters: "El-Erian, Stiglitz, Krugman and other top economists offer insights on the future of supply chains," CNBC, September 14, 2020; Arjun Appadurai, "Coronavirus Won't Kill Globalization. But It Will Look Different After the Pandemic," Time, May 19, 2020; Fareed Zakaria, *Ten Lessons for a post-pandemic world*, W.W. Norton, 2020; "How the world will look after the coronavirus pandemic," *Foreign Policy*, March 20, 2020.

appear stable as long as you can ignore major "external trade cost shocks" between the large[3], developed country with a large consumer base and its 'supply chain' suppliers in developing countries. Once we include risks associated with breaks in the supply chain due to the Covid-19 pandemic, there may be a push to redirect FDI resources to other developing country manufacturing locations to minimize dependence on a single source like the PRC or India. There may also be a redirection of FDI resources back into the home country in sensitive industries.

To elucidate the spatial production location choices in an economic geography model, it is essential to include elements such as the increasing returns to scale, positive trade costs and imperfect competition. Krugman (1991) and Krugman and Venables (1995) had such common features in their models and showed how they created core-periphery structures through externalities among economic agents. One of the main differences between the two papers is their assumption of factor mobility. In Krugman (1991), where workers are mobile, industrial firms simply alter their production location. In this case, a firm relocates and increases labor demand in that place, which increases the wage rate, and the higher wage may attract workers to move to that place.

In Krugman and Venables (1995), labor is not mobile between countries. In that case, the firm is not only a final goods' supplier to consumers, but also serves as a source of intermediate goods' demand and supply. When a firm shifts its location, it increases the intermediate goods' demand in that new location, which increases its price. The higher price of the intermediate goods will attract another intermediate firm to move to that place.

Puga and Venables (1997) extended Krugman and Venables (1995) to a model of multiple nations. They made several comparative static analyses of exogenous trade barriers among

[3] The reference to 'large' refers to the 'large country case' scenario and not physical characteristic.

countries and of their impact on the firms' profitability. The two main results are as follows. First, in a symmetric case with positive trade costs, when the internal trade barriers begin to drop between two countries in a trade agreement, the firm outside the trade agreement starts to move inside because of the higher profits created by lower trade-cost advantages. A similar finding was demonstrated in Baldwin and Venables (1995). What is novel in their paper is the prediction that, when the internal trade barriers continue to drop to zero, even within the regional integration, there occurs a local industrial concentration in one member of the regional trade agreement. Given a positive and symmetric level of all trade costs among countries, the preferential removal of internal trade costs between RTA members causes a production shift into the RTA region. This result confirms the production shifting-in effect, that has been argued for in the economic geography models. (Puga and Venables, 1997).

In all these models, the assumption made is that the industrial sector has imperfectly competitive firms producing differentiated goods under increasing returns to scale. The goods are traded with iceberg cost, τ_{ij}. (Ottaviano and Thisse, 1998). This implies that *z* units have to be shipped from country j so that one unit arrives in country *i*.

While all these general equilibrium models appear to be a useful direction for an economic analysis of the Covid-19 pandemic's impact on the location of the supply-chains, it is far too aggregated. The economic response to the current pandemic has to be addressed at the micro level with supply chain considerations in a partial equilibrium world where tradable modulations have to be considered. The question of how one can model all the micro interruptions that occur when the Covid-19 pandemic is treated as sock to a stable economic relation is presented in Section II. The algorithm of the value-added supply chain in international trade is presented in Section III. Our approach to measuring the impact of the Covid-19 pandemic on the supply chain of a single

firm in international trade is presented in Section IV. Concluding remarks are presented in Section V.

II. Modeling the Economic Impact of the Covid-19 Pandemic in the Case of Micro Interruptions of the Supply Chain – Where Does One Look?

Despite recent negative proclamations and predictions of the disastrous impact of the Covid-19 pandemic on global trade and the supply chain, the data supports the argument that the Covid-19 pandemic is a one-time shock with a projected uneven recovery across the globe. The ratio of gross exports to world GDP has fallen from a peak of 32% in 2008 to 29% in 2019. To put this in historical context, this ratio reflecting global trade integration is still 20% higher than it was in 2000. Having said that, the data does not support the assumption that, even in a worst-case scenario, the Covid-19 pandemic might reduce trade beyond the large reductions observed in 2020.[4] The OECD projections of the impact of the Covid-19 pandemic presented in its *Economic Outlook, Volume 2020 Issue 2* are reproduced in Table 1 below. While the impact in 2020 was substantial, most of the countries are recovering with China projected to grow substantially, accounting for over one-third of world economic growth in 2021.

[4] Penn World Tables 9.0; exports 1960–2019.

Table 1 - A gradual but uneven global recovery

OECD area, unless noted otherwise

	Average 2013-2019	2019	2020	2021	2022	2020 Q4	2021 Q4	2022 Q4
				Per cent				
Real GDP growth[1]								
World[2]	3.3	2.7	-4.2	4.2	3.7	-3.0	3.8	3.8
G20[2]	3.5	2.9	-3.8	4.7	3.7	-2.3	3.6	3.9
OECD[2]	2.2	1.6	-5.5	3.3	3.2	-5.1	3.7	2.9
United States	2.5	2.2	-3.7	3.2	3.5	-3.2	3.4	2.9
Euro area	1.8	1.3	-7.5	3.6	3.3	-7.3	4.7	2.9
Japan	0.9	0.7	-5.3	2.3	1.5	-3.2	2.0	1.5
Non-OECD[2]	4.3	3.6	-3.0	5.1	4.2	-1.2	3.8	4.5
China	6.8	6.1	1.8	8.0	4.9	5.4	4.1	5.4
India[3]	6.8	4.2	-9.9	7.9	4.8			
Brazil	-0.5	1.1	-6.0	2.6	2.2			
Unemployment rate[4]	6.5	5.4	7.2	7.4	6.9	7.2	7.3	6.6
Inflation[1,5]	1.7	1.9	1.5	1.4	1.6	1.2	1.5	1.7
Fiscal balance[6]	-3.2	-3.0	-11.5	-8.4	-5.7			
World real trade growth[1]	3.3	1.0	-10.3	3.9	4.4	-9.9	5.1	4.1

1. Percentage changes; last three columns show the change over a year earlier.
2. Moving nominal GDP weights, using purchasing power parities.
3. Fiscal year.
4. Per cent of labour force.
5. Private consumption deflator.
6. Per cent of GDP.

Source: OECD Economic Outlook 108 database. Table 1.1

The data on FDI stocks as a percentage of world GDP having nearly quadrupled since 1990, hit a new all-time high in 2019. With the Covid-19 pandemic, FDI flows to certain locations shrunk in 2020. At the same time, the data on multinational firms shows that some firms have continued to expand their foreign operations.[5] Despite the US-PRC trade dispute, it appears that there is far less interruption than one would expect. (Lardy and Huang, 2020)

Despite the expected recovery in 2021, 2022 and 2023, the Covid-19 pandemic has impacted a wide range of supply chains around the world in 2020. The first obvious reaction to the Covid-19 pandemic came from reduced revenue of developed country firms, which were major

[5] UNCTAD, *World Investment Report* (various editions) and International Monetary Fund, *World Economic Outlook* (various editions)

participants in the global supply chains. As developed market countries implemented lockdowns and factory shutdowns, demand from both upstream producers declined for the duration of the lockdown. If we add to this shock, reduced consumer spending and consumer confidence, developed country firms probably focused on selling stocks rather than newly produced products. Lower demand in virus-affected countries across the world shifted down the supply chain, affecting demand and production levels at each stage, even in areas not directly affected by the virus.

The impact of reduced demand varies across sectors (e.g. the demand for agricultural products, and pharmaceuticals will be less affected than for seasonal items) and the number of employees negatively affected are dependent on the degree of labor-intensive stages in the production process. (Nimmagadda, Reiners and Wood, 2019).

While overall demand declined in developed countries dependent on supply chains located in developing countries, certain highly sensitive sectors observed a push by their local governments to reach out to domestic firms to initiate import substitution. Movement in the pharmaceutical industry and in the production of agriculture are prime examples of the shift to import substitution.[6]

In addition to the impact on demand and on employment, both in the developed market economy buyers and the less developed market supply chain participants, the specific supply chain operations were further hampered due to logistical constraints as well as constraints in primary

[6] Sixteen electronics manufacturers have announced investment plans in India under New Delhi's ambitious production linked incentive (PLI) scheme to boost manufacturing. Foxconn is moving in next door to Salcomp as Pegatron announced a $150m investment for its new India unit. The $6bn, India's five-year scheme provides a short-term subsidy for goods made in India if the companies hit targets set by the government. The scheme is designed to make the cost of manufacturing more competitive with rivals China and Vietnam. "Manufacturers look to India to tap market and diversify supply chains," *Financial Times*. (accessed on 12/1/2020).

and intermediate suppliers' production and reliability.[7] In particular, the widespread measures relating to air traffic have virtually halted air cargo transport on a number of corridors, severely affecting products with a high value-to-sector in weight ratio as well as perishables (e.g. floriculture, consumer electronics etc.). [8]

Other forms of transport have also been constrained, as some governments have implemented measures preventing the export of strategic goods[9] , and shipping transport has been reduced as well.[10]

Clearly there are several general consequences of the Covid-19 pandemic on the supply chain. Firms in developing countries who are participating in the final stages of the supply chain usually can forecast reduction in demand better than those firms who are further up the supply chain, unless there is complete transparency of the induvial production functions by stage. Lacking that transparency, the local firms that are removed from the final demand, react to shifts in demand as if they were an unexpected shock. The risk-averse producer may either overproduce or underproduce, generating heavy production costs to handle the unexpected discrepancy.

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[7] The Covid-19 pandemic is playing havoc with Apple's production schedules. The US giant is expected to miss its schedule for mass producing a more affordable iPhone, while inventories for existing models could remain low until April or longer, according to this exclusive in the Nikkei Asian Review. Non-local workers at Foxconn's factory complex in Zhengzhou, where many iPhones are assembled, were told not to return to work following the outbreak. The complex employs 200,000 workers, many of whom come from outside Zhengzhou. "Apple suffers further supply chain setbacks in China" *Financial Times*. (accessed on 2/19/2020).

[8] Samsung has begun flying electronic components for its latest Galaxy phones from China to its factories in Vietnam as it grapples with sweeping supply chain disruptions caused by coronavirus. It has been reported that the Vietnamese government is restricting the daily transport volume from China to Vietnam through land routes, but it is relying on increasing parts supplies from China via planes. "Samsung flies phone parts to Vietnam after coronavirus hits supply chain," *Financial Times*. (accessed on 2/17/2020.

[9] International Trade Centre, 2020. COVID-19 Temporary Trade Measures, https://macmap.org/en/covid19 (accessed November 25, 2020). So far, some 97 countries have enacted export restrictions.

[10] Lines, B., 2020. "COVID-19 and its impact on container movements: Monitoring the impact of the coronavirus pandemic on the global container market", https://www.marinetraffic.com/blog/covid-19-and-its-impacton-container-movements/ (accessed November 25,2020).

While the negative impact on upstream operators in the supply chains is magnified in the literature, and viewed as shocks, even those firms that can see the impending drop in demand may not always be sufficiently flexible to be able to adjust to signs of reduced demand. Long supply chains involving many production steps with long cycle times, low inventories and significant vertical integration may face difficulties in adjusting when demand falls or individual links stop working, as individual producers have made significant upfront investments or may face difficulties in cooperating with new partners.

In some developing country production hubs, some supply chains were hampered by specific location constraints along with specific critical goods or services, in that hub which can create defenseless bottlenecks. An example from the PRC is found in the automotive industry, which was heavily affected by the initial outbreak of the Covid-19 pandemic in Wuhan, as several manufacturers sourced critical components from the affected area.[11]

Clearly, the Covid-19 pandemic had differing impacts on different supply chains, as well as within each individual supply chain. While the impact of demand reductions eventually affect all producers in the supply chain, the financial burden is unlikely to be shared equally by producers across the chain. Developing country supply chain producers have an incentive to protect their own operating revenue position through such measures as delayed payments to suppliers, increased efforts to collect customer payments and delayed investments - all designed to weather the pandemic storm. Clearly, the bargaining power of different producers in the chain is key in determining which supply chain partners will manage to avoid closure.

[11] Ewing, J., Boudette, N., and Abdul, G., 2020. "Virus Exposes Cracks in Carmakers' Chinese Supply Chains," February 4th, https://www.nytimes.com/2020/02/04/business/hyundai-south-koreacoronavirus.html (accessed November 25, 2020).

III. A Formal Algorithm of the Value-Added Supply Chain in International Trade

To better understand the tracking of international trade via value-added chains, we summarize the methodology applied by Koopman et. al. (2010) as it was implemented at the OECD-WTO-TVA data base. The starting point for the conceptual framework is the standard 2 x 2 model, where each country produces differential tradable goods (i) ranging from 1 to N in T sectors.[12] Tradable goods include final, intermediate and raw material goods. Countries can treat these products as direct consumer goods or as intermediate inputs. For the data base, it is assumed that each country exports both intermediate and final goods to the other.

In this framework, it is assumed that country ***j's*** output must be used as an intermediate good or a final good at home or abroad, or

$$X_j = A_{jj}X_j + A_{jk}X_k + Y_{jj} + Y_{jk} \qquad j,k = 1,2 \tag{1}$$

where X_j is the N×1 gross output vector of country ***j***, Y_{jk} is the N×1 final demand vector from country ***k*** for final goods produced in ***j***, and A_{jk} is the N×N IO coefficient matrix, giving intermediate use in ***k*** of goods produced in ***j***. The 2 x 2 production and trade relationship can be restated in matrix notation applied by the OECD-WTO-TVA:

$$\begin{bmatrix} X_1 \\ X_2 \end{bmatrix} = \begin{bmatrix} A_{11} & A_{12} \\ A_{21} & A_{22} \end{bmatrix} \begin{bmatrix} X_1 \\ X_2 \end{bmatrix} + \begin{bmatrix} Y_{11} & Y_{12} \\ Y_{21} & Y_{22} \end{bmatrix} \tag{2}$$

Rearranging terms, we have:

$$\begin{bmatrix} X_1 \\ X_2 \end{bmatrix} = \begin{bmatrix} I - A_{11} & -A_{12} \\ -A_{21} & I - A_{22} \end{bmatrix}^{-1} \begin{bmatrix} Y_{11} + Y_{12} \\ Y_{21} + Y_{22} \end{bmatrix} = \begin{bmatrix} B_{11} & B_{12} \\ B_{21} & B_{22} \end{bmatrix} \begin{bmatrix} Y_1 \\ Y_2 \end{bmatrix} \tag{3}$$

[12] The rationale for adding the T sectors is that while trade occurs across N possible goods, the IO table is limited to only T sectors.

where B_{kj} is the N×N Leontief inverse matrix, representing the total requirement matrix that gives the amount of gross output in producing country ***k*** required for a one-unit increase in final demand in country ***j***. Y_j is a 2N×1 vector that gives the global use of ***j's*** final goods. That is:

$$X = (I - A)^{-1} Y = BY \tag{4}$$

where X and Y are 2N×1 vectors, and A and B are 2N×2N matrices.

To decompose international trade into transactions in intermediate and final demands requires measuring domestic and foreign contents, first for production, and then for international trade. Let V_k be the 1×N direct value-added coefficient vector. Each element of Vs gives the share of direct domestic value added in total output. This is equal to one minus the intermediate input share from all countries (including domestically produced intermediates):

$$V_j \equiv u(I - \sum_k A_{kj}) \tag{5}$$

where u is a 1×N unity vector. One can consider V to be a 2×2N matrix of direct domestic value added for both countries:

$$V \equiv \begin{bmatrix} V_1 & 0 \\ 0 & V_2 \end{bmatrix} \tag{6}$$

The unique contribution of the OECD-WTO-TVA data base as explained by Koopman, (2010) is their creation of a "direct value-added share" (VAS) matrix by source:

$$VAS \equiv VB = \begin{bmatrix} V_1 B_{11} & V_1 B_{12} \\ V_2 B_{21} & V_2 B_{22} \end{bmatrix} \tag{7}$$

Within the VAS matrix, the individual elements represent domestic value-added share of domestically produced products in a particular sector at home. For example, V_2B_{21} denote the share of country 2's value-added in in a particular product. The first N columns in the VAS matrix

includes all value-added, domestic and foreign, needed to produce one additional unit of domestic products in country 1. The second N columns present value-added shares for production in country 2. This matrix is expanded to N x N countries. Because all value-added must be either domestic or foreign, the sum along each column is one:

$$V_1 B_{11} + V_2 B_{21} = V_1 B_{12} + V_2 B_{22} = u \tag{8}$$

In order to link the value-added shares to exports the OECD-WTO-TVA data base (Koopman et. al., 2010) denote E_{jk} to represent an N×1 vector of gross exports from *j* to *k*.

$$E_{j*} = \sum_{k \neq j} E_{jk} = \sum_{k} (A_{jk} X_k + Y_{jk}) \quad j.k = 1,2 \tag{9}$$

$$E = \begin{bmatrix} E_{1*} & 0 \\ 0 & E_{2*} \end{bmatrix} \tag{10}$$

and

$$\hat{E} = \begin{bmatrix} diag(E_{1*}) & 0 \\ 0 & diag(E_{2*}) \end{bmatrix} \tag{11}$$

where E is a 2N×2 matrix and $\hat{E}$ is a 2N×2N diagonal matrix.

Combining the value-added share matrix and an export matrix as weights produces a 2×2N matrix $VAS\_\hat{E}$ the sectoral measure of value-added share by source country:

$$VAS\_\hat{E} \equiv VB\hat{E} = \begin{bmatrix} V_1 B_{11} \hat{E}_1 & V_1 B_{12} \hat{E}_2 \\ V_2 B_{21} \hat{E}_1 & V_2 B_{22} \hat{E}_2 \end{bmatrix} \tag{12}$$

The elements of this matrix captures all upstream sectors' contributions to value added in a specific sector's exports. For example, for the famous Chinese iPhone case $VAS\_\hat{E}$ includes value added in the electronics component sector itself as well as value added in inputs from all

other sectors (such as glass, rubber, transportation, and design) used to produce the iPhone for exports by China.

Domestic and foreign content of exports and value-added exports are different concepts. Despite the fact that both concepts measure the value generated by factors employed in the producing country, domestic content of exports is independent of where that value is used. Value-added trade, on the other hand, depends on how a country's exports are used by importers. It is the value added generated by country 1 but absorbed by country 2. Consequently, the OECD-WTO-TVA data base (Koopman et. al., 2010) define related measures of domestic and foreign contents in sector level gross exports, not sector level value-added exports. Because the latter depends on who absorbs the value added it has to be defined in terms of final demand after zeroing its diagonal.

$$\hat{VAT} \equiv \hat{V}BY = \begin{bmatrix} \hat{V}_1 & 0 \\ 0 & \hat{V}_2 \end{bmatrix} \begin{bmatrix} B_{11} & B_{12} \\ B_{21} & B_{22} \end{bmatrix} \begin{bmatrix} Y_{11} & Y_{12} \\ Y_{21} & Y_{22} \end{bmatrix} \tag{13}$$

In equation (13), Y_{kj} is an N by 1 vector and Y is 2N by 2 final demand matrix. $\hat{V}_j$ is a N by N diagonal matrix with direct value-added coefficients along the diagonal. The resulting $\hat{VAT}$ is a 2N by 2 value-added production matrix, its diagonal elements represent each country's production of value added absorbed by itself while its off diagonal elements constitute the 2N by 2 bilateral value-added trade matrix. It excludes value added produced in the home country that returns home after processing abroad.

The aggregate (2×2) measure of value added by source in gross exports is given by:

$$VAS\_E \equiv VBE = \begin{bmatrix} V_1 B_{11} E_{1*} & V_1 B_{12} E_{2*} \\ V_2 B_{21} E_{1*} & V_2 B_{22} E_{2*} \end{bmatrix} \tag{14}$$

VAS_E represents the OECD-WTO-TVA data base's (Koopman et. al., 2010) the value added by source measure. Diagonal elements of VAS_E define the domestic value added in each

country's exports. Off-diagonal elements give the foreign value added embodied in each country's exports.

Gross exports are decomposed into foreign value added (FV) and domestic value added (DV) as follows:

$$DV = \begin{bmatrix} V_1 B_{11} E_{1*} \\ V_2 B_{22} E_{2*} \end{bmatrix} = \begin{bmatrix} V_1 (I - A_{11} - A_{12}(I - A_{22})^{-1} A_{21})^{-1} E_{1*} \\ V_2 (I - A_{22} - A_{21}(I - A_{11})^{-1} A_{12})^{-1} E_{2*} \end{bmatrix} \tag{15}$$

$$FV = \begin{bmatrix} V_2 B_{21} E_{1*} \\ V_1 B_{12} E_{2*} \end{bmatrix} = \begin{bmatrix} u(A_{21} - A_{12}(I - A_{22})^{-1} A_{21})(I - A_{11} - A_{12}(I - A_{22})^{-1} A_{21})^{-1} E_{1*} \\ u(A_{12} - A_{21}(I - A_{11})^{-1} A_{12})(I - A_{22} - A_{21}(I - A_{11})^{-1} A_{12})^{-1} E_{2*} \end{bmatrix} \tag{16}$$

The OECD-WTO-TVA data base (Koopman et. al., 2010) accounts for a country importing its own value added, which has been exported but returns home after being processed abroad. VAS_E attributes foreign and domestic contents to multiple countries when intermediate products cross borders in the N x N cases.

In the N x N cases, the OECD-WTO-TVA data base (Koopman et. al., 2010) provides all value-added components despite the various complications. Production, value-added shares, and sources of value added in gross exports are given by:

$$\begin{aligned} X &= (I - A)^{-1} Y = BY \\ VAS &= VB \\ VAS\_E &= VBE \end{aligned} \tag{17}$$

With N countries and N sectors, X and Y are NN×1 vectors; A and B are NN×NN matrices; V and VAS are N×NN matrices; E is a NN×N matrix; and VAS_E is a N×N matrix.

Summing over all trading partners for all goods, the OECD-WTO-TVA data base (Koopman et. al., 2010) provides the key decomposition equation that states that a country's gross exports to the world is the sum of the following five broad terms:

$$
\begin{aligned}
E_{j^*} &= DV_j + FV_j \\
&= V_j B_{jj} \sum_{k \neq j} Y_{jk} && \text{(a)} \\
&+ V_j B_{jj} \sum_{k \neq j} A_{jk} X_{kk} && \text{(b)} \\
&+ \mathrm{V}_j \, B_{jj} \sum_{k \neq j} \sum_{l \neq j,k} A_{jk} X_{kl} && \text{(c)} \\
&+ \mathrm{V}_j \, B_{jj} \sum_{k \neq j} A_{jk} X_{kj} && \text{(d)} \\
&+ FV_j && \text{(e)}
\end{aligned}
\qquad (18)
$$

where (Koopman et. al., 2010, p. 14) notes that (a) Domestic value added embodied in the exports of final goods and services absorbed by the importer; (b) Domestic value added embodied in exports of intermediate inputs used by the importer to produce its domestically needed products; (c) Domestic value added embodied in intermediate exports used by the importer to produce goods for third countries ("indirect value-added exports') (d) Domestic value added embodied in intermediate exports used by the importer to produce goods shipped back to the source country ("reflected domestic value added") and (e) Value added from foreign countries embodied in gross exports ("foreign value added used in exports").

Summing (a), (b), and (c) generates each country's value-added exports to the world. Summing (a), (b), (c), and (d) generates domestic content in a country's gross exports. As such, the OECD-WTO-TVA data base (Koopman et. al., 2010) captures only the direct effect and the first round of the indirect effect in the value chain stream. If the value-chain stream consists of multiple segmentations, then the only way to capture the full order of the decomposition is by

using information on domestic final demand in the importing country to obtain domestic value added embodied in the intermediate goods used by direct importers to produce domestically needed final goods. This estimate is the best that can be provided by this data set. In that case, one can obtain a full-order decomposition, using the five value-added components to account for 100% of the country's gross exports only when trade values are summed over all sectors and all trading partners (total exports to the world).

IV. An Empirical Approach to Measure the Impact of the Covid-19 Pandemic on the Supply Chain of a Single Firm in International Trade

In order to measure the impact of the Covid-19 pandemic on the supply chain of any developing country, we extract from the detailed presentation above and set up a partial equilibrium empirical approach for a single firm that has to decide on how to respond to a projected loss in profits as its supply chain gets interrupted.

Our interest is to break down the firm's total revenue into its basic component - the domestic value added (DVA). It is the actions of the domestic firm that participated in the supply chain that will determine how the Covid-19 pandemic will affect firm output and revenue.

We start with the accounting identity where total revenue (TR) consists of profits π_i, wages wL_i, cost of capital K_i, the cost other domestic intermediate factors of production adjusted by foreign content $P^D FI_i^D (1-\gamma^W)$, the cost of other international intermediate factors of production adjusted for domestic content $P^W FI_i^W (1-\gamma^D)$ where γ^D is the domestic share of factor inputs and γ^W is the foreign share of domestic inputs and FI stands for other factor inputs.

$$TR_i \equiv \pi_i + wL_i + rK_i + P^D FI_i^D (1-\gamma^W) + P^W FI_i^W (1-\gamma^D) \tag{19}$$

In order to simplify the elements that we are interested in, let us denote the foreign imported content in domestic intermediate factor inputs as ϕ^W, the domestic content in imported intermediate factor inputs as ϕ^D, purely domestic content intermediate factor inputs as λ^D and purely foreign content of intermediate factor inputs as λ^W.

This will allow us to rewrite

$P^D FI_i^D (1-\gamma^W) = \phi^D + \lambda^D$ and

$P^W FI_i^W (1-\gamma^D) = \phi^W + \lambda^W$

A firm's DVA in the supply chain network will therefore equal the sum of its profits, wages, rental costs of capital, and both direct and indirect domestic intermediate factors purchased.

$$DVA_i \equiv \pi_i + wL_i + rK_i + \lambda^D + \phi^D \tag{20}$$

The supply uncertainty as a risk factor due to the pandemic will appear in the foreign imported content in domestic intermediate factor inputs as ϕ^W and in the domestic content in imported intermediate factor inputs as ϕ^D. In a long run scenario, one would expect the domestic firm in the supply chain for sector *i* will look for either domestic alternatives or divert to a third country supplier of the imported factor input. However, in the short run, the firm's decision to look for alternative suppliers, either domestic or foreign will depend on the decisions impact on its profits. A more complicated production function would have many decision trees in the calculation.

Consider the following short run decision of a firm that carries insurance or a non-compliance clause in its purchase contract with an assigned penalty to cover the cost of non-performance by a supplier to deliver the contracted intermediate inputs. The firm can either start the search for alternative suppliers, resulting in an expected profit after all transaction costs are

internalized and non- compliance penalty paid $E(\pi)_i^A$ or to rely on the penalty for the non-performing supplier and continue to wait for compliance without initiating a search $E(\pi)_i^N$.

Let's assume that one decision outcome may be

$$E(\pi)_i^N < E(\pi)_i^A \quad (21)$$

The drivers in the firm's decision-making process revolve around two factors: first the size of the fine under the penalty clause (F) and second, the search cost for alternative suppliers (SC). Ignoring the search cost for now, we focus on the three options the firms face depending on the size of fine under the penalty clause.

	Fines	Expected Profit of the Mover (A)	Expected Profit of the non-Mover (N)
Option 1	$E(\pi)_i^N < E(\pi)_i^A < F_1$	0	π_i^N
Option 2	$F_2 < E(\pi)_i^N < E(\pi)_i^A$	$\pi_i^A - F_2$	F_2
Option 3	$E(\pi)_i^N \leq F_3 < E(\pi)_i^A$	$\pi_i^A - F_3$	F_3

Where

F_i = the specific penalty clause fine.

$E(\pi)_i^N$ = expected profit of non-mover.

$E(\pi)_i^A$ = expected profit of mover.

Under the first option, where the penalty clause fine is greater than the expected profit of the firm, considering alternative suppliers, the firm stops searching and relies on the fine. In the second case, where the fine is less than the expected profit of both the mover and non-mover, the mover will make a net profit [$\pi_i^A - F_2$]. The firm choosing to search will receive the fine, but it will not fully compensate it for expected losses. In the third case, where the fine is less than the expected

profits of the mover, the firm will receive a net profit of [$\pi_i^A - F_3$]. The expected profit of the non-mover will be the penalty clause fine.

Consider the second alternative situation where:

$$E(\pi)_i^A < E(\pi)_i^N \quad (22)$$

When expected profits of the mover are less than that of the non-mover, we can outline the probable outcomes based on the size of the fines.

	Fines	Expected Profit of the Mover (A)	Expected Profit of the non-Mover (N)
Option 1	$E(\pi)_i^A < E(\pi)_i^N < F_1$	0	π_i^N
Option 2	$F_2 < E(\pi)_i^A < E(\pi)_i^N$	$\pi_i^A - F_2$	F_2
Option 3	$E(\pi)_i^A \leq F_3 < E(\pi)_i^N$	0	π_i^N

Under the first option, where the fine is greater than the expected profit of both the firm choosing to stay in place and the firm that is looking for alternative suppliers, the expected profits for the mover will be zero, while that for the non-mover it will be [π_i^N]. In the second case, where the fine is less than the expected profit of both the mover and non-mover, the non-mover will get the fine, and the mover will get [$\pi_i^A - F_2$]. In the third case, where the fine is less than the expected profits of the non-mover, but greater than the mover, there is no need to search for alternative suppliers. The non-mover will receive its expected profits, [π_i^N].

In the cases outlined above, it should be obvious that the size of a fine under the penalty clause in a contract with the firm's intermediate factor suppliers must be set to equal the expected losses of non-compliance. In the short run, except for cases where suppliers have a "force majeure" exclusion in the contract, there appears to be little incentive to shop for alternative suppliers in the

global supply chain. The search for alternative suppliers starts when the short-run begins to look like the long-run. That has been the recent case of Vietnamese and Indian businesses trying to provide an alternative to the PRC supply chain suppliers.

V. Concluding Remarks

Globalization and its associated supply network accelerated in the 1990s, with the integration of the PRC into the world trading community, the reduction of tariffs and the development of efficient and low-cost ICT. With the new and more efficient digital age, the separation of production locations from management was complete. The rapid connectivity of the world economies led to the creation of increasingly complex production systems, and has also created the spread of new forms of economic risk, as well as benefits. To cover most of these risks, firms contracted fines to cover the cost of non-compliance in their supply chain contracts. Major airport hubs facilitate not only travel, but also supply logistics in a world production system. The success of globalization was operating under the assumption that all short run risks could be covered by insurance. The Covid-19 pandemic threatened this globalization paradigm, by highlighting the size of these new risks associated with the elaborate production systems, and forced many suppliers - including the PRC - to initiate “force majeure” in their contracts.

Many in the policy community argued that the Covid-19 pandemic would structurally change the global nature of international trade and kill globalization. This could not be further from the truth. What we have shown in our paper is that the Covid-19 pandemic will accelerate the growth and transformation of international trade, as multinational corporations look for alternatives to the PRC in their supply systems. The Covid-19 pandemic has highlighted the need to diversify sourcing, and this will further encourage cross-border flows from a widening range of

countries. The restructuring of trade to meet new demands and reflect new production methods, as well as risk management concerns, will not reverse globalization—it will transform it.

The methodology outlined in this paper provides a very reasonable approach of assessing the short-run decision making of firms participating in the global supply chain network.

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