Extraction-cum-substitution: A KISS approach to mapping the impacts of bilateral trade conflicts

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Contents

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EXTRACTION-CUM-SUBSTITUTION:
A KISS APPROACH TO MAPPING THE IMPACTS OF BILATERAL TRADE CONFLICTS

H. ESCAITH

1. Introduction

A new business model arose in the late 1980's, based on the geographical fragmentation of complex production processes. As a consequence, trade in intermediate parts, components and business services grew in importance, increasing economic interdependency within the World economy.

This paper presents a new approach that builds on input-output and trade analysis to derive plausible scenarios in the case of trade conflicts that could disrupt the international supply chains. The approach was developed following a *Keep It Super Simple* (KISS) design principle; the R program is available in annex. The method remains exploratory, it offers a series of "markers" corresponding to extreme or expected situations that should help mapping what remain largely unchartered waters: the direct and indirect effects of bilateral trade conflicts on global production networks. Despite its simplicity, it is able to reproduce several of the facts that were observed in previous trade conflicts involving two large economies. We show that it can also be used to generate "*in silico*" a large data set of numerical "observations" of the mode of insertion of countries and industries in the international market that can be further analysed using appropriate exploratory statistical techniques.

The paper counts with three parts, besides introduction and conclusion. The first one is theoretical, including a review of the literature and a formal exposition of the methodology, starting with a formal model of inter-industry trade before describing the empirical application to input-output analysis. The second part is didactic, applying the method to a small six-countries/three-industries model designed to mimic inter-industry interactions between hypothetical trade partners with different comparative advantages. The third part applies the methodology to the bilateral trade conflict that arose between China and the USA in 2018, using the WIOD database. It presents the spill-over effects on third countries through international supply chains and export restructuring. Applying exploratory data statistical analysis to the results obtained by simulating a large series of bilateral shocks, the paper shows how the method can also be used for generating analytical data and identify modes of insertion in the global economy.

2. Formal and Empirical Models

Global Value Chains (GVCs) changed the traditional way of analysing international trade and comparative/competitive advantages. Established trade theories struggled to adapt to a world where countries trade in intermediate inputs. Similarly, the spill-over effects of a bilateral trade conflicts affecting trade in intermediate goods are much more difficult to assess than what was previously understood in traditional models, when trade takes place in final goods.

1. Theoretical Model of GVC Trade

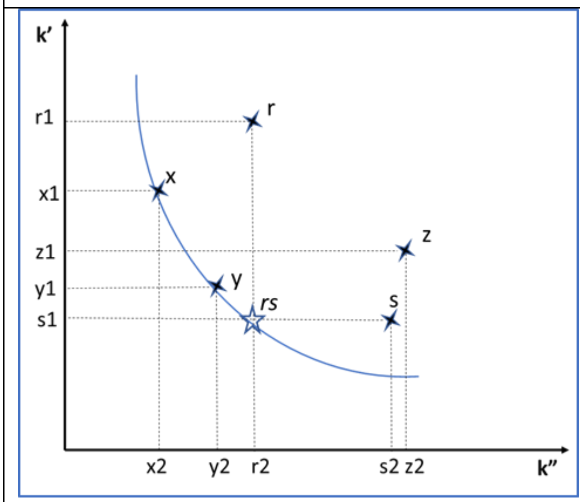
When firms belong to a geographically fragmented production network, what they actually export is not intermediate products —even if this is the visible trade flows that cross borders— but the value-added they are able to create and incorporate into these products. This is reason why this type of business-to business (B2B) exports is known by trade analysts as “trade in tasks” or “trade in value-added”. [2] Mapping and measuring this new type of trade in value-added has led to the definition of new empirical methodology. But it also required adapting the theoretical models that had been used to explain trade since the 19th century, because those models were not describing satisfactorily the logic of comparative advantages when trade in intermediate inputs is pervasive (Grossman and Rossi-Hansberg, 2006).

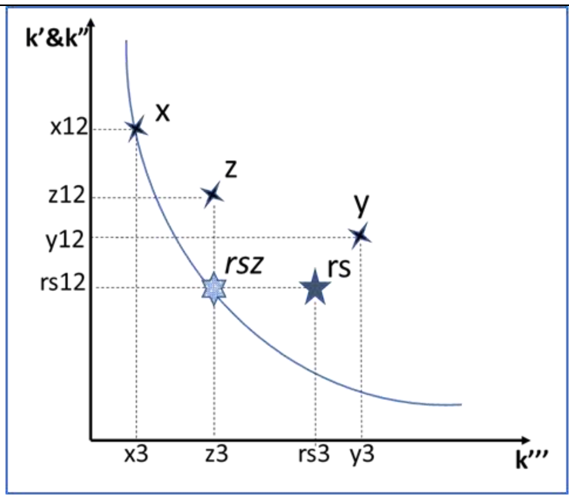
Indeed, in the traditional Ricardo or Heckscher-Ohlin models, comparative advantages are somewhat “natural” and come from the unequal distribution of primary production factors such as land, labour and capital. In a global value chain, what the lead-firm (the firm which is the main driver of the upstream supply chain and the down-stream sales to the final users) looks for is creating value by selecting the best suppliers of the required tasks –research and development, design, production, logistics and distribution—on a worldwide basis. In this process, comparative advantages from the lead-firm perspective are “created” instead of “natural”, because they may not correspond to the factor endowment of the lead-firm country.

An intuitive way of looking at the competitive gains through GVC is to borrow from Efficiency Frontier Analysis using Data Envelopment Analysis (DEA), a branch of Operational Research (see Cooper et al, 2011, for a review). At the difference of standard DEA, in this case the prices of non-tradable differ from country to country. Figure 1 shows on a diagram how two inefficient productors in two different countries can join forces and become internationally competitive. The diagram in panel (a) depicts the relative efficiency of five production units (*r, s, x, y, z*) located in different countries, and using two inputs to produce a variety of similar goods: the first input is produced with a technology k’ intensive in labour and the second one (based on k’’ technology) is intensive in technology. The *r* firm is located in country A while *s* is in country B. Other firms are located in various countries in the Rest of the World.

Figure 1 Gaining efficiency through production sharing

a. Gaining efficiency through production sharing	**b. Increasing the length of the supply chain**





Note: k’: use of intermediate input based on labour intensive technology to produce q_0; k”: use of capital-intensive input; k”’: use of natural resource intensive input.

[2] For historical reasons, many national accountants still use “trade in value-added” to refer to the origin of value-added embodied in final demand, rather than for measuring the value of domestic tasks embodied in exports.

Under frictionless free market, all physical inputs and outputs are priced the same, but firms face different labour wage rates $\boldsymbol{w}$. An additional hypothesis is that, following the Balassa–Samuelson effect, the higher the technological level of the country, the higher the unit cost of labour. In other words, advanced industrial countries pay higher wages than developing and emerging countries.

The isoquant shows the minimum combination of inputs to produce a given quantity of good q_0 (we look here at a mix of technical efficiency and allocative (price) efficiency through the minimization of the value of inputs used for producing a fixed level of output). In a traditional Efficiency Frontier Analysis, the isocost line would be a straight line, because the unit cost of input produced by k' and k" would be the same for all firms. In our case, the isocost line is curved and blends with an isoquant because the price of labour is supposed to be inversely proportional to the technology level attained by countries. For the sake of simplicity, we assume that all firms that are technically efficient are also price efficient (overall efficiency).

Out of the five firms in panel a of Figure 1, two (*x, y*) are on the isoquant and are competitive at world price. Other three firms (*r, s, z*) are away from the curve and inefficient for this production technique. Yet, *r* inefficiency relates only to its use of input produced using k' technology (a "slack" in Frontier Analysis), while *s* is inefficient mainly for input of the k" type. The comparison of slacks is clearer when we measure it as the "city block" metric, i.e. the sum of the horizontal and the vertical segments from *r* or *s* to the isoquant. If it is possible to separate the production of intermediate inputs of type k' and k" in two separate steps, then unbundling the production of q_0 in two components allows *r* to specialise in the production of the components intensive in input of k" type, while *s* specialises in the tasks that are labour intensive (technology k').

Because slacks are independent of each other by construction of the data envelopment technique defining the efficiency frontier, the unbundling maintains the efficiency of each firm for each zero-slack input (*s*1 and *r*2) and creates a new virtual firm *rs* that is now cost efficient and located on the isoquant.[3] Production of the final good *q* will be physically located in *s*, the country efficient in the labour-intensive inputs (labour being not tradable).

On the other hand, inefficient firm *z* cannot use the GVC business model, due to its relative inefficiency in the use of both inputs (panel a). But a production technique requires many different inputs, and *z* may be efficient in the use of another component required for producing q_0. In panel b, the vertical axis is now a projection of the isoquant in panel a, and represents the mix of efficient use of inputs of k' and k" type (note that the origin of the axis is not 0 anymore but the horizontal asymptote of the isoquant in panel a). The horizontal axis represents another type of inputs, for example one that requires a technology k''' that is intensive in natural resources. Only one firm, *x*, is on the new isoquant, when all three inputs are taken into consideration. But the joint-venture *rs* can now become cost-competitive by incorporating *z* into the value-chain, sharing production in order to move to the new production unit *rsz*, on

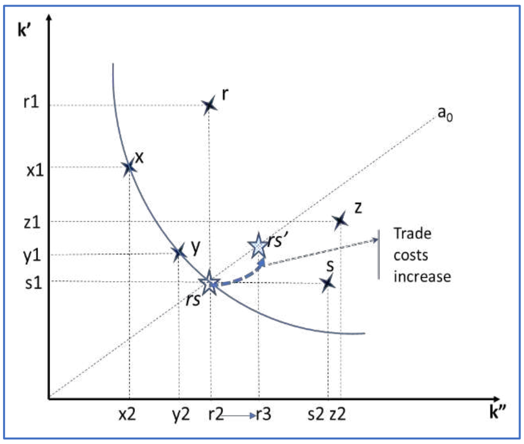
[3] Input slacks are the input reduction required to reach efficiency. They are associated with the constraints associated with the optimal solution of the input minimization linear program used to define the efficiency frontier in DEA. These constraints are mutually independent in the optimization model.

the isoquant. Production of the final good q will remain located in the country of *s*, the country with the efficient use of the labour-intensive input.

What happens when bilateral trade costs between r and s increase, due to the imposition of prohibitive trade barriers between country A and country B? The world price of the final good q_0 does not change because it is efficiently produced by *x* and can be freely imported by *s* and *r* countries. But the initial joint-venture between *r* and *s* is no more cost-efficient, as pictured in Figure 2. Due to bilateral trade barriers, the cost of delivering *r* intermediate inputs to s increases, and *r* cost-efficiency moves from r2 to r3. Because of the trade barriers, the cost of producing the bundled q_0 goods for the joint-venture moves away from the origin and the isoquant, along the line a_0. At *rs'*, the joint-venture is no more competitive and the GVC arrangements breaks-up, causing mutual damages to both *r* and *s*.

The disruption will also affect firm *z*. This is a spill-over effect of the trade conflict between the countries where r and s are located. Due to this bilateral trade conflict, the *rsz* joint-venture is no more profitable at international process and exits the market. Only one firm (*x*) remains competitive at free trade final good price. [4]

Figure 2 Losing GVC efficiency due to trade barriers



Note: see Figure 1

This bilateral trade conflict diverts trade patterns away from their comparative advantages in value-added and impedes the specialization in tasks that was beneficial for the three countries involved.

What happens if A initiated the trade conflict and *r*, the lead-firm located in country A, used to re-import the finished product assembled by *s* for sales on its home market or exports it to third markets? Disrupting the *rs* supply-chain increases the cost for *r* of procuring intermediate inputs and lowers its competitiveness on both its home and export markets (the case analysed in Figure 2). The unexpected end-result may be for *r* to exit this market if the related increase in production costs turns the production unprofitable at current world prices. So, if the origin of the trade conflict between A and B was the shift of labour from country A to country B, because the *s* firm located in B is more competitive in the labour-

[4] This discussion applies only when the surge in trade costs is bilateral and does not affect the price of the final good. If A wants to raise the Home market price of the imported final good irrespective of its origin, country A needs to raise trade costs with all trade partners. Firm r would then be able to compete with its foreign competitors, but will be profitable only at the inflated price in its Home market. We recognise here the anti-export bias of trade costs and protectionist policies, see Escaith (2017) for an analysis when GVC trade is prevalent.

intensive intermediate input, the end result of the trade war may be worst for A than the GVC option: A will also lose the *r* jobs that were related to production of the capital-intensive intermediate input produced by *r* for the *rs* joint-venture.

This is not a purely theoretical outcome: estimating the outcome of the NAFTA demise, Walmsley and Minor (2017) show, using CGE models, that the US automotive industry –the same one which was expected to be protected from the competition of other NAFTA producers– could suffer from negative side effects. The production of light passenger cars would be reduced due to the loss of competitively priced parts imported from Mexico and the resulting decline in the competitiveness of US producers on export markets.

A formal treatment of this can be derived from Shiozawa (2007) and Shiozawa and Fujimoto (2018), who push forward the reinterpretation of the Ricardian model away from the general equilibrium strand, adding micro-foundations that can be traced to the work of Sraffa (1960). Looking for an optimal trade and production pattern from the supply side of the economy, they define for each country the domain of (i) technically feasible and (ii) comparatively efficient with respect to other trade partners' production functions.

Their Neo-Ricardian model and its cost-of-production based theory is also particularly relevant for our empirical research on trade in value-added, because it has an almost one-for-one counterpart with International Input-Output modelling. In input-output modelling, the final demand side is also considered exogenous to the model and the focus of attention is on the supply-side, in particular on the role of inter-industry linkages, as described in Figure 3.

Figure 3 International Input-Output matrix

Outputs / Inputs		Intermediate Use				Final Demand				Total Output
		1	2	…	M=kxn	1	2		M	
Intermediate Inputs	1	Z^{11}	Z^{12}	…	Z^{1m}	Y^{11}	Y^{12}	…	Y^{1m}	X^{1}
	2	Z^{21}	Z^{22}	…	Z^{2m}	Y^{21}	Y^{22}	…	Y^{2m}	X^{2}
	…	…	…	…	…	…	…	…	…	
	M	Z^{m1}	Z^{m2}	…	Z^{mm}	Y^{m1}	Y^{m2}	…	Y^{mm}	X^{m}
Value-added		$(VA^{1})'$	$(VA^{2})'$	…	$(VA^{m})'$					
Total output		$(X^{1})'$	$(X^{2})'$	…	$(X^{m})'$					

Notes: $\boldsymbol{Z}^{sr}$ is an $k{\times}k$ matrix of intermediate input flows that are produced in country *s* and used in country *r,* k being the number of activity sectors (goods and services) and n the number of countries; $\boldsymbol{Y}^{sr}$ is an k×1 vector giving final products produced in country *s* and consumed in country *r*; $\boldsymbol{X}^{s}$ is also an *k*×1 vector giving gross outputs in country *s*; and $\boldsymbol{VA}^{s}$ denotes an *k*×1 vector of direct value added in country *s*.
Source: Adapted from Wang, Wei and Zhu (2013)

Formulated from an international perspective, there are N countries and K traded products, each product being identified with one industry. Following the notation in Shiozawa (2017) as much as possible, the formal model can be written as: [5]

$\mathbf{p} = (1+r)\,[(\mathbf{w}.\mathbf{a}0) + \mathbf{A}\,\mathbf{p}]$ Equation 1

With

p: the price vector (of dimension K, K being the number of products/industries)
r: rate of net profit, assumed to be identical across industries and countries.
w: vector of countries' wage rates
a0: vector of labour input coefficients
A: the matrix of intermediate input coefficients for one unit of the corresponding output X_j, in quantity.

Under the usual conditions of $(\mathbf{I}-\mathbf{A})^{-1}$ existence in input-output analysis, this equation can be written:

$\mathbf{p} = \mathbf{w}\,(1+r)\,\mathbf{a}0\,[\mathbf{I} - (1+r)\mathbf{A}]^{-1}$ Equation 2

Equation [2] relates the real rates of profit and wage in a long-term situation where the economy is at full capacity and budgetary constraints are binding (consumption must be paid out of wages and gross investment out of savings). [6] In the tradition of mark-up pricing, the factory-gate price is fixed by multiplying the full production cost (including wages) by a pre-determined rate, or mark-up. In a situation of frictionless trade, the price of a traded product is equal across countries.

Labour within each country is assumed homogeneous, but may differ across countries; there is no international movement of labour forces. The wage rate for country "k" is uniform across industries and denoted w_k. There are H different possible techniques. [7] A good can be produced by different processes/countries. The set of all production techniques applied to all (traded) goods is H x N. The essential point when technologies are widely available, as it is the case in today's globalised world, is the large difference of wage rates between countries.

This is an important feature when considering the issue from the "*new*" new trade theory that puts the emphasis on firms and not on countries. In agreement with this perspective, it is wrong to state that "GVCs involve several countries, where each economy has specialization in a stage of the production process" because countries do not actually trade, firms do. But countries have different wage rates for similar levels of skills, and –excluding trade costs and disparities in hard and soft infrastructure– this difference explains trade in tasks specialization in modern manufacturing supply chains.

The productive capacity of any country is determined by the quantity of labour and the set of feasible production techniques. Given these technology sets, there exists an international value where all firms

[5] This section draws on Escaith and Miroudot (2016). It is based on reduced-form input-output models and differs from other theoretical models, as in Shiozawa (2017), where each country exports a distinct variety of K products, leading to a total of N.K differentiated commodities.
[6] Note that this inequality also holds when applying the analysis to an input-output framework. It becomes an identity when all income sources (wages and gross profit) are taken into consideration.
[7] In a neo-classic approach "à la Armington", the differencing factors is not technology but goods produced by different countries and that are inherently imperfect substitutes by virtue of their provenance.

are (1) producing with the best production technique and (2) purchasing input products from the least cost providers (including price and trade costs).[8]

For example, let's consider two countries, A and B, and one product q. If trade takes place at no cost, the price of the two traded goods is the same in both countries. For one unit of output for product q, the material input coefficients for country A are $\mathbf{a}_+(\mathbf{k}^A)$ and the labour inputs $\mathbf{a}_0(\mathbf{k}^A)$. If $\mathbf{k}^A$ is superior to $\mathbf{k}^B$ for a given international value vector $\mathbf{v} = (\mathbf{w}, \mathbf{p})$, the following inequality holds:

$$\mathbf{a}_0(\mathbf{k}^A)\, w(A) + (\mathbf{a}_+(\mathbf{k}^A)\, , \mathbf{p}) < \mathbf{a}_0(\mathbf{k}^B)\, w(B) + (\mathbf{a}_+(\mathbf{k}^B)\, , \mathbf{p}) \qquad \text{Equation 3}$$

If the possible set of production techniques are similar in A and B —a common feature of GVC where technology and know-how is directly or indirectly shared between GVC participating firms— the difference in competitiveness arises because of higher workers' productivity in A at the existing wage structure.

$$\mathbf{a}_0(\mathbf{k}^A)\, w(A) < \mathbf{a}_0(\mathbf{k}^B)\, w(B) \qquad \text{Equation 4}$$

$$w(A) / w(B) < \mathbf{a}_0(\mathbf{k}^B) / \mathbf{a}_0(\mathbf{k}^A) \qquad \text{Equation 5}$$

In order to mimic more precisely the inter-industry nature of GVC, Escaith and Miroudot (2016) split the production of good q into two production steps. Each of these two steps is operated a level y(**k'**) and y(**k''**) and are part of subsets $\mathbf{k}^A$ and $\mathbf{k}^B$. **k'** and **k''** are producing complementary intermediate inputs that are not substitutable. For example, y(**k'**) produces the body of a car, and y(**k''**) the engine. **k'** is labour intensive, **k''** is technology intensive.

As long as Equation 6 holds for both **k'** and **k''**, the car is produced entirely in country A. But if the relative productivities and/or wages change in such a way that:

(i) $\mathbf{a}_0(\mathbf{k}'^A)\, w(A) > \mathbf{a}_0(\mathbf{k}'^B)\, w(B)$

(ii) $\mathbf{a}_0(\mathbf{k}''^A)\, w(A) < \mathbf{a}_0(\mathbf{k}''^B)\, w(B)$ Equation 7

Then (discounting trade costs), it will be profitable for A to outsource to B the part of its production corresponding to y(**k'**).

Thus, a steep addition to bilateral trade costs reduces not only the competitiveness of the targeted country, but will also negatively affect the protected industry and raises, in relative term, the competitiveness of its foreign competitors. The net effect for the A country industry that was supposed to be protected by the high trade barriers may be negative if it faces competition from third countries on its home and export markets. This is the same result obtained graphically in Figure 2.

It is therefore particularly relevant, at the moment of analysing the effects of raising the bilateral trade barriers in a GVC context, to look at (i) the shares of bilateral trade in intermediary goods vs. final ones, and (ii) the relevance of exports for the home industry. Bosker and Westbrock (2018) provide a formal treatment of this ambivalent result on vertically specialised firms in the more general case of a multilateral reduction of trade costs. They show that the exposure differs when firms are further up- or downstream in the global production network. The aim of the extraction-cum-substitution method is to map more precisely these side effects.

[8] For a proof, see Shiozawa and Fujimoto (2018) Theorems 6.1 and 6.2.

2. Hypothetical Extraction with Substitution and Trade in Value-Added

The empirical method builds on two interrelated strands of research, both of them based on input-output models. The first one is the "Extraction Method", which has been used in national and regional input-output analysis to identify the most relevant sectors or regions. Miller and Lahr (2001) provide a review of the different approaches under this method; Dietzenbacher and Lahr (2013) generalize the approach. We will return to this approach after presenting the main tenets of the analysis of trade in value-added.

- Measuring trade in value-added

This strand of empirical research is directly associated to the analysis of trade along Global Value Chains (GVCs), also known as "Trade in Value-Added". It is closely associated with new dimensions in trade statistics, following the concept of Vertical Specialization. Balassa (1967) defined Vertical Specialization as the production process of a commodity when it is divided into a vertical trade chain, each country adding value at each stage of the production process. Hummels, Ishii and Yi (2001) extend Balassa's concept and propose a measurement method based on national input-output tables. In their seminal contribution, they split gross exports between a share of domestically produced inputs and a share of imported ones. Daudin, Rifflart and Schweisguth (2009) apply this new line of trade analysis to international input-output models.

The first application using official data was published in 2011 by WTO and IDE-JETRO, with an application on Eastern Asia. It is also the guiding methodology used by the Trade in Value-Added (TiVA) database (OECD-WTO, 2012). Jones, Demirkaya and Bethmann (2019) provide a comprehensive review of the applications of this concept to trade analysis in the business and economics literature.

The value-added decomposition of trade starts with the so-called Leontief model:

$$\mathbf{X} = \mathbf{A}.\mathbf{X} + \mathbf{Y} \qquad \text{Equation 8}$$

where:

X: is an n.k*1 vector of the output of k industries within an economy of n countries.
A: is the n.k*n.k matrix of technical coefficients describing the interrelationships between industries; with a_{ij} the ratio of inputs from domestic industry i used in the output of industry j. [9]
Y: is an n.k*1 vector of final demand for domestically produced goods and services, including exports.

The contribution of exports to the country's GDP is equal to:

$$\mathbf{v}.(\mathbf{I}-\mathbf{A})^{-1}.\mathbf{e} \qquad \text{Equation 9}$$

where:

v: is a 1 x n.k vector components m_j (ratio of value-added to output in industry j)
I: is an n.k x n.k identity matrix.
e: is a n.k x 1 vector of gross exports by industry.

This "Leontief decomposition" approach has been further refined by Koopman, Powers, Wang and Wei (2011) who decompose GVC trade into several trade in value-added indicators. Pursuing this line of

[9] Matrix and vectors will appear in bold character in the paper.

work, Wang, Wei and Zhu (2013) (WWZ from now) extend the information contained in inter-country input-output tables to decompose GVC trade and derive additional indicators. [10]

The domestic value-added or GDP in each country/sector pair is generated from the following three types of production activities:

(1) Production of domestically produced and consumed value-added

(2) Production of value-added embodied in final product exports

(3) Production of value-added embodied in exports of intermediate goods and services. WWZ further splits this value-added into three additional categories: (a) Directly absorbed by partner country *r* without further border crossing; (b) Returned (re-imported) to exporting country *s* and finally consumed domestically; and (c) Indirectly absorbed by partner country *r or* re-exported to a third country *t*.

We use both the Leontief and the WWZ decomposition implemented in Quast and Kummritz (2015) for mapping the pre-crisis trade in value-added, then use extractions and simulations for building successive scenarios.

- Extractions and simulations

A recent paper by Los and Timmer (2018) shows that these new "Trade in VA" measures can be also derived with the method of hypothetical extraction in a general input-output model. Their starting point is the inter-country input-output model presented in Figure 3. In the traditional hypothetical extraction method, one deletes the industry that is analysed in the actual input-output matrix (Dietzenbacher and Lahr, 2013). This is simply done by setting to 0 its row or column in the input-output matrix and in the final demand vector. A new Leontief model is constructed. The difference between the initial and the modified models indicates the importance of the industry for the entire economy (a country in traditional input-output analysis, or the world economy in the present case).

In their application to the measure of trade in value-added applied to an intercountry model, Los and Timmer (2018) do not extract entire industries from the system, but only some transactions. So, only part of the line or column is set to 0, indicating trade to or from a specific set of industries belonging to a specified country.

For example, imagine we want to know the importance of Chinese value chains exporting to the USA. If China is country 1 in Figure 3and the USA is country 2, Los and Timmer (2018) suggest to set to 0 all the elements in **A** corresponding to Z_m^{12} as well as the output of industry "m" imported by country "2" for its final demand ($\mathbf{Y}_m^{12}$).

A new GDP for country 1 is calculated:

$$GDP_1^{*2} = \mathbf{v}_1^{*2}.(\mathbf{I}-\mathbf{A}_1^{*2})^{-1}.\ \mathbf{Y}_1^{2*}\ .\ \mathbf{i} \qquad \text{Equation 10}$$

Where:

$\mathbf{v}_1^*$ is the n.k vector as in Equation 9 with all elements not corresponding to the extracted country set to 0;

[10] The calculus behind the WWZ decomposition is too complex to be exposed here and we refer the interested reader to the original papers.

A_1^{*2} and Y_1^{*2} are the matrices of technical coefficients and final demand after extraction of exports of product "m" from country "1" to country "2";
i: is the summation vector of dimension n.m (all elements are equal to 1)

The difference between the actual GDP_1 value of "1" and GDP_1^{*2} gives the value-added created by "1" and consumed by "2" for industry "m".

$$VAXD_{1,2}^{m} = GDP_1 - GDP_1^{*2} \qquad \text{Equation 11}$$

VAXD is also known in Trade in Value-Added analysis as the indicator of the value-added embodied into exports. It is one of the indicators calculated by Wang, Wei and Zhu (2013) but using another decomposition method.

In commenting their approach, Los and Timmer (2018) state page 10 something that is of upmost importance for the present paper: "*We would like to emphasize that* GDP_r^{*s} *should not be seen as the GDP level that would result if exports to s would be prohibitive. In a general setting with more flexible production and demand functions, substitution effects will occur. As a consequence, the total production structure and final demand levels will change and the global production structure after the shock will not be represented by* $\boldsymbol{A_s}^*$ *and* $\boldsymbol{Y_s}^{r*}$. $VAXD_{rs}$ *should therefore be regarded as an upper limit of the loss in* GDP_r^* *and is most meaningful if compared to other scenarios of extracted transactions*".

Our approach builds on their suggestions: not only do we extract some transactions (those affected by the bilateral trade conflict), but we also contemplate for the replacement of extracted outputs. [11] In our simulations, we will let other industries seize the business opportunity created by the withdrawal of a competitor and fill the gap opened by the exit firms. The extracted inputs will be replaced by a mix of domestic and imported inputs. The substitutive trade flows will follow a standard gravity equation reflecting the parameters of the pre-crisis situation, in particular that trade frictions with other trade partners are unaffected by the bilateral trade conflict. [12]

As in Los and Timmer (2018) example and using the notation in Figure 3, extraction means we first set to 0 all the elements in **A** corresponding to Z_m^{12} as well as the output of industry "m" produced by 1 and imported by country "2" for its final demand ($\mathbf{Y}_m^{12}$) in Figure 3. In the case of final demand (the same reasoning applies to intermediate products), the bilateral flows of products "m" exported by country "i" to country "j" respect the following gravity equation:

$$Y_m^{ij} = \frac{X_m^{i.} X_m^{.j}}{X_m^{..} d_{ij}^2} \qquad \text{Equation 12}$$

where Y_m^{ij} are exports of m from *i* to *j*, $X_m^{i.}$ is *i*'s economic size from the "m" supply-side perspective (the mass of m products supplied at origin *i)*, $X_m^{.j}$ is *j*'s market size (the mass of products *m* demanded at destination *j*). At world level, total supply of *m* equals total demand and is noted $X_m^{..}$; d_{ij} is the economic distance between *i* and *j* (a measure of the bilateral trade frictions that impede pure free trade).

[11] This suppose a deviation from the traditional Leontief production functions, which do not contemplate substitution and suppose that inputs (intermediate and primary) are complementary. A radical interpretation of this strict complementation means that an extraction is disruptive. Computable general equilibrium models, at the contrary, do contemplate substitution effects.

[12] This hypothesis assumes that bilateral distances are mutually independent, a traditional assumption in gravity modelling that has been challenged by Anderson and Wincoop (2003).

What happens when an industry producing *m* in country *s* is excluded from exporting to country *r*? The relative sizes of all other producers for this specific market are artificially increased because *s* has to withdraw from the competition. From the specific viewpoint of the competition on the *r* market, it is "*as if*" $X_{\ddot{m}}^{s.}$ had been extracted from the World competition $X_{\ddot{m}}$. The new gravity equation for this specific market is:

$$\mathrm{Y'}_{\mathrm{m}}^{\mathrm{ir}} = \frac{\mathrm{X}_{\mathrm{m}}^{\mathrm{i.}}\mathrm{X}_{\mathrm{m}}^{\mathrm{.r}}}{\mathrm{X'}_{\ddot{\mathrm{m}}}\,d_{\mathrm{ij}}^{2}} \qquad \text{Equation 13}$$

For all i ≠ s ; with $X'_{\ddot{m}} = (X_{\ddot{m}} - X_{\ddot{m}}^{s.})$.

And $\mathrm{Y'}_{\mathrm{m}}^{\mathrm{sr}} = 0$ due to extraction.

Keeping *r* final demand $X_{\ddot{m}}^{.r}$ and d_{ij} constant by hypothesis, the ratio between the new sales from country i ≠ s to country *r* and the previous ones is, after a few substitutions:

$$\frac{\mathrm{Y'}_{\mathrm{m}}{}^{\mathrm{i}}}{\mathrm{Y}_{\mathrm{m}}{}^{\mathrm{i}}} = \mathrm{X}_{\ddot{\mathrm{m}}}/\mathrm{X'}_{\ddot{\mathrm{m}}} \qquad \text{Equation 14}$$

After extraction and substitution, (*i*) the exports of *s* to *r* drop to 0; (*ii*) the sales of all other countries --including *r* itself-- already present on the *r* market increase and (*iii*) the ratio of the new market shares between these countries remains similar to their pre-extraction ratio (See Annex for further discussion).

The methodology simulates a situation where industries and consumers resume business-as-usual, attempting to follow previous trade patterns as closely as possible. At the difference of Computable General Equilibrium models (CGE), the substitution does not result from a complex optimization process but uses all the information contained in the input-output matrix. The additional sales are reassigned in proportion of the existing market shares before the extraction. Actually, the simulation is more akin to analysing a shock to the general equilibrium described by input-output data from a partial equilibrium point of view. [13]

While the philosophy of the KISS exercise is avoiding changes in prices in order to keep demand in line with the equilibrium situation as long as possible, we make a short-term exception. Substituting inputs at short notice may imply a higher price for procuring the additional products, since shifting to new suppliers may be costly. The rise in prices for the additional supplies produced in addition to the previous requirement is probably not permanent. When the supply chain leaders renegotiate their long-term procurement contracts with their suppliers, we expect them to ask for the same price for all the inputs supplied. Thus, after some time, input prices should return to their initial situation. The short-term case is illustrative of the negative feed-back on the industries that were supposed to be protected by the high trade barriers: the increase in procurement cost reduces their competitiveness and may induce a severe blow on the profitability of the most exposed ones. [14]

[13] From an economic perspective, the *ex-ante* situation was the product of a general equilibrium and the existing market share represented the relative competitive advantages of the various countries on the extracted market. Reassigning the market shares in proportion of the previous equilibrium means simply the relative competitiveness of the non-extracted industries and the impact of trade frictions as specified in a standard gravity model have remained the same, under a *ceteris paribus* assumption.

[14] Perhaps forcing them to exit if the loss in price competitiveness is irreversible. The present method cannot properly model the price effects on market shares. It is one of its limitations compared to CGE modelling.

This is not the end of the story. The firms affected by the extraction of some of their markets will try to redeploy its production to other markets. This “export restructuring” in the face of trade conflict is known as “deflection” in the trade literature. In order to exclude a situation of dumping that would affect final prices (and demand, which is supposed to remain constant in this phase), we will consider that extracted industries will redeploy the lost output to other markets by marketing more aggressively their products. The previous suppliers will be displaced in proportion of their previous market shares, but prices will not be affected.

It may not be possible for the extracted industry to redeploy all the lost sales to other markets, because its competitors will defend their market share. Thus, redeployment will probably apply to a smaller share of the lost sales. In absence of any additional information on the degree of substitutability of the respective product, we will consider three scenarios. Two of them are extreme solutions: zero or full substitution.

The third is a mixed one where only half of the lost production can be redeployed to other markets. This simple solution is also, from a statistical perspective, the “expected value” of the redeployed share when no prior information is available, as long as the probability distribution of the possible outcomes is symmetric. If, in addition, the distribution is unimodal (a traditional hypothesis in statistics), then the expected value is also the most probable.

These scenarios translate into the following simulation sequence when considering that the trade war between country “A” and “B” is initiated by “A” and affect some industrial product “q”:

1. The first stage extracts B’ exports of the targeted industry to A for intermediate and final goods. This step is similar to traditional extraction without replacement.
2. In a second stage, other countries substitute exports of “B” to “A” for both Intermediate and Final Goods but the additional sales of intermediate goods take place at a higher price (the price of final goods remains the same in order to keep Final Demand constant through all the scenarios). The corresponding technical coefficients for the industries in country “A” that have to substitute for the inputs originating from “B” are now larger and the rate of value-added is smaller.[15]
3. With the passing of time, the higher procurement cost disappears and the competitors of “B” supply their intermediate products to “A” at the pre-crisis prices. The rate of value-added of the industries in “A” returns to it pre-crisis situation.
4. Country “B” aggressively markets its product to third countries in order to compensate for the market losses in “A”, without changing the price of its intermediate and final products. There is no change in the volume and structure of final demand. This scenario has two variants:
    a. Partial substitution: only 50% of the losses can be redeployed. This variant corresponds to the expected value, from a statistical perspective.
    b. Full substitution: all sales are redeployed, if feasible. [16]

[15] By construction, the price of the products “m” sold to final consumers do not change: Value Added in the industries “2” need to be reduced in proportion of the higher procurement cost, in order to keep the price of the output unchanged. Here again, we remain in a partial equilibrium approach where only inter-industry trade is affected, other things remaining constant.
[16] If the extracted industry is dominant on a given market and its competitors have little market share, it may not be possible to fulfil the redeployment target, even after taking 100% of the competitors’ market share.

Except for the short-run scenario, the simulation does not change the prices nor the rate of value-added. The substitution does affect the geographical origin of purchases for both intermediate and final products and the monetary value of sectoral trade and value added will be affected in relation to the variations in sales and output. So will be GDP and employment. We mentioned when commenting Table 8 above that the total value of final demand remained constant by construction and only its distribution was affected by the process of extraction-cum-substitution and redeployment. This is obviously an over-simplification as income, measured through the GDP, does not remain constant. But keeping final demand constant has the merit from an exploratory mapping perspective of isolating the trade effects from other considerations. And this mapping was the main objective of our simulation exercise.

Yet, let's go one step further and look at final demand.

5. Final Demand adjusts to changes in GDP. A new vector of Final Demand is calculated applying an income elasticity of 1, meaning that countries' Final Demand varies in direct proportion of the change in their GDP, then the model is re-estimated. The simplifying hypothesis of a constant unitary income-elasticity of demand for all categories of goods and services is consistent to the KISS modelling option. It corresponds no prior information in a Bayesian inference perspective. It is obviously an over-simplification as the income-elasticity of demand varies according to products but also to per capita income levels (the so-called Engel's Law).

The procedure stops here, even if this is only the first stage of an iterative process: in truth, each change in the final demand **Y** does induce a new change in output **X** via the Leontief model in Equation 8, which in turn modifies GDP and final demand, and so on and so forth until a convergence is reached. To keep with our favoured KISS approach, we do not model this convergence and stop at estimating the first step, using the expected scenario corresponding to the mean value of substitution.

The extraction-cum-substitution method is exploratory in nature, it is both its strength and its limitation. As mentioned in footnote 14, our substitutions cannot properly reflect the effects of prices on demand. If the straightforward nature of the methodology allows to progress step by step in the implementation of the model and generate relevant analytical data, there are also limitations in its use.

3. Uses and limitations of the method

This heuristic method is purely exploratory. It aims at revealing inter-industrial trade structures that would not be easily identified using standard input-output or network analysis. Needless to say, this level of interactions would be unobservable using official trade statistics.

It provides also information on the systemic implications of the disruption of an industrial supply chain beyond the two countries directly involved. Indeed, redeploying exports of final and intermediate products of a single industrial sector will reverberate through the whole global economy. Domestically, a change affecting a single exporting industry will have ramifications to the whole national economy, even for those sectors that, apparently, were not exposed to external shocks.

These systemic interactions are calculated in a traditional input-output analysis through the Leontief model which gives an idea of the total (direct and indirect) inputs required by a given industry to produce its output. This approach provides an intuitive and computationally tractable way to explore alternative scenarios. It goes beyond indirect requirements by quantifying the extent of the struggle for market share that could follow such a disruption.

Finally, the method can be used for more general statistical analysis, besides studying trade conflicts. The way industries in different countries react to extraction then to substitution and redeployment, provides important information on their mode of insertion in the global economy. By running a large set of simulations covering several industries and several "conflictual" pairs of trade partners, it is possible for the analyst to generate a large sample of data that provide a comprehensive and multidimensional set of indicators.

This said, this method has limitations and should not be used for making forecasting or predictions. The main caveats that limit the use of our methodology for economic analysis is the substitutability assumption, on the one hand, and the hypothesis that income and prices remain constant on the other hand. In particular, substitution ignore the gains from trade from the consumers' perspective. Even when looking at the producer side, the surplus (as measured by value-added) is reduced only in the short time. Moreover, the method does not contemplate a situation where the conflict would terminally disrupt an entire supply chain, resulting in the bankruptcy of the firms most dependents of the extracted inputs. As a result, trade disruption in our methodology always results in a net gain for the protectionist country, something that contradicts both theory and practice. For this reason, we strongly recommend to use the method only for what it was developed: measuring the spillover effects on third countries rather than estimating the impact on the two belligerents.

The method is exploratory in nature. At the difference of CGE modelling or other macro and multi-sectoral models such as Caliendo and Parro (2015), it does not pretend to "predict" an outcome of a bilateral trade conflict on the World Trade Network or measure its welfare effect. The objective is mainly descriptive, to produce a series of "markers" corresponding to extreme or expected points that should help mapping what remain largely unchartered waters: the direct and indirect effects of a bilateral trade war between two economic giants. Actually, the simulation is more akin to analysing the shock from a partial equilibrium approach. In particular, and except for the short-run scenario, the simulation avoids the issue of price elasticity by keeping prices constant.

The approach is an intermediary step towards providing a reasonable estimate of the trade-related economic impacts of a disruptive event on by-standers. It may be seen as a complement to Oosterhaven and Bouwmeester (2016), who follow a similar approach (i.e., fixed technical coefficients, flexible trade coefficients, partial import and export substitution) in a scenario of infrastructure destruction or trade boycott in a hypothetical open, two regions, two industries economy. Their approach focuses on the impacts on the two economies directly involved, while the present one does not pretend providing a prediction on these two cases, but focuses on bystanders and includes trade redeployment.

4. Model and simulation results

In order to test the methodology and visualize more clearly the cascading effects of a bilateral trade war on other trade partners, we use a toy model example, based on a very simplified representation of the World economy.

1. Model starting point

The guiding principles for the designing the Toy Model were as followed: The model must be as simple as possible, yet show the direct and induced impacts of a bilateral trade disruption between two large and inter-connected countries such as China and the USA. The specificities of each country, represented schematically by the structure of their production and trade, should be as schematic –or exaggerated– as possible, in order to clearly identify the different impacts according to each country's specialization in the global value chain.

The Toy Model includes six countries, each economy has three sectors, producing commodities (agriculture, mining, fuels), manufactures and services. Sectors are identified by letters P, M, S. Services are not tradable as final products. Each country has specific GVC comparative advantages:

Sierra is a small, services-oriented economy. Sierra is the sole economy in the model that exports services as intermediate products. In the model, Sierra would stand for a small developed or emerging economy relying on financial and business services exports.

Papa is mainly exporting commodities, with a reduced manufacturing sector for domestic consumption. In the Toy Model, Papa personifies natural resources-rich developing economies.

Kilo and ***Echo*** are high technology manufacturers. In addition, Echo is a large market for consumption. Here, one may identify Kilo with Japan and Echo with the USA.

Charly and ***Mike***: Two low and middle technology manufacturers, using their own inputs and processing imported inputs for exports. Mike exports also commodities to Charly as intermediate inputs, but does not import intermediates from Charly. Mike's manufacture supply chain is focused on Echo, Charly's GVCs are more diversified. In a very simple way, we can consider that Charly –a large emerging country– stands for China and Mike –a medium sized emerging country with a sizeable oil sector– stands for Mexico.

Trade conflict is between Charlie and Echo, and affects trade in Manufacture (both intermediate goods such as parts and components, and final goods such as consumer goods, machinery and equipment). Echo initiates the conflict and block all bilateral trade in manufacture from Charlie. The building block for the simulation is the Toy Model input-output matrix, including inter-industry trade, final demand, production and value-added. This matrix is also called the table of direct requirements.

Table 1 Toy Model: Initial Inter-industry trade, sectoral production and Value-Added in monetary terms

Country	Sector	Sierra P	Sierra M	Sierra S	Papa P	Papa M	Papa S	Kilo P	Kilo M	Kilo S	Charlie P	Charlie M	Charlie S	Mike P	Mike M	Mike S	Echo P	Echo M	Echo S
Sierra	**P**	5	5	15	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	M	5	10	10	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—
	S	5	5	15	—	5	—	—	15	—	—	10	—	—	5	—	10	10	15
Papa	**P**	—	—	10	50	15	20	—	50	—	—	50	—	—	20	—	—	50	—
	M	—	—	—	20	10	10	—	—	—	—	—	—	—	—	—	—	—	—
	S	—	—	—	20	5	20	—	—	—	—	—	—	—	—	—	—	—	—
Kilo	**P**	—	—	—	—	—	—	10	10	20	—	—	—	—	—	—	—	—	—
	M	—	—	5	20	—	10	30	60	30	—	50	—	—	—	—	—	30	20
	S	—	—	—	—	—	—	10	40	30	—	—	—	—	—	—	—	—	—
Charlie	**P**	—	—	—	—	—	—	—	—	—	20	10	30	—	—	—	—	—	—
	M	—	—	5	10	—	—	—	10	10	20	40	20	—	—	—	—	10	10
	S	—	—	—	—	—	—	—	—	—	15	20	30	—	—	—	—	—	—
Mike	**P**	—	—	—	—	—	—	—	—	—	—	30	—	15	10	20	—	—	—
	M	—	—	—	—	—	—	—	—	—	—	—	—	20	20	10	—	40	20
	S	—	—	—	—	—	—	—	—	—	—	—	—	10	20	30	—	—	—
Echo	**P**	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	20	10	40
	M	—	—	5	20	—	—	—	30	10	—	30	—	—	30	—	20	60	30
	S	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	30	30	60
Value Added		20.0	25	70	165	45	65	50	295	130	70	245	95	60	145	80	90	285	225
Output		35.0	45	135	305	80	125	100	510	230	125	485	175	105	250	140	170	525	420

Source: Author's elaboration based on a purely hypothetical case for illustration purpose

In the Toy Model, services are only exported as intermediate by Sierra and primary goods (agriculture, mining, fuels) are exported by Papa and Mike. Manufactures are exported by all other countries. Table 2 shows the matrix of final demand (consumption and investment products) before the trade war. Echo imports more than 50% of its final consumption of Manufacture goods, especially from Charlie and Mike. Note that in this presentation, imports of final products are on the upper extra-diagonal elements.

Table 2 Toy Model: Final demand in the initial situation

		Sierra			Papa			Kilo			Charlie			Mike			Echo		
		P	**M**	**S**	**P**	**M**	**S**	**P**	**M**	**S**	**P**	**M**	**S**	**P**	**M**	**S**	**P**	**M**	**S**
Sierra	**P**	10																	
Sierra	**M**		20																
Sierra	**S**			40															
Papa	**P**				*40*														
Papa	**M**					*40*													
Papa	**S**						*80*												
Kilo	**P**							*60*											
Kilo	**M**		*15*			*20*			*150*			*40*			*20*			*10*	
Kilo	**S**									*150*									
Charlie	**P**										*65*								
Charlie	**M**		*10*			*40*			*40*			*150*			*40*			*70*	
Charlie	**S**												*110*						
Mike	**P**													*30*					
Mike	**M**								*10*			*10*			*70*			*50*	
Mike	**S**															*80*			
Echo	**P**																*100*		
Echo	**M**		*10*			*30*			*50*			*30*			*20*			*150*	
Echo	**S**																		*300*

Source: Author's elaboration

At macro-level, the industrial interactions are measured by the Leontief matrix, net of the final output $[(\mathbf{I}\text{-}\mathbf{A})^{-1} - \mathbf{I}]$ which gives the total inter-industrial requirements needed to produce one unit of industrial output when all direct and indirect interactions have taken place. The input-output matrix in Table 1 provided a view of the direct requirements to produce one unit of output for each sector of activity.

To understand the difference between direct and total requirements, let's take an example. In order to produce one unit of manufacture, Papa's industry purchased 0.25 from Papa commodity. Charlie's industries were more efficient in the use of commodities and required only half this amount (0.12). But this is not the end of the process, because Papa's primary sector had to purchase additional inputs in order to produce the additional products required by its manufacturing clients. For one additional unit of commodity produced, Papa primary sector needs to purchase 0.07 manufacturing inputs from its own industry and from Echo and Kilo manufacture. In order to produce this additional 0.07, these manufacture sector will need to purchase additional inputs from other industries, domestic or foreign). And so on and so forth. The sum of all these additional requirements can be calculated using the Leontief model, to obtain the table of total requirements (Table 3). It is obtained multiplying each column of the Leontief matrix net of final output by the output of the corresponding industry.

There are two main important differences between direct and indirect requirements (Table 1 and Table 3, respectively). First, the total requirements are much larger than the direct ones. While Charlie_M firms purchased 240 million of inputs to produce 485 of output, the total requirement induced by this production amounts to 438 million, 83% more than directly required by Charlie_M industry. The ratio Total Requirements/Direct Requirements varies from 1.75 to 1.85 when considering all industries in our simple model. This is linked to the multiplicator effect of the Leontief model: as long as there is a sufficient productive capacity, each unit of additional demand will generate a higher level of total production in all the industries that are involved directly or indirectly with the production process.

The second implication is more directly related to the economics of trade in value-added. When we look at total requirements, we see that some products that are non-tradable and are not directly internationally exchanged, such as the services in our Toy Model, become part of total requirements. For example, Charlie_M manufacture production indirectly induces some 7 million of additional services activity in Papa and Kilo, 6 in Mike and 4 in Echo; yet these countries did not export any services at all, at least directly. Because of the existence of these intangible international trade flows, the analysis of the macro effects is much richer and also more complex than what was perceived at micro level.

Table 3 Toy Model: Table of total requirements by industry

Total requirements	Sierra_P	Sierra_M	Sierra_S	Papa_P	Papa_M	Papa_S	Kilo_P	Kilo_M	Kilo_S	Charlie_P	Charlie_M	Charlie_S	Mike_P	Mike_M	Mike_S	Echo_P	Echo_M	Echo_S
Sierra_P	8.0	9.0	23.1	0.7	1.0	0.3	0.2	3.4	0.4	0.1	2.6	0.2	0.1	1.2	0.1	2.4	3.1	4.2
Sierra_M	8.7	15.4	19.4	0.6	0.9	0.2	0.2	2.9	0.3	0.1	2.2	0.1	0.1	1.0	0.1	2.0	2.6	3.5
Sierra_S	8.0	9.0	23.9	5.0	7.1	2.0	1.7	23.5	2.9	1.0	18.0	1.2	0.8	8.2	0.6	16.6	21.1	28.8
Papa_P	0.9	1.0	18.0	84.2	24.3	36.0	6.1	85.3	11.2	4.9	87.9	5.8	3.5	34.8	2.6	7.0	89.6	19.5
Papa_M	0.1	0.1	1.5	32.2	14.1	16.7	0.5	7.1	0.9	0.4	7.3	0.5	0.3	2.9	0.2	0.6	7.4	1.6
Papa_S	0.1	0.1	1.5	32.8	8.9	27.9	0.5	7.2	0.9	0.4	7.4	0.5	0.3	2.9	0.2	0.6	7.5	1.6
Kilo_P	0.0	0.0	0.3	1.1	0.1	0.5	13.7	18.7	27.5	0.1	2.4	0.2	0.0	0.2	0.0	0.2	1.7	1.1
Kilo_M	0.5	0.6	9.9	37.2	3.3	17.6	42.3	96.9	53.8	4.3	76.9	5.1	0.7	6.6	0.5	6.2	54.4	36.8
Kilo_S	0.0	0.1	0.9	3.5	0.3	1.6	16.9	56.9	42.5	0.4	7.2	0.5	0.1	0.6	0.0	0.6	5.1	3.5
Charlie_P	0.0	0.0	0.3	0.6	0.0	0.1	0.1	0.8	0.5	29.4	19.4	45.7	0.0	0.1	0.0	0.1	0.7	0.6
Charlie_M	0.4	0.4	7.6	16.0	1.3	1.9	2.1	21.1	15.2	30.3	57.7	35.8	0.3	2.7	0.2	2.9	19.7	17.4
Charlie_S	0.0	0.0	0.4	0.9	0.1	0.1	0.1	1.2	0.8	23.9	29.8	44.6	0.0	0.2	0.0	0.2	1.1	1.0
Mike_P	0.0	0.0	0.6	1.4	0.1	0.2	0.2	1.9	1.2	2.3	40.9	2.7	21.9	18.5	31.7	0.5	5.0	3.4
Mike_M	0.0	0.1	1.0	3.2	0.2	0.4	0.4	5.0	2.0	0.8	13.5	0.9	28.0	31.6	21.1	5.1	55.1	32.0
Mike_S	0.0	0.0	0.2	0.5	0.0	0.1	0.1	0.7	0.4	0.4	6.3	0.4	18.2	30.9	44.2	0.6	6.2	3.7
Echo_P	0.0	0.0	0.3	1.0	0.1	0.1	0.1	1.6	0.6	0.1	1.6	0.1	0.1	1.2	0.1	28.0	18.2	55.8
Echo_M	0.5	0.5	9.4	33.6	2.5	4.2	4.4	53.1	19.4	3.0	53.0	3.5	4.2	42.1	3.2	32.3	94.0	59.0
Echo_S	0.0	0.0	0.7	2.4	0.2	0.3	0.3	3.9	1.4	0.2	3.9	0.3	0.3	3.1	0.2	42.9	45.0	85.4
Sum:	27.4	36.4	119.0	256.9	64.5	110.2	89.9	391.0	182.1	102.1	438.0	147.9	78.9	188.9	105.1	148.6	437.6	358.9

Source: Author's elaboration

Applying the Leontief decomposition of GVC trade is closely related to the table of total requirements, but instead of indicating the gross value of production, it indicates the origin of the value-added. Applied to exports, it shows the contribution of all trade partners in the value of the products exported by a given industry. Table 4 shows the results obtained for Charlie's gross exports of manufacture, totalling 255 million (55 of intermediate goods and 200 of final products).

Table 4 Global Value Chain Decomposition: Value Added embodied in Charlie's Manufacturing Exports, by country/sector of origin

Source_Country	Source_Industry	VA in Exp.	Percent.
Sierra	P	0.8	0.3%
Sierra	M	0.6	0.3%
Sierra	S	4.9	1.9%
Papa	P	25.0	9.8%
Papa	M	2.1	0.8%
Papa	S	2.0	0.8%
Kilo	P	0.6	0.2%
Kilo	M	23.4	9.2%
Kilo	S	2.1	0.8%
Charlie	*P*	*5.7*	*2.2%*
Charlie	*M*	*144.2*	*56.5%*
Charlie	*S*	*8.5*	*3.3%*
Mike	P	12.3	4.8%
Mike	M	4.1	1.6%
Mike	S	1.9	0.7%
Echo	P	0.4	0.2%
Echo	M	15.1	5.9%
Echo	S	1.1	0.4%
Total		***255.0***	***100.0%***

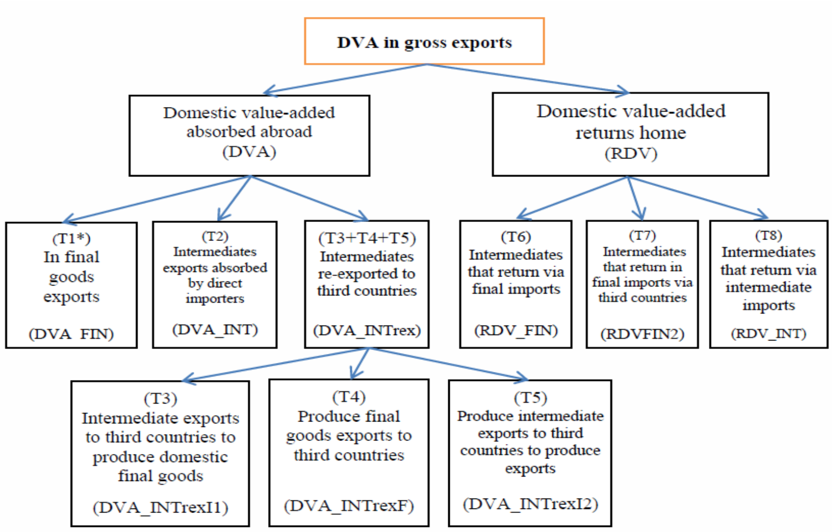
Source: Elaborated using R package Decompr (Quast and Kummritz, 2015)

10% of the exported value originates from Papa's primary sector value-added. In second position of the foreign contributors, Echo's manufacture contribution is close to 6%. We see that Mike's contribution is also at 5% for its commodity sector, but the contribution of its manufacture sector is above 1.5% despite not exporting anything to Charlie: its contribution is indirect, through the exports of parts and components to Echo's manufacturing sector, which in turn exports to Charlie. One can check that the sum of the contribution is 100%: the total exported value is fully split between the various countries and sectors that contributed in the value chain.

Wang, Wei and Zhu (2013) further decompose the value added into several sub-components. Table 5 presents the WWZ decomposition by importing countries, showing the source industry and the use country (when the exporting and importing sectors are the same, the value is 0). Note that the value added is the domestic aggregate and not only the value created by the exporting industry itself. In the present case, Charlie's manufacture exports also domestic value-added from the primary and the services sectors

WWZ decomposition is rather complex (see Figure 4) and it is not the place here to go much into details; we refer the readers to Wang, Wei and Zhu (2013) and Quast and Kummritz (2015). For example, DVA_FIN represents the domestic VA embodied in exports of final product. Those products are consumed (absorbed) in the importing country and do not continue participating in a value chain. DVA_INT is the VA embodied in intermediate goods that will be further processed as final goods and absorbed by the importer. DVA_INTrex correspond to the exported domestic value-added that is reprocessed by the importing country and re-exported to third countries as intermediate goods. DVA_INTrex is further split into three categories according to its use by the second importer.

Figure 4 WWZ Decomposition of Domestic Value-Added embodied in Gross Exports



Source: to Wang, Wei and Zhu (2013)

RDV concerns the domestic value added that returns to the exporter, embodied in imports of final or in intermediate goods. Other terms ─not included in Figure 4 which deals only with the domestic value-added content of gross exports─ correspond to other concepts: MVA is the foreign value-added embodied in the exports and sourced from the importing country, OVA is the foreign value-added embodied sourced from all other countries. MVA and OVA are further split according to their use for intermediate of final goods. DDC, ODC and MDC capture double counting, a statistical issue happening when trade takes place within GVCs. Because pure double counting of foreign value-added in a country's exports can only occur when there is back and forth trade of intermediate goods, it is also an indirect indicator of the deepening of GVC trade (Wang, Wei and Zhu, 2013).

Table 5 Global Value Chain WWZ Decomposition of Value Added embodied in Kilo and Charlie's Manufacturing Exports

Exporting Country	Importing Country	DVA_FIN	DVA_INT	DVA_INTrex	RDV_INT	RDV_FIN	RDV_FIN2	OVA_FIN	MVA_FIN	OVA_INT	MVA_INT	DDC_FIN	DDC_INT	ODC	MDC
Charlie	Sierra	6.2	1.2	1.5	0.2	0.0	0.1	3.5	0.2	0.7	0.0	0.2	0.0	1.1	0.1
Charlie	Papa	24.8	1.7	2.7	0.7	0.0	0.3	10.6	4.6	0.7	0.3	0.7	0.1	1.9	0.8
Charlie	Kilo	24.8	8.3	2.3	0.4	0.7	0.0	11.1	4.1	3.7	1.4	0.5	0.2	1.8	0.7
Charlie	Mike	24.8	0.0	0.0	0.0	0.0	0.0	12.3	2.9	0.0	0.0	0.0	0.0	0.0	0.0
Charlie	Echo	43.5	8.6	2.6	0.3	0.5	0.1	22.0	4.6	4.3	0.9	0.3	0.2	2.0	0.4
Kilo	Sierra	11.5	1.5	1.8	0.3	0.0	0.1	3.0	0.5	0.4	0.1	0.1	0.1	0.6	0.1
Kilo	Papa	15.4	10.7	8.0	2.0	0.0	0.9	2.5	2.1	1.7	1.5	1.0	0.5	2.0	1.7
Kilo	Charlie	30.8	16.0	16.3	1.3	3.5	0.2	8.3	0.9	4.3	0.5	0.3	0.9	6.0	0.7
Kilo	Mike	15.4	0.0	0.0	0.0	0.0	0.0	4.4	0.2	0.0	0.0	0.0	0.0	0.0	0.0
Kilo	Echo	7.7	24.5	8.2	1.4	2.7	0.3	1.7	0.6	5.3	2.0	0.5	0.9	3.1	1.1

Source: Elaborated using R package Decompr (Quast and Kummritz, 2015)

The WWZ decomposition will be useful for interpreting the results of the trade simulations, as it provides interesting information on the GVC specialization of each country. For example, Charlie's manufacture is more downstream than Kilo's, if one looks at the use of the respective products: Most of Charlie's exports of manufacture to Kilo are used to satisfy its domestic final demand (DVA_FIN), while Charlie uses Kilo manufacture more as intermediate inputs, either for domestic consumption (DVA_INT) or for re-exports (DVA-INTrex).

2. First and second rounds of the trade conflict

The trade war between Charly and Echo affects manufacture goods and is initiated by Echo. Charlies' manufacturing exports to Echo are boycotted (extracted) for both intermediate and final goods. This first stage of the trade conflict can be split into two rounds, separating short run and long run effects.

- Short term: Other countries, including Echo's manufacture itself, substitute Charlies exports to Echo for both Intermediate and Final Goods. But in the short run effects, some of Charlie s' intermediates goods are not easily substitutable and will have to be procured by Echo at a higher cost. This situation arises because, for example, Non-Charlie suppliers of this type of products will seize the opportunity to increase their mark-up margin, or will have to increase production above their normal capacity, paying additional production cost. This impact to Echo is limited to intermediate goods only, and there is no change in the price of Final Demand products. Inour example, the additional inputs sourced from domestic and foreign suppliers required by Echo are arbitrarily set to be 30% more expensive than the purchases established through previous arrangements. Suppliers to Echo benefit from the higher price of the additional production required to substitute Charlies exports of intermediate goods to Echo. Echo' s products will be more expensive or its industry will have to reduce its mark-up to remain competitive. If this short-term effect extends to the medium-term, Echo's industry may have to exit because it is deprived of competitively-priced intermediate inputs, a situation depicted in Figure 2, above.[17]

- Long term: With the passing of time, supply adjusts to demand and the additional mark-up and production costs disappear. The substitution of Charlie's sales of intermediate products is done at pre-crisis prices.

Table 6 shows the impact on direct and indirect exports of manufacture value-added to Echo, before and after Echo blocked manufacture imports from Charlie. In the first round, Charlie's exports of manufacture VA to Echo falls by 94%.

Note that if direct exports were blocked ('extracted'), Charlie's manufacture Value-Added would still be indirectly purchased by Echo when it is embodied into third countries intermediate and final products. Echo's sales on its own market increase a lot (by 33.4 million, an increase of 24%), but the major relative gains are registered by Mike's manufacturing sector, which jump almost 30% in the short term, due to the combined effect of an increase in demand (both final and intermediate) and in the price of intermediates. [18] When prices return to their long-term value, the relative gains of all Echo's trade partners are slightly reduced, except for Echo's manufacture, which benefits from the price reduction on the substituted inputs to recuperate its initial rate of value-added.

Table 6: First round of the trade war: demand of manufacture value-added by the protected market by origin

	In monetary value			**Index Initial=100**	
	Initial	***Short***	***Long***	***Short***	***Long***
Sierra_M	2.8	2.8	2.8	100.8	100.4
Papa_M	3.0	3.0	2.9	98.7	97.5
Kilo_M	40.4	42.4	41.4	105.0	102.5
Charlie_M	50.0	3.0	3.0	6.0	5.9
Mike_M	58.0	75.1	74.0	129.5	127.6
Echo_M	138.5	171.9	172.2	124.1	124.4

Note: for the short-term case, Echo pays 30% more for the additional intermediate inputs needed to substitute Charlie's ones.

Table 7 provides information on the overall effect of the sectoral impacts presented above.

Table 7: First round of the trade war: sectoral value-added of the manufacturing sector

	In monetary value			**Index Initial=100**		
	Initial	***Short***	***Long***	***Initial***	***Short***	***Long***
Sierra_M	25.0	25.0	25.0	100.0	100.1	100.0
Papa_M	45.0	45.0	44.9	100.0	99.9	99.8
Kilo_M	295.0	298.0	296.6	100.0	101.0	100.5
Charlie_M	245.0	194.9	194.8	100.0	79.5	79.5
Mike_M	145.0	163.7	162.2	100.0	112.9	111.9
Echo_M	285.0	319.0	320.3	100.0	111.9	112.4

Note: see Table 6

[17] In truth, the simulation does not look at the market losses that would be caused by this loss of price competitiveness and our model assumes that Echo's firms adjust their mark-up to keep their output price competitive. In order to include this price effect, the model would need to take into consideration input price elasticities. Doing so would add complexity to a model we wished to keep as simple as possible. Such price effects would be better treated in a general equilibrium context.

[18] In truth, Charlie's indirect sales should not have indirectly benefited from the increase in the price of substituted inputs. But the impact is very small and disappears in the long term.

As expected in this first round, Charlie's economy is the most affected and suffers a 20% drop in GDP from the loss of its most important export market. Echo's sectoral GDP increases by 12% thanks to import substitution, but Mike (the middle-income country specializing highly integrated into Echo's manufacturing sector) gains more in relative terms in the short term (13%) because it increases its Echo market share while benefiting also from the increase in procurement prices. These price benefits are eroded in the long term, and its long-term gains, while remaining significant, return to being slightly lower than Echo's. [19]

The manufacturing sector of other countries do not gain much, because their gain on the Echo's market are compensated by lower sales of intermediate products to Charlie. The lower sales may come from two effects: the first one is the cumulated effect of direct and indirect demand originating from the reduced activity of Charlie manufacture, the other one is the re-composition of the total requirement table due to the changes in Echo's direct coefficients. We look more in detail into theses systemic effects in the next section.

3. Third round: Trade redeployment and struggle for market shares

Charlie's manufacturing sector should not be expected to remain passive after the loss of its Echo market. Because Echo was such an important market, Charlie's factories are now running at a portion of their initial capacity and part of the labour force remains idle. We can therefore expect Charlie's manufacture to redouble efforts to sell more intermediate and final products and increase their global market share outside Echo.

Excluding, as in the rest of the model, any change in unit price, Charlie uses only marketing efforts (promoting products and brand recognition). This effort is directed at both its exports and its own domestic market. In the process, they displace other suppliers, including Echo's exports (excluding, obviously, Echo's market which remains closed to Charlie's products). Because gaining market share is not an easy process in the face of stiff competition, Charlie cannot expect to recoup all its losses, and our preferred scenario on a purely statistical criterium is the one where only half the losses can be recouped.

But for illustrative purpose, Table 9 and Table 8 show the changes occurring when full redeployment takes place. This scenario has additional properties. It is only in case of full redeployment that the total value of final and intermediate demand remains constant: the losses of some parties in some markets are fully compensated by gains somewhere else. This extreme case has also the merit of attributing changes exclusively on variation in trade, and not on variations of total demand (this option is modelled in the final steps). Note also that in full or partial substitution, the rate of value added remains constant for all industries, including Echo's (last row of Table 9) once the input prices have returned to their long-term trend.

The evolution of final demand sheds important light on what will be the overall economic impact of the trade war. By construction, total demand does not change at country level, only the distribution of this demand between providers, be they domestic and foreign sources. Because Charlie is barred from exporting to Echo, it has to redeploy its exports to all remaining markets. In the case of full redeployment, Charlie's competitors will suffer net losses ranging from -6% to -11% from the intensified competition

[19] Keep in mind that the bilateral positive impacts of the protectionist country are exaggerated by the method (see page 13).

against Charlie's redeployed products, with the exception of Echo and Mike. Echo is protected from Charlie's increased competition on its own domestic market and registers a 10% net increase of its sales of final products. Mike manufacture industry, which exports mainly to Echo, remains a net winner with gains balancing losses by a positive margin of 4%.

Echo's gains remain positive because Charlie has not retaliated by blocking its imports of Echo's products and Echo's industry does not rely much on exports. Yet, we could have expected Echo's market shares to have suffered during the "Short Run" simulation, due to the losses of price competitiveness following the disruption of its supply chain connections with Charlie. These losses are not calculated in the model, as mentioned in footnote 17. It is implicitly assumed in the model that the disruption is manageable and that Echo's manufacture firms absorb the higher production costs by reducing their mark-up margin. This assumption is probably optimistic.

In a Tit-for-Tat situation, the same simulation procedure would have to be repeated, with the difference that it would be Charlie blocking Echo's exports of intermediate and final manufacturing goods. The modelling process would remain exactly the same and the positive and negative spill-over effects on by-standers even larger.[20]

Table 8: Third round of the trade war: change in final demand in case of full substitution (in percentage)

	Sierra	Papa	Kilo	Charlie	Mike	Echo	Total
Sierra_P	0.0%	…	…	…	…	…	0.0%
Sierra_M	-5.6%	…	…	…	…	…	-5.6%
Sierra_S	0.0%	…	…	…	…	…	0.0%
Papa_P	…	0.0%	…	…	…	…	0.0%
Papa_M	…	-11.1%	…	…	…	…	-11.1%
Papa_S	…	0.0%	…	…	…	…	0.0%
Kilo_P	…	…	0.0%	…	…	…	0.0%
Kilo_M	-5.6%	-11.1%	-4.8%	-46.9%	-9.1%	33.3%	-10.8%
Kilo_S	…	…	0.0%	…	…	…	0.0%
Charlie_P	…	…	…	0.0%	…	…	0.0%
Charlie_M	25.0%	25.0%	25.0%	25.0%	25.0%	-100.0%	0.0%
Charlie_S	…	…	…	0.0%	…	…	0.0%
Mike_P	…	…	…	…	0.0%	…	0.0%
Mike_M	…	…	-4.8%	-46.9%	-9.1%	33.3%	3.7%
Mike_S	…	…	…	…	0.0%	…	0.0%
Echo_P	…	…	…	…	…	0.0%	0.0%
Echo_M	-5.6%	-11.1%	-4.8%	-46.9%	-9.1%	33.3%	9.6%
Echo_S	…	…	…	…	…	0.0%	0.0%
Total	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Note: changes are expressed in percentage of initial pre-crisis situation, before the trade war.

Changes in direct requirements (Table 9) are compounded when looking at indirect requirements (Table 10). They affect all productive sectors using Charlie's manufacture as inputs or not, at the difference of direct requirements where only the markets where Charlie was active in the initial situation were affected. Another difference with direct requirements, which sum up to the same total in order to maintain constant the rate of value-added, the sum of total requirements changes from industry to industry because each one has different production function (as measured by the technical coefficients).

[20] With an important qualitative difference from an analytical perspective. We mentioned that the initial simulation could be understood as a partial deviation from a general equilibrium state described by the actual input-output table. It is no more the case as the retaliation will be modelled on the basis of the outcome of the first iterations, which differs from the initial equilibrium.

Table 9: Third round of the trade war: change in direct requirements of Manufacture industry in case of full substitution (in percentage)

	Sierra_M	Papa_M	Kilo_M	Charlie_M	Mike_M	Echo_M
Sierra_P	0.0%	…	…	…	…	…
Sierra_M	0.0%	…	…	…	…	…
Sierra_S	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
Papa_P	…	0.0%	0.0%	0.0%	0.0%	0.0%
Papa_M	…	0.0%	…	…	…	…
Papa_S	…	0.0%	…	…	…	…
Kilo_P	…	…	0.0%	…	…	…
Kilo_M	…	…	-1.9%	-8.7%	…	7.7%
Kilo_S	…	…	0.0%	…	…	…
Charlie_P	…	…	…	0.0%	…	…
Charlie_M	…	…	17.4%	17.4%	…	-100.0%
Charlie_S	…	…	…	0.0%	…	…
Mike_P	…	…	…	0.0%	0.0%	…
Mike_M	…	…	…	…	0.0%	7.7%
Mike_S	…	…	…	…	0.0%	…
Echo_P	…	…	…	…	…	0.0%
Echo_M	…	…	-1.9%	-8.7%	0.0%	7.7%
Echo_S	…	…	…	…	…	0.0%
V-A	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

Note: Changes are expressed in percentage of initial pre-crisis situation, before the trade war. They affect all sectors using Charlie's manufacture as inputs, even if only manufacture is shown here.

Note also that while Echo had stopped all direct imports of Charlie's inputs, its indirect demand drops only by 66%, instead of 100% as observed in Table 9). This reflects Charlie's value-added content embodied in inputs imported by Echo from third countries which processed and re-exported Charlie's intermediate products (this corresponds to the DVA_INTrex in Table 5).

For many countries, the variation is similar across industries. This is due to the sparse nature of the initial direct coefficients, where countries export only one intermediate good (Primary, Manufacture or Services). This intermediate good, in turn, is composed of various components supplied domestically from the two other industries or imported from other countries. Therefore, while the changes in direct requirements showed only a single change (e.g., 25% increase in purchases from Charlie_M), the increase will be reflected in a change of total requirements corresponding to all sectors contributing to the production of Charlie_M.

Table 10: Third round of the trade war: change in total requirements of Manufacture industry in case of full substitution (in percentage)

	Sierra_M	Papa_M	Kilo_M	Charlie_M	Mike_M	Echo_M
Sierra_P	-0.1%	-0.5%	-0.5%	-0.8%	-0.5%	-0.4%
Sierra_M	-0.3%	-3.6%	-3.6%	-3.9%	-3.6%	-3.5%
Sierra_S	-0.1%	-0.1%	-0.2%	-0.4%	-0.1%	0.0%
Papa_P	0.5%	0.0%	0.0%	0.1%	-0.1%	-0.3%
Papa_M	-2.2%	-0.4%	-2.6%	-2.6%	-2.7%	-2.9%
Papa_S	0.3%	0.0%	-0.2%	-0.1%	-0.2%	-0.5%
Kilo_P	-2.8%	-1.8%	-0.3%	-6.7%	0.8%	3.5%
Kilo_M	-2.8%	-1.8%	-2.0%	-6.7%	0.8%	3.5%
Kilo_S	-2.8%	-1.8%	-0.3%	-6.7%	0.8%	3.5%
Charlie_P	15.8%	13.9%	12.1%	1.5%	-22.9%	-66.3%
Charlie_M	15.8%	13.9%	12.1%	14.5%	-22.9%	-66.3%
Charlie_S	15.8%	13.9%	12.1%	1.5%	-22.9%	-66.3%
Mike_P	14.9%	12.9%	11.2%	1.5%	-0.1%	-13.0%
Mike_M	6.8%	6.8%	7.1%	1.7%	1.0%	8.6%
Mike_S	10.3%	9.0%	8.4%	1.6%	0.1%	6.5%
Echo_P	-2.4%	-1.7%	-1.2%	-5.5%	0.8%	1.0%
Echo_M	-2.4%	-1.7%	-1.2%	-5.5%	0.8%	6.7%
Echo_S	-2.4%	-1.7%	-1.2%	-5.5%	0.8%	1.0%
Total	0.02%	0.03%	0.07%	0.20%	-0.03%	-0.30%

Note: Changes are expressed in percentage of initial pre-crisis situation, before the trade war. They affect all sectors, even if only manufacture is shown here.

The combined changes in total requirements and in the distribution of final demand have an impact on GDP. Table 11 shows the evolution of the sectoral value-added through the various steps of the simulation, from the initial pre-crisis situation to extraction and substitution (short term implying a 30% increase in the additional procurement costs substituting Charlies extracted inputs) then redeployment by Charlie of the extracted sales.

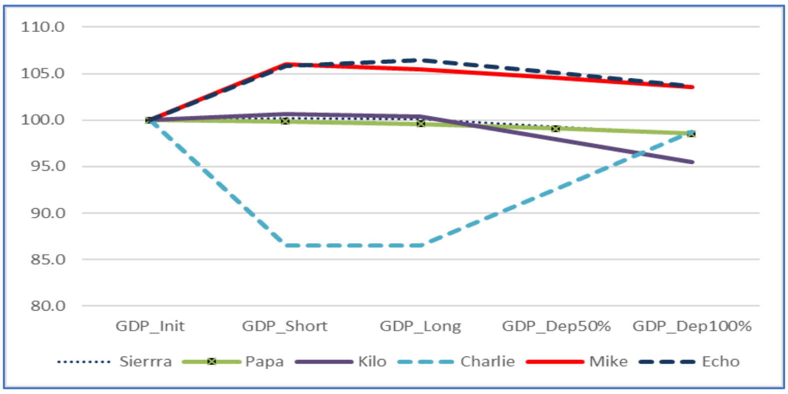
Table 11 Evolution of sectoral value-added through the different simulation scenarios

		Extraction and substitution		Extraction, substitution and redeployment	
	Initial	Short term	Long term	50% redeployment	100% redeployment
Sierra_P	20.00	20.03	20.01	19.90	19.79
Sierra_M	25.00	25.03	25.01	24.42	23.82
Sierra_S	70.00	70.22	70.08	69.86	69.63
Papa_P	165.00	164.62	164.07	164.32	164.58
Papa_M	45.00	44.97	44.92	43.32	41.71
Papa_S	65.00	64.97	64.92	64.83	64.74
Kilo_P	50.00	50.08	50.04	49.77	49.49
Kilo_M	295.00	297.95	296.61	286.38	275.95
Kilo_S	130.00	130.27	130.15	129.21	128.25
Charlie_P	70.00	68.01	68.01	68.91	69.82
Charlie_M	245.00	194.86	194.80	217.49	240.50
Charlie_S	95.00	92.04	92.04	93.38	94.73
Mike_P	60.00	57.02	56.92	58.55	60.21
Mike_M	145.00	163.68	162.23	158.16	154.07
Mike_S	80.00	81.51	81.36	81.14	80.94
Echo_P	90.00	91.07	91.01	90.79	90.57
Echo_M	285.00	319.02	320.28	312.59	304.77
Echo_S	225.00	224.65	227.53	226.98	226.42

Note: see Table 6

Figure 5 shows the evolution of the total GDP index, based on the initial situation.

Figure 5 Evolution of GDP through the different simulation scenarios (Initial=100)



As mentioned, the 50% redeployment case (GDP_Dep50%) is the expected one from a statistical perspective while the 100% case is an extreme point that has the advantage of keeping constant total demand. Echo is gaining in all scenarios, albeit its gains are eroded if Charlie partially displaces it from its export markets (from a gain of 12% to 10% in manufacture, and from 6% to 4% for GDP). Charlie recoups almost all its substantial losses in case of full redeployment: its manufacture sector, which retracted by 20% after losing the Echo market, ends with a loss smaller than 5%. The impact on its GDP follows a similar pattern: from -13% to only -1%. This is built in the simulation scenario, which allows Charlie to redirect its extracted sales to other markets, be they domestic or export. The more plausible 50% redeployment scenario indicates that Charlie would suffer a -7% recession in GDP, induced by a 17% drop in its manufacture value-added.

The contrast between no redeployment (the long-term extraction-cum-substitution scenario) and full redeployment indicates that the main casualties in a bilateral trade war between two large traders are the by-standers when the targeted industry is able to redirect its exports to other markets. In the present case, Kilo is the country most affected by export re-structuring after trade deflection. Its manufacture industry gains very little if no redeployment takes place (0.5%) but loses more than 8% if Charlie is able to redeploy all its lost sales to other markets. Even in the most plausible case of 50% redeployment, Kilo GDP still registers a 2% recession. Mike, which is not exposed to Charlie's competition (its main export market for manufacture is Echo, a market that exclude Charlie's products), gains about 4% in total (almost 10% for manufacture only). Its gains are even larger if Charlie can only redeploy 50% of its lost sales, especially for its manufacture sector (9%) while its primary sector, which exports commodities to Charlie and lost 5% after Charlie's extraction, would recoup all its losses and even register small gains if Charlie's recovery is maximum (not a plausible outcome).

4. Fourth round: Final demand responds to changes in gross domestic income

We mentioned when commenting Table 8 above that the total value of final demand remained constant by construction and only its distribution was affected by the process of extraction-cum-substitution and redeployment. This is obviously an over-simplification as income, measured through the GDP, does not remain constant.

Let's go one step further and see what will happen to our Toy Economy if final demand emanating from each country adjusts in proportion of the changes in its GDP. As expected, the adjustment favours the winners and penalises the losers, due to the strong home bias of demand (most of demand is covered by local production). Another influential factor is the difference in trade exposure: countries exporting to winning countries will gain relatively more than countries exporting to countries registering a recession due to the trade war.

Table 12 Final Demand Adjustments: changes with the no-adjustment situation (percent)

Sector	50% redeployment	100% redeployment
Sierra_P	0.0	-0.5
Sierra_M	-0.2	-0.3
Sierra_S	0.6	0.1
Papa_P	-0.6	-0.3
Papa_M	-0.8	-0.6
Papa_S	-0.9	-1.2
Kilo_P	-2.0	-4.1
Kilo_M	-1.5	-2.0
Kilo_S	-1.9	-4.0
Charlie_P	-7.3	-1.4
Charlie_M	-6.8	-2.7
Charlie_S	-7.3	-1.4
Mike_P	0.9	1.4
Mike_M	4.1	3.3
Mike_S	4.1	3.3
Echo_P	4.9	3.6
Echo_M	3.6	3.0
Echo_S	4.9	3.6

Note: changes are expressed in percentage of the corresponding (50%-100%) simulation as in Table 11.

Echo's gains are amplified, as well as Mike's. If Charlie is not able to redeploy 100% of its lost exports to Echo, it is doubly penalised: first, because its Final Demand will shrink as its GDP did; second because it is not able to benefit from Echo's bonanza, being barred from exporting to this market. Even if it can redeploy 100%, the second penalisation will still apply, while its direct competitors will be able to recoup some of their losses due lower domestic demand and to Charlie's increased competition by selling more to Echo.

As mentioned in the methodological section, the KISS procedure stops here even if this is only the first step of an iterative process where each change in GDP induces a new change in final demand, which in turn modifies GDP and final demand, and so on and so forth until a convergence is reached.

4. An application to the China-USA 2018 trade conflict

Year 2018 has seen an increase in bilateral trade tensions between China and the USA. In January 2018, the US administration placed a 30% tariff on foreign solar panels and a 20% on washing machines. This was followed in March by tariffs of 25% on steel and 10% on aluminium. In April China responded by imposing tariffs on 128 products it imports from America. The Tit-for-Tat escalation continued during most of 2018 and tensions remained high in 2019. At the time of writing this article, some of the planned increases in tariffs had been postponed pending the outcome of bilateral negotiations. But the economic uncertainty raised by this conflict was taking its toll on the world economy.

Some branches of activities were particularly targeted by either the USA or China during the 2018 conflict: Agriculture, Basic Metals, Electronics and Vehicles. For this exercise, Escaith and Lei Zhang (2019) apply the methodology to the WIOD database in its November 2016 edition, with results updated at year 2014. The World Input-Output Tables (WIOT) cover 43 countries plus an aggregate for the rest of the world. Industry data are provided for 56 sectors producing goods and services. The simulation focuses on 17 countries belonging to the G20 group, or to the Asian region.[21]

- ***Gains and losses from the bilateral conflict***

Table 13 presents the results of the simulation for two cases: USA blocks bilateral imports of Basic Metal from China and China blocks bilateral imports of motor vehicles, trailers and semi-trailers from USA. In the first case, the US manufactures of basic metal gain most, while China's losses are significantly reduced thanks to export redeployment. The sectoral value added of Canada and Mexico, closely associated to the USA through a free trade agreement, register also net gains.

All other countries register negative spill-overs due to the Chinese exports to the US being redeployed towards third countries. Japan, who initially gained from the removal of Chinese competition on the US market, suffers large losses due to trade deflection. This redeployment in the face of trade conflict was first analysed quantitively by Bown and Crowley (2003) in the context of the United States' use of import restrictions on Japanese exports between 1992 and 2001.

A similar pattern is observed when it is China who blocks the US imports, in this case of vehicles (second panel of Table 13). China's automobile industry gains much from substituting US imports and US losses are mitigated thanks to the redeployment of these exports to third markets. Canada, Germany, Japan, Korea and Mexico register large losses due to the increased US competition on their domestic and export markets.

[21] WIOD does not cover three of the G20 members: Argentina, Saudi Arabia and South Africa.

Table 13 Evolution of sectoral value-added following extraction and substitution, selected sectors (Mn dollar)

	USA blocks bilateral imports of Basic Metal from China					**China blocks bilateral imports of motor vehicles, trailers and semi-trailers from USA**				
Scenarios	Short	Long	Subst-FD	Subst 50%	Subst 100%	Short [a]	Long	Subst-FD [b]	Subst 50%	Subst 100%
AUS	3.88	3.07	-7.45	-61.52	-122.33	-0.08	-0.09	-5.09	-3.02	-5.96
BRA	41.17	33.21	20.85	1.28	-29.67	-1.98	-2.00	-10.50	-7.88	-13.77
CAN	246.48	197.21	175.68	159.71	124.10	-24.16	-24.17	-426.35	-243.82	-463.44
CHN	-1 684.57	-1 686.00	-1 412.10	-1 005.37	-420.64	2 449.73	2 559.78	2 498.46	2 513.65	2 467.41
DEU	38.71	32.04	-41.35	-54.04	-119.83	116.37	113.88	-477.45	-201.64	-517.30
FRA	6.11	4.84	0.36	-3.62	-11.68	2.17	2.03	-11.88	-6.05	-14.14
GBR	13.40	10.67	-4.51	-44.34	-97.21	24.17	24.11	-41.03	-10.05	-44.22
IDN	2.74	2.07	-3.17	-14.49	-30.54	-1.24	-1.27	-7.72	-5.57	-9.87
IND	32.21	29.12	2.17	-20.70	-65.32	-2.42	-2.45	-6.91	-6.25	-10.07
ITA	14.86	12.59	-7.93	-4.71	-17.99	1.84	1.78	-39.74	-21.24	-44.27
JPN	49.25	41.26	-60.29	-211.83	-401.48	21.34	19.50	-694.33	-364.48	-748.62
KOR	34.41	27.70	2.05	-70.87	-152.24	2.11	1.30	-246.87	-132.38	-266.14
MEX	97.09	77.37	76.81	73.19	69.13	-72.80	-72.86	-553.08	-353.07	-633.51
RUS	51.39	41.79	22.78	-9.57	-59.11	0.15	0.13	-6.07	-3.26	-6.64
TUR	18.87	15.38	5.36	6.31	-1.42	-0.30	-0.31	-5.93	-3.72	-7.14
TWN	8.69	6.39	5.96	-49.58	-105.38	-7.88	-7.94	-8.85	-12.40	-16.89
USA	1 746.45	1 713.99	1 706.25	1 689.62	1 668.44	-2 615.11	-2 615.14	-429.26	-1 399.64	-183.52

Note: The table shows the differences with the initial sectoral value added before trade conflict for Basic Metal (first panel) and Vehicles (second panel).

a/ Short-term effects of extraction include price effects (30% price hike on additional inputs).

b/ 100% of extracted exports of final products are redeployed to third countries, but no intermediate goods.

Source: Escaith and Lei Zhang (2019) based on WIOT data

The table illustrates also the difference between an upstream sector like Basic Metal and a downstream one like Vehicles: redeploying only final products (the "Subst-FD" column) has little impact in the first case, but a large one in the second one.

- ***Further use of the extraction-cum-substitution method***

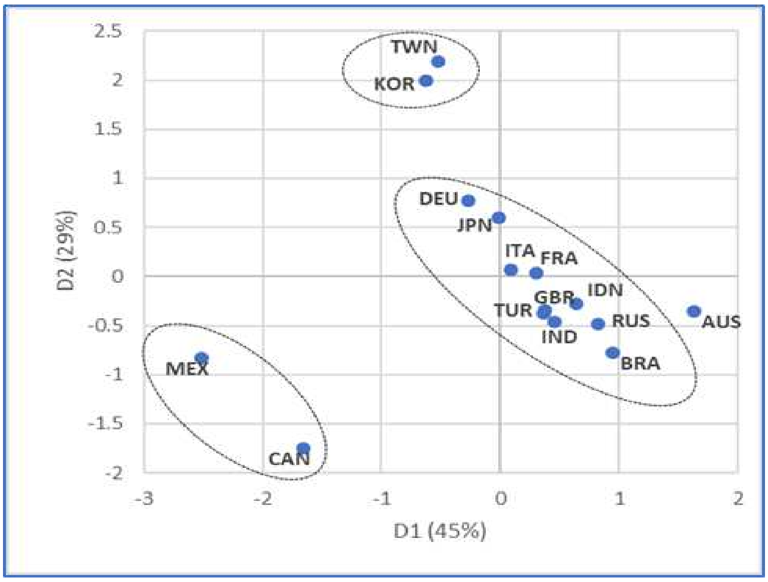
The extraction-cum-simulation method opens also the possibility of generating experimental data that can serve for further statistical analysis. Simulating a large series of bilateral shocks using the computational algorithm in Annex produces numerical results that a dependent on the mode of international insertion of countries and allows building an analytical database. To this aim, we simulate a series of bilateral shocks affecting 12 good-producing sectors emanating alternatively from China and from the USA, giving a total of 24 simulations.

In our first example, we consider only the impact on GDP of the two extreme scenarios of extraction-substitution without and with full redeployment for each one of the 12 sectors. The first scenario gives the gains or losses accruing to third countries from the exclusion of Chinese products on the US market or, symmetrically, the exclusion of US products from China. The second one indicates the vulnerability of these third countries to China and USA being successful in redeploying the excluded exports to other markets.

The simulation generates a total of 720 observations: 24 sectoral shocks on 15 G20 countries indirectly affected by the bilateral conflict between China and the USA), and two datapoints per simulation. The statistical treatment is conducted using exploratory data analysis (e.g. principal component analysis or cluster analysis).

Figure 6 shows the results obtained for the first two components, after a varimax rotation. These two components represent about 75% percent of the total information (or variance) provided by the 720 datapoints. As usual with this type of exploratory analysis, the interpretation of the components requires a separate analysis of the correlations of the variables (the sectoral shocks) and the observations (the 15 countries).

Figure 6 Principal Component Analysis of the GDP responses to bilateral China-USA shocks



Note: Analysis performed on the variation of GDP resulting from a trade shock affecting sectoral trade between China and the USA.
Source: Escaith and Lei Zhang (2019), based on WIOD data

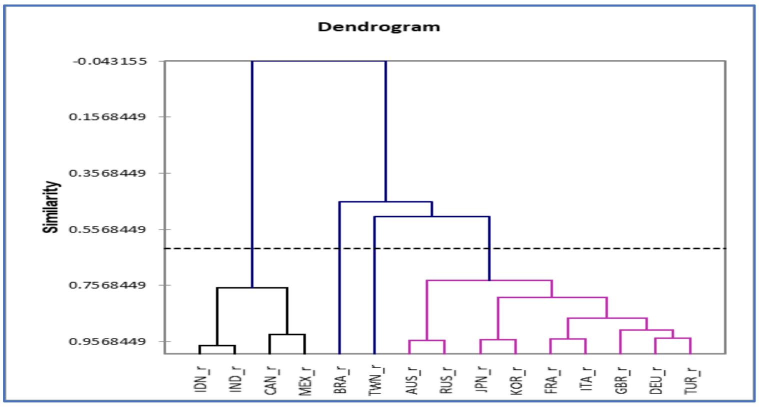
The first component, on the horizontal axis, explains 45% of the total variance. Its interpretation is relatively straightforward: on the left-hand side of the diagram, we find countries that register, in average of the sectors, a positive gain when China exports are targeted by the USA while the right side of the graph corresponds to countries that tend to gain when US exports are targeted by China.

Interpreting the vertical axis (29% of the total variance) is more complex: On the top side of the graph, we find countries that (i) loose when China is able to redeploy 100% of its extracted exports or (ii) gain when the US exports are blocked by China and the USA is not able to redeploy its lost exports.

The combination of these two components identifies three groups of countries, with Australia being in a separate category. Mexico and Canada make a first group of countries that gain when China is excluded from the US market and are not much affected by China's increased competition on other markets. This situation reflects their strong export-orientation to the US market. The second group (Chinese Taipei and Korea) gains also when China is excluded from the US market, but are very vulnerable to a redeployment of Chinese exports to other markets. The third group, more numerous, is arranged along the first diagonal of the graph. We find here countries like Germany and Japan that share some of the Taipei and Korea characteristic, and other, at the lower end of the diagonal, that are suppliers of primary goods to China (Brazil, Russia) and are not much affected by Chinese competition on their other export markets. Australia is relatively close to this situation, but with some specificities that puts it in a special case. In particular, Australia is more vulnerable to the redeployment of Chinese exports in some sectors such as basic metal.

The second example is based on the relative variation of the sectoral value added for the following four scenarios: extraction and substitution effects in the Short and Long term; redeployment of 100% of the extracted final goods only and of 100% of the total extracted exports. The statistical analysis is conducted using agglomerative hierarchical clustering (AHC) on the resulting dataset. Figure 7 shows the results of analysing the similarities between the 17 countries (China and the USA excluded).

Figure 7 Agglomerative hierarchical clustering based on the similarity of sectoral response to bilateral China-USA shocks

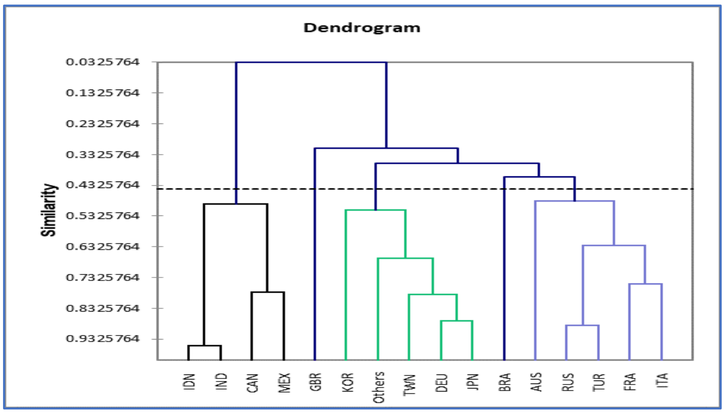


Note: Similarity is based on the Pearson coefficient of correlations calculated on the relative variation of sectoral value-added following a trade shock affecting sectoral trade between China and the USA.
Source: Author's elaboration, based on WIOD data

Brazil and Taiwan appear to stand out as special cases that are only loosely connected to the rest of countries. At the contrary, we observe strong similarities between India and Indonesia, on the one hand, and Australia and Russia on the other hand. Both country duplets show also similarities between them. We observe also close similarities between Japan and Korea, France and Italy, and Germany and Turkey, joined also by the UK.

The same analysis can look at the effect of the same series of sectoral shocks on the whole GDP, and not only on the respective industries.

Figure 8 Agglomerative hierarchical clustering based on the similarity of GDP response to bilateral China-USA shocks

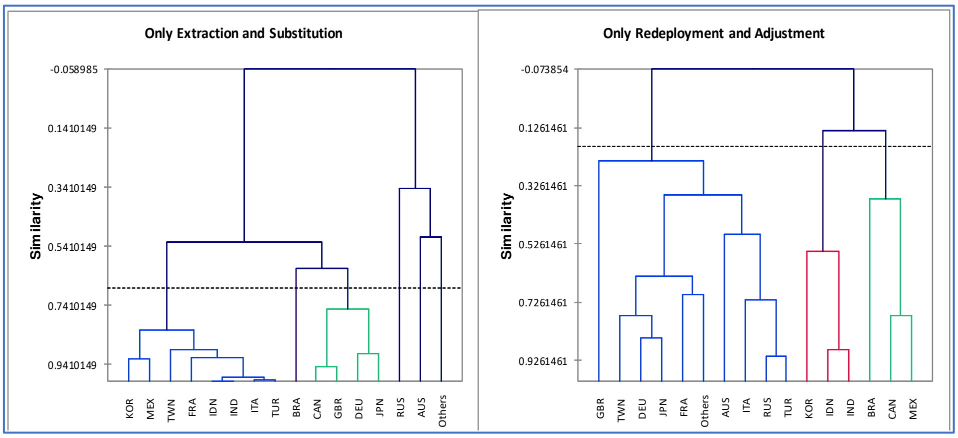


Note: Similarity is based on the Pearson coefficient of correlations calculated on the relative variation of Gross Domestic Product following a trade shock affecting sectoral trade between China and the USA.
"Others" denotes the other countries included in WIOT plus the ROW aggregate.
Source: Author's elaboration, based on WIOD data

The nature and extent of the impacts differ when considering only the sectoral effects (Figure 7) or when looking at their influence on the whole economy (Figure 8). This is due to differences in (i) the nature of inter-industrial linkages and (ii) the relative weight of services sectors (the bilateral trade shocks affecting only good-producing industries). In Figure 8, we still have strong similarities between India and Indonesia, or between France and Italy. But Germany and Japan are now close together and joined by Taiwan. At the contrary, UK and Brazil stand alone as outsiders.

The data generated by the method can also be used to characterise countries' mode of World trade insertion by analysing separately the successive scenarios. For example, Figure 9 splits the previous AHC analysis into two successive steps: first, the extraction of Chinese or US imports and the short- and long-term effects of their substitution in the protectionist market, then the redeployment of extracted exports to third markets and the impact on final demand. The first panel (Extraction and Substitution only) will mainly segregate countries according to their commercial presence in China or in the USA. The second panel will look at their vulnerability to an increased competition from China or the USA on their other markets. UK is an outlier here, probably because its specialisation in exports of services means it is relatively protected from the competition of Chinese exports. Understanding the differences in classification would require looking more in details into sectoral characteristics, and is beyond the scope of this paper. Our aim was only to show the analytical potential of the methodology.

Figure 9 Agglomerative hierarchical clustering based on the similarity of GDP response to successive phases of the bilateral China-USA trade shocks



Note: see Figure 8

These results are only provided as example of the potential of the methodology to map the reaction of several economies to trade shocks. The similarities and dissimilarities in economic responses would need to be further analysed by crossing the various sectoral and global results, and correlating them with other indicators related to the structure of the economies and their trade integration.

5. Conclusions

This introductory paper presents a simple yet powerful methodological tool for analysing the impact of a bilateral trade conflict on third countries when trade includes intermediate inputs. Mixing input-output modelling with recent development of trade in value-added analysis, the extraction-cum-substitution approach maps and measures the sectoral and global interactions that are caused by vertical integration and global value chains.

The method is voluntarily kept as simple as possible, following the KISS principle of model building. It remains descriptive, or better say, exploratory. But it is not simplistic: it generates a rich collection of results that shows the complexity of the inter-actions and their economic relevance when the countries involved in a trade war are two large economies. When the country that is targeted in the bilateral conflict is a large and competitive exporter closely inserted in global value chains, the depth of the spill-over effects on third countries may be larger than the direct impacts on the two trade belligerents. These impacts would not be easily identified using standard input-output or network analysis. Finally, the method can be used for more general statistical analysis, besides the study of trade conflicts. The way industries in different countries react to extraction, then to substitution, provides important information on their mode of insertion in the global economy. By running a large set of simulations covering several industries and several "conflictual" pairs of trade partners, it is possible for the analyst to generate a large sample of data that provide a comprehensive and multidimensional set of indicators. Because the methodology is relatively straightforward, it does not require complex programming and can be easily iterated to generate "big data". Then, the resulting set of indicators can be analysed through exploratory data analysis to reveal similarities between countries, or singularities.

This said, this method has limitations and should not be used for making forecasting or predictions. To use an analogy with literature, it is like a science fiction novel: Sci-Fi is not chiefly predictive, its scenarios of the future should be understood more as a contemplation of the present. The main caveats that limit its use from an economic modelling perspective is the substitutability assumption, on the one hand, and the hypothesis that income and prices remain constant on the other hand. In particular, substitution ignore the gains from trade from the consumers' perspective. Even when looking at the producer side, the surplus in the protected country (as measured by value-added per unit of output) is reduced only in the short time, which is probably over-optimistic. Moreover, the method does not contemplate a situation where the conflict would disrupt an entire supply chain, resulting in the bankruptcy of the firms most dependents of the extracted inputs. As a result, trade disruption in our methodology always results in a net gain for the protectionist country, something that contradicts both theory and practice. For this reason, we recommend using the method only for what it was developed: measuring the spillover effects on third countries rather than estimating the impact on the two belligerents.

In brief, the method should be interpreted as a first step before applying fully fledged economic models. Actually, the complexity is in the data and not in the methodology, and this complexity reflects the depth and variety of inter-industry interrelations in the global economy. By providing a mapping of the deep structure of inter-industrial interactions at the time of the trade shock, the method helps the analysts in understanding the results of more sophisticated economic models.

Its application to a real-case bilateral trade conflict opposing China and the USA in 2018 confirms the importance of the direct and indirect spill-over effects. Trade deflection (the redeployment of boycotted exports) inflicts potentially large losses to third countries and would probably induce them to take their own protectionist measures to shield their industries from the increased trade competition. The end-result would prove disastrous for the multilateral trade governance, mimicking the spiralling protectionism that followed the Smoot-Hawley Tariff Act in 1930, which raised U.S. tariffs on over 20,000 imported goods to record levels and was reciprocated by many countries, deepening the global recession.

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Annexes

1. Further discussion on the gravity equation used for substitution

The standard gravity Equation 12 used for substitution means that, when an industry *s* is excluded from a market *r*, the previous exports of *s* to *r* are redistributed between the other countries that were already present on this market in proportion to their existing market shares. The ratio of the new bilateral economic distance d'_{ar} and d'_{ir} remains also constant for *a* and *i≠s* while d'_{sr} –> ∞ for gross trade flows because trade costs became prohibitive under the extraction hypothesis. When considering trade in value-added, the bilateral distance d'_{sr} is still much higher than d_{sr} but not prohibitive: *s* is still able to indirectly export domestic value added to *s* through the global value chain.

While the above-mentioned extraction-cum-substitution uses a trade model to estimate bilateral flows, alternative approaches leading to broadly similar constructs that have been used by the IO community to build interindustry flows in multiregional models (Isard, 1954; Leontief and Strout, 1963 or more recently Oosterhaven and Bouwmeester, 2016). From an information perspective, the simulation makes use of all the information contained in the initial IO data. It can also be considered as a special case of 'Iterative Proportional Fitting', better known in input-output analysis as RAS (the meaning of the RAS acronym is unknown).

The RAS method is used in a situation when only row and column sums of desired input-output table are known. The table is than estimated from an older fully-known input-output table in a way that the resulting table is consistent with given row and column sums. Mathematically, RAS is an iterative scaling method whereby a non-negative matrix is adjusted until its column sums and row sums equal to some pre-specified totals. In a typical RAS, each entry in one row is multiplied by a scalar that is chosen in such a way that the sum of all entries in the row or column becomes equal to its target total. Then, the same method is used to make the columns consistent with their required totals.

As a result, the constraints on the row totals is not satisfied anymore. So, the algorithm repeats itself on rows and columns until the resulting matrix is consistent with all required row and column totals. The adjustment of the entries of the matrix is iterative and proportional to the row and column totals.

Our case differs from a typical RAS because the adjustment starts from a pre-defined shock (extraction) and redistributes the missing trade across rows and columns in such a way that (i) the sum of rows and columns remain constant and (ii) the new coefficients of unextracted columns are related to the old ones in proportion to their initial market shares. Our algorithm assigns final demand on the basis of transactions and inputs on the basis of technical coefficients. Dietzenbacher and Miller (2009) prove that, under some conditions that are fulfilled in a typical input-output matrix, the rescaling vectors are unique. [22] Updating the transactions matrix or the corresponding coefficients matrix yields the same results.

Yet, as mentioned previously, recent developments in the micro-foundations of gravity (Anderson and van Wincoop, 2003) show the bilateral relation does not depend only on the bilateral distance but also of a multilateral resistance terms, which captures general equilibrium forces. Extracting a market modifies both the bilateral and the multilateral resistance terms, especially if, as in our substitution hypothesis, the extracted industry makes extra efforts to reassign the missing trade to other markets. This is one of the reasons we restrict our method to analysing partial equilibrium simulations.

It should ideally be limited to small deviations from the general equilibrium solution (the one observed in the initial input-output matrix). But, by definition, the extraction method that is the building block of our approach is far from being a marginal variation. Moreover, it is only applicable to small economies, because it relies on the assumption that the extraction of a supplier (a row of the IO matrix) can be compensated by an increase in purchases from other sources. In other words, the assumption of fixed IO technical coefficients is permissible because of fully flexible trade coefficients (Oosterhaven and Bouwmeester, 2016).

This explains why the method should be considered as exploratory only, amplifying the contrast in order to provide a better mapping of underlying inter-industry relationships in third-countries. It is to forecasting what caricature is to photography: a way to amplify the most distinguishing aspects of a portrait.

2. R program

When discussing the pro and cons of the KISS principle, it is often mentioned that C. Chapman, the founder of Lotus Cars, urged his designers to "Simplify, then add lightness". I am afraid the R program that I wrote is neither simple nor light. Its clumsiness is entirely due to my almost complete ignorance of R programming when I started this work. My sole ambition here was to have something that was working and was relatively free of bugs. I cross-checked the results on small examples, but there is no guaranty at all the script is without errors. Sure, some bugs must be remaining, thanks to Mr Murphy’s Law. So, use it at your own risks and improve it.

[22] Property 1) under the following condition: (i) Z is a square matrix (i.e. each country is recorded both as an importer and an exporter); (ii) its diagonal elements are strictly positive (i.e. every country trades with itself); (iii) it is not block diagonal (or cannot be made block diagonal by permutations of its rows and columns, i.e. there is no group of countries operating in complete autarky).

```
#Project Spillover Effects of China USA trade War: Testing the R program on a simple Toy Model
# Final draft by H. Escaith April 2019-Valencia
library(decompr)
library(openxlsx)
library(readr)
library(data.table)
# Set the working directory (needs to be changed accordingly)
mainDir <- "F:/ToyModel_3"
subDir <- "outputTest"
dir.create(file.path(mainDir, subDir), showWarnings = FALSE)
setwd(mainDir)
#Load data already stored as csv files and assign them the required R class (vector, matrix...)
Countries <- read.table("Countries.csv", quote="\"", comment.char="",stringsAsFactors = F)
Countries <- Countries$V1
Industries<- read.table("Industries.csv", quote="\"", comment.char="",stringsAsFactors = F)
Industries <- Industries$V1
Country_Sector<- read.table("Country_Sector.csv", quote="\"", comment.char="",stringsAsFactors = F)
Country_Sector <- Country_Sector$V1
Output <- read.table("Output.csv", quote="\"", comment.char="", stringsAsFactors=FALSE)
Output <- as.vector(unname(unlist(Output[,1])))
Final <- read_delim("E:/TinVA (C)/UIBE_GVC/ToyModel_3/Final.csv",
                    ";", escape_double = FALSE, col_names = FALSE,
                   trim_ws = TRUE)
Final <- as.matrix(Final)
colnames(Final) <- Countries
rownames(Final) <- Country_Sector
Intermediate <- read.table("Intermediate.csv", quote="\"", sep=";", comment.char="",stringsAsFactors = F)
Intermediate <-as.matrix(Intermediate)
colnames(Intermediate) <- Country_Sector
rownames(Intermediate) <- Country_Sector
#To match other name used in previous instances of the program
Country_Industry <-Country_Sector

# Calculating TiVA indicator using Decompr
ToyLeon<-decomp (Intermediate, Final, Countries, Industries, Output, method = "leontief")
ToyWWZ<-decomp (Intermediate, Final, Countries, Industries, Output, method = "wwz")
# Write results as CSV files
write.csv(ToyLeon, file = "ToyLeon.csv",row.names=FALSE)
write.csv(ToyWWZ, file = "ToyWWZ.csv",row.names=FALSE)

# Calculating Leontief inverse on Initial data and Calculation of direct requirements
Acoef<- t(t(Intermediate)/Output)
M_size <- ncol(Acoef)
Imat<-diag(M_size)
IA_Init <- (Imat - Acoef)
L_Init <- solve(IA_Init, tol=1e-04)
#Calculating Total requirements and documenting lines and columns
TotReq <- L_Init-Imat
colnames(Acoef)<-Country_Industry
rownames(Acoef)<-Country_Industry
colnames(TotReq)<-Country_Industry
rownames(TotReq)<-Country_Industry
#Loading country names to the markets of final demand
colnames(Final)<-Countries
rownames(Final)<-Country_Industry
#Saving Direct and Total Requirements. Using slower xlsx because csv to xls failed on large datasets
write.xlsx(Acoef, file = "Acoef.xlsx",row.names = TRUE, col.names = TRUE, append=FALSE)
write.xlsx(TotReq, file = "TotRequirements.xlsx", row.names = TRUE, col.names = TRUE, append=FALSE)
#END first part

#SECOND PART: substitutions. Must be run repeatedly changing the extracted sectors after FIRST Part which loads IO data
# Manually change Country and sector index of origin that is extracted in A and Y: r_extr (r_extr is a scalar: only one line_sector extracted)
#Change directory to save Simulation Data in separate area
setwd(file.path(mainDir, subDir))
# 1. Extraction without replacement (traditional extraction method): Set extracted industry
Ind_extr <- "Charlie_M"
# Set list of similar industries, including Ind_extr and its competitors (can be a subset or all similar sectors).
Manuf<-c("Sierra_M", "Papa_M", "Kilo_M", "Charlie_M", "Mike_M", "Echo_M")
#Set extracted final demand market country (and demand categories, if needed)
Y_extr <- "Echo"
#Set extracted columns for intermediate inputs (must be contiguous columns of the IO matrix)
First_col<- "Echo_P"
Last_col<- "Echo_S"
# Enter PCost: additional procurement cost when substituting extracted inputs, decimal format: 0.15 for 15%)
PCost <- 0.3
r_extr<-which(rownames(Acoef)==Ind_extr)
firstcol<-which(colnames(Acoef)==First_col)
lastcol<-which(colnames(Acoef)==Last_col)
Acol_extr <- c(firstcol:lastcol)
#Modify Final demand vector on protectionist market by setting extracted final exports of r_extr to Y_extr to 0
Final_Less1 <-Final
Final_Less1[r_extr,Y_extr]<-0
#Compute new Acoef after extraction: A*= A_less1 to be calculated on Acoef
myMat0 <-Acoef
colnames(myMat0) <- Country_Industry
rownames(myMat0) <- Country_Industry
myMat<-myMat0
myMat[Ind_extr,Acol_extr] <- 0
#Compute (I-A*) -> IA* and Invert (IA*) -> L* I is a M_size square matrix
myMat <- Imat - myMat
L_less1 <- solve(myMat, tol=1e-04)
#Calculate X*= L* %*% Y* (matrix multiplication, or %*% in R)
X_less1 <- L_less1 %*% Final_Less1
#Calculating Production, Value-Added and GDP vectors on extracted Leontief and Final demand
#Calculating the Value-Added on the original A coefficients (simple extraction does not modify VA coefficient)
VA_Init <- (1-colSums(Acoef))
GDP_less1<-(VA_Init)*rowSums(X_less1)
write.csv(GDP_less1, file = "GDP_less1.csv",row.names=TRUE)
```

```
#Cleaning and resetting the intermediate results
remove(myMat, myMat0)

# 2. Extraction with substitution. Substitution is based on input-output matrix and final demand.
# Short term substitution: i) adds additional procurement cost for inputs and excludes redeployment of extracted out-
puts
#Long term effects (saved in Acoef_Long file): extraction of Acoef, with substitution, no extra cost
#myMat0: original matrix; myMat: to be modified
myMat0 <-Acoef
colnames(myMat0) <- Country_Industry
rownames(myMat0) <- Country_Industry
myMat<-myMat0
# Extraction of one industry for several inputs markets: set desired values to zero
myMat[Ind_extr, Acol_extr] <-0
# Calculation of the market share to be redistributed among Ind_extr competitors selected in variable "Manuf"
# Compare original sum over all lines with extracted sum and create a multiplier matrix
orginal_colSum <- colSums(myMat0[Manuf, ])
extract_colSum <- colSums(myMat[Manuf,])
multiplier <- matrix(rep(orginal_colSum/colSums(myMat[Manuf,]), ncol(myMat)),
            ncol = ncol(myMat),byrow=TRUE)
# Include an exception when the column is 0 to avoid NA results
multiplier[is.na(multiplier)] <- 1
colnames(multiplier) <-Country_Industry
rownames(multiplier) <-Country_Industry
#Substitution using the multiplier matrix (only on A coefficients whithout change in price)
myMat[Manuf,Acol_extr] <-myMat[Manuf,Acol_extr]*multiplier[Manuf,Acol_extr]
# Check if the row sum is the same (no change in Value Added)
Check<- round(sum(colSums(myMat) - colSums(myMat0)), digits=4)
try(if(Check !=0) stop("CHECK FAILED"))
#Saving results in ACoef_2: substitution without increase in input cost
ACoef_2 <-myMat
#Cleaning and resetting intermediate results
remove(Check, myMat, myMat0, multiplier)

#Short term effects (saved in Acoef_Short): substitution in Acoef with additional procurement cost "PCost".
#myMat0: original matrix; myMat: to be modified
#Re-Initialising the calculation
myMat0 <-Acoef
myMat<-myMat0
# Extraction: set extracted values to zero
myMat[Ind_extr, Acol_extr] <-0
Denominator <- colSums(myMat[Manuf, ])
multiplier <- matrix(rep(orginal_colSum/colSums(myMat[Manuf,]), ncol(myMat)),
            ncol = ncol(myMat),byrow=TRUE)
# Include an exception when the column is 0 to avoid a NA result
multiplier[is.na(multiplier)] <- 1
colnames(multiplier) <-Country_Industry
rownames(multiplier) <-Country_Industry
# Add additional procurement cost in markets where extraction took place (where multiplier[i,j]>1)
for (i in 1:nrow(multiplier)) {
  for (j in 1:ncol(multiplier)) {
   if (multiplier[i,j]>1){multiplier[i,j]<-multiplier[i,j]*(1+PCost)}
  }
}
# The additional cost applies only to the additional procurement needed to replace extracted inputs
#  The previous instruction added procurement cost to all. To correct this:
for (j in Acol_extr)
{if (myMat0[Ind_extr,j]>0){myMat[Manuf, j]<-(myMat[Manuf,j]*
                          multiplier[Manuf, j])-(myMat[Manuf,j]*PCost)}}
# 5. Additional procurement costs: lower Value Added: Check if sum of Acoef by column is higher (V-A is lower) due to
additional cost
Check<- round(sum(colSums(myMat) - colSums(myMat0)), digits=4)
try(if(Check<=0) stop("CHECK FAILED"))

#Saving results in ACoef_1: substitution with increase in procurement cost
ACoef_1 <-myMat
#Cleaning and resetting the intermediate results
remove(Check, myMat, myMat0, orginal_colSum, multiplier)

# Final demand: Extraction of Ind_Extr exports to Y_extr (no extra cost on final demand in both short and long term)
#Re-Initialising the calculation
myMat0<-Final
rownames(myMat0) <-Country_Industry
colnames(myMat0) <-Countries
myMat<-myMat0
myMat[Ind_extr, Y_extr] <-0
orginal_colSum <- colSums(myMat0[Manuf, ])
multiplier <- matrix(rep(orginal_colSum/colSums(myMat[Manuf,]), ncol(myMat)),
            ncol = ncol(myMat), nrow = nrow(myMat),byrow=TRUE)
# Include an exception when the column is 0 to avoid a NA result
multiplier[is.na(multiplier)] <- 1
colnames(multiplier) <-Countries
rownames(multiplier) <-Country_Industry
# Apply multiplier to redeploy in myMat the extracted Ind_extr sales in initial myMat0
if (myMat0[Ind_extr, Y_extr]>0){myMat[Manuf, Y_extr]<-(myMat[Manuf, Y_extr]*
                              multiplier[Manuf, Y_extr])}
# Check if the sum per column is the same: no change in total final demand
Check<- round(sum(colSums(myMat) - colSums(myMat0)), digits=4)
try(if(Check !=0) stop("CHECK FAILED"))

#Saving results
Final_1 <-myMat
#Cleaning and resetting the intermediate results
remove(Check, myMat, myMat0, orginal_colSum, multiplier)

#Calculating impact of extractions on GDP using the Leontief Model
#Building the Leontief (I-A)^-1 on initial A coefficients: L_Init
IA_mat <- (Imat - Acoef)
L_Init <- solve(IA_mat, tol=1e-04)
X_Init <- L_Init%*%Final
```

```
GDP_Init<-(VA_Init)*rowSums(X_Init)
#Building the Leontief (I-A)^-1 on extracted short term A coefficients: L_Short
IA_mat <- (Imat - ACoef_1)
L_Short <- solve(IA_mat, tol=1e-04)
#Calculating Production, Value-Added and GDP vectors on extracted Leontief and Final demand
X_Short <- L_Short%*%Final_1
VA_Short <- (1-colSums(ACoef_1))
GDP_Short<-(VA_Short)*rowSums(X_Short)

#Building the Leontief (I-A)^-1 on extracted long term A coefficients: L_Long
IA_mat <- (Imat - ACoef_2)
L_Long <- solve(IA_mat, tol=1e-04)
#Calculating Production, Value-Added and GDP vectors on extracted Leontief and Final demand
X_Long <- L_Long%*%Final_1
VA_Long <- (1-colSums(ACoef_2))
GDP_Long<-(VA_Long)*rowSums(X_Long)
TotReq <-L_Long-Imat
# Saving results in default directory
write.csv(GDP_Init, file = "GDP_Init.csv",row.names=TRUE)
write.csv(GDP_Short, file = "GDP_Extracted_Short.csv",row.names=TRUE)
write.csv(GDP_Long, file = "GDP_Extracted_Long.csv",row.names=TRUE)
write.csv(TotReq, file = "TotReq_Extract_Long.csv",row.names=TRUE)
remove(IA_mat, TotReq)

# THIRD SUBSTITUTION: Full redeployment of the extracted output to other export and domestic markets:
#    First part Final goods (to be saved as Final_3)
#Re-Initialising the calculation
myMat0<-Final
myMat<-Final_1
rownames(myMat0) <-Country_Industry
colnames(myMat0) <-Countries
rownames(myMat) <-Country_Industry
colnames(myMat) <-Countries
myMat0[Ind_extr, Y_extr] <-0
#Calculate sum of lost exports of final goods from r to s from initial data : YRS
YRS<-sum(colSums(Final))-sum(colSums(myMat0))
#Calculate share of YRS in total exports of final goods from r : YRS_pc : YRS / Sum [r, .] Y
# r will need to increase its exports by same YRS_pcmargin on other markets
YRS_pc<- rowSums(myMat0)
YRS_pc <- YRS /YRS_pc[Ind_extr]
#Print lost market share
cat("Lost final market ($):", round(YRS, digits=2))
cat("Lost final market (%):", round(YRS_pc*100, digits=2))

#Each export of r to non-s country is increased by the percentage of losses from the s market
#Non-r countries are displaced in non-s markets in proportion of their initial market share.
#Include an exception if the extracted industry is dominant on a market and cannot fully redeploy
YNR<-colSums(myMat0[Manuf,])
YNR<-YNR-(myMat0[Ind_extr,])
names(YNR) <-Countries
for (i in Manuf[Manuf!=Ind_extr]) {
  for (j in colnames(myMat)){if(j!=Y_extr){
    if (myMat0[i,j]-(myMat0[Ind_extr,j]*(YRS_pc))*((myMat0[i,j]/YNR[j]))>0) {
      myMat[i,j]<- myMat0[i,j]-(myMat0[Ind_extr,j]*(YRS_pc))*((myMat0[i,j]/YNR[j]))} else {
        myMat[i,j] <-0
      }}}}
#"Ind_extr" increases its share by the losses of the displaced non-r countries
Gain <-colSums(Final_1)-colSums(myMat)
myMat[Ind_extr,]<- myMat[Ind_extr,]+Gain
Check<- round((sum(colSums(myMat) - colSums(myMat0))-YRS), digits=4)
try(if(Check !=0) stop("CHECK FAILED"))
#Saving results
Final_3<-myMat

write.csv(Final_3, file = "Final_3.csv",row.names=TRUE)
#Cleaning and resetting the intermediate results
remove(Check, myMat, myMat0)

# Second part of redeployment process, based on long term Acoef_2 results:
# redeployment of the extracted output to other markets second part: Intermediate goods. Including the domestic market
myMat0 <-ACoef_2
colnames(myMat0) <- Country_Industry
rownames(myMat0) <- Country_Industry
myMat<-myMat0
#colnames(X_Init) <- Countries
#rownames(X_Init) <- Country_Industry
colnames(Intermediate) <- Country_Industry
rownames(Intermediate) <- Country_Industry

#Intermediate goods: country r increases shares in all non s markets in proportion of losses in s
# Calculate sum of lost exports of intermediate goods from r to s on initial data: ZRS = RowSum [r,s] Z
# Calculate share of ZRS in total non-s sales of intermediate goods from r relative to all non-s markets: ZRS_pc : ZRS / RowSum [r, j≠s] Z
#  Each sale (export or domestic) of r to non-s country is increased by the percentage of losses from the s market. But this is doable only if there is enough foreign inputs in the initial production process to be substituted. If not, skip the reallocation, and keep the initial one.

# Calculation and print of the initial market share to be redistributed (in % of all markets, including domestic and extracted)
Share <- sum(Intermediate[Ind_extr,Acol_extr])
cat("Lost intermediate market due to extraction (in $)", round(Share, 2))
Share <- sum(Intermediate[Ind_extr,Acol_extr])/sum(Intermediate[Ind_extr,])
cat("Lost intermediate market due to extraction (in %)", round(Share*100, 2))

# Calculation of "Share": initial market share to be redistributed (excluding Acol_extr)
# "Share" is higher than actual share because it excludes Acol_ext (redistribution must be done on other markets)
Share <- sum(Intermediate[Ind_extr,Acol_extr])/(sum(Intermediate[Ind_extr,])-sum(Intermediate[Ind_extr,Acol_extr]))
#The extracted industry will increase by "multiplier Share" its sales of intermediate products to other markets. Other industries are displaced:
```

```r
# Calculation of the market share to be redistributed
# Compare original sum over all lines with extracted sum and create a multiplier vector
orginal_colSum <- colSums(myMat0[Manuf, ])-myMat0[Ind_extr, ]
names(orginal_colSum) <- Country_Industry

#Substitution in matrix
#Because myMat0[Ind_extr,j]=0 if "j" belongs to Acol_extr, the function does not modify the corresponding myMat0 values
for (i in Manuf[Manuf!=Ind_extr]) {
  for (j in colnames(myMat)){
    if(orginal_colSum[j]!=0) {
      myMat[i,j]<-myMat0[i,j]-((myMat0[Ind_extr, j]*(Share))*(myMat0[i,j]/orginal_colSum[j]))
    }}}
# Redeployment for the extracted industry. If it is already too dominant [else] applies
Gain<-colSums(myMat0[Manuf, ])-colSums(myMat[Manuf,])
Gain<-as.vector(Gain)
myMat[Ind_extr,]<-myMat0[Ind_extr,]+Gain


# Check if the row sum is the same (no change in Value Added)
Check<- sum(colSums(myMat[Manuf, ]))-sum(colSums(myMat0[Manuf,]))
Check<-round(Check, digits=4)
try(if(Check !=0) stop("CHECK FAILED"))
#Saving results
ACoef_3<-myMat
write.csv(ACoef_3, file = "Acoef_Sub3.csv",row.names=TRUE)
#Calculating Production, Value-Added and GDP vectors on substituted Leontief and Final demand
IA_mat <- (Imat - ACoef_3)
L_Sub <- solve(IA_mat, tol=1e-04)
X_Sub <- L_Sub%*%Final_3
VA_Sub3 <- (1-colSums(ACoef_3))
GDP_Sub3<-(VA_Long)*rowSums(X_Sub)
TotReq <-L_Sub-Imat
colnames(TotReq) <- Country_Industry
rownames(TotReq) <- Country_Industry
write.csv(GDP_Sub3, file = "GDP_Sub3.csv",row.names=TRUE)
write.csv(TotReq, file = "TotReq_Sub3.csv", row.names = TRUE)
#Cleaning and resetting the intermediate results
remove(Check, myMat, myMat0, orginal_colSum, Share)

#VARIANT: Partial export redeployment
# Expected redeployment = 0.5 of losses if the probability distribution is symmetric: use now (YRS_PC*0.5) as share.
#Include an exception if the extracted industry is dominant on a market and cannot fully redeploy
#Final goods: Re-Initialising the calculation
myMat0<-Final
myMat<-Final_1
rownames(myMat0) <-Country_Industry
colnames(myMat0) <-Countries
rownames(myMat) <-Country_Industry
colnames(myMat) <-Countries
myMat0[Ind_extr, Y_extr] <-0
Share<- YRS_pc*0.5
for (i in Manuf[Manuf!=Ind_extr]) {
  for (j in colnames(myMat)){if(j!=Y_extr){
    if (myMat0[i,j]-(myMat0[Ind_extr,j]*Share)*((myMat0[i,j]/YNR[j]))>0) {
      myMat[i,j]<- myMat0[i,j]-(myMat0[Ind_extr,j]*Share)*((myMat0[i,j]/YNR[j]))} else {
        myMat[i,j] <-0
      }}}}
#"Ind_extr" increases its share by the losses of the displaced non-r countries
Gain <-colSums(Final_1)-colSums(myMat)
myMat[Ind_extr,]<- myMat[Ind_extr,]+Gain
Check<- round((sum(colSums(myMat) - colSums(myMat0))-YRS), digits=4)
try(if(Check !=0) stop("CHECK FAILED"))
#Saving results
Final_3a<-myMat

# Second part of partial redeployment process, based on long term Acoef_2 results:
myMat0 <-ACoef_2
colnames(myMat0) <- Country_Industry
rownames(myMat0) <- Country_Industry
myMat<-myMat0
#colnames(X_Init) <- Countries
#rownames(X_Init) <- Country_Industry
colnames(Intermediate) <- Country_Industry
rownames(Intermediate) <- Country_Industry

#Intermediate goods: country r increases shares in all non s markets in proportion of 0.5*losses in s
#  Each sale (export or domestic) of r to non-s country is increased by half the percentage of losses from the s market. But this is doable only if there is enough foreign inputs in the initial production process to be substituted. If not, skip the reallocation, and keep the initial one.
# Calculation and print of the initial market share to be redistributed (in % of all markets, including domestic and extracted)
Mkt <- sum(Intermediate[Ind_extr,Acol_extr])
# Calculation of "Share": 0.5*initial market share to be redistributed (excluding Acol_extr)
Share <- sum(Intermediate[Ind_extr,Acol_extr])/(sum(Intermediate[Ind_extr,])-sum(Intermediate[Ind_extr,Acol_extr]))
#The extracted industry will increase by "multiplier Share" its sales of intermediate products to other markets. Other industries are displaced:
orginal_colSum <- colSums(myMat0[Manuf, ])-myMat0[Ind_extr, ]
names(orginal_colSum) <- Country_Industry
#Substitution in matrix (same as before, but reduced by multiplying by 0.5
#Because myMat0[Ind_extr,j]=0 if "j" belongs to Acol_extr, the function does not modify the corresponding myMat0 values
for (i in Manuf[Manuf!=Ind_extr]) {
  for (j in colnames(myMat)){
    if(orginal_colSum[j]!=0) {
      myMat[i,j]<-myMat0[i,j]-(0.5*(myMat0[Ind_extr, j]*(Share))*(myMat0[i,j]/orginal_colSum[j]))
    }}}
# Redeployment for the extracted industry. If it is already too dominant [else] applies
Gain<-colSums(myMat0[Manuf, ])-colSums(myMat[Manuf,])
Gain<-as.vector(Gain)
```

```
myMat[Ind_extr,]<-myMat0[Ind_extr,]+Gain

# Check if the row sum is the same (no change in Value Added)
Check<- sum(colSums(myMat[Manuf, ]))-sum(colSums(myMat0[Manuf,]))
Check<-round(Check, digits=4)
try(if(Check !=0) stop("CHECK FAILED"))
#Saving results
ACoef_3a<-myMat

#Calculating Production, Value-Added and GDP vectors on extracted Leontief and new Final demand
# Note: No change in Value Added if the Check-test passed: use VA_Long results
IA_mat <- (Imat - ACoef_3a)
L_Suba <- solve(IA_mat, tol=1e-04)
X_Sub3a <- L_Suba%*%Final_3a
VA_Sub3a <- (1-colSums(ACoef_3a))
GDP_Sub3a<-(VA_Sub3a)*rowSums(X_Sub3a)
write.csv(GDP_Sub3a, file = "GDP_Sub3a.csv",row.names=TRUE)
TotReq <-L_Suba-Imat
colnames(TotReq) <- Country_Industry
rownames(TotReq) <- Country_Industry
write.csv(TotReq, file = "TotReq_Sub3a.csv", row.names = TRUE)
write.csv(ACoef_3a, file = "Acoef_Sub3a.csv",row.names=TRUE)
myMat<-myMat[rep(seq_len(nrow(myMat)), each=3),]
myMat[ , -1] <- myMat[, -1]/myMat$GDP_Init
Final_3Mod<-Final_3*myMat$GDP_Sub3
Final_3aMod<-Final_3a*myMat$GDP_Sub3a
#Cleaning and resetting the intermediate results
remove(Check, myMat, myMat0, Share)

#END Variant and END subprogram substitution

#Table production: Selecting results for countries of interest and aggregating all others
#Using Country code part of Country_Industry taking the first 3 characters
Countries_repeat<- substr(Country_Industry, 1, 3)
Manuf_repeat <-substr(Manuf,1,3)
Countries_repeat[!Countries_repeat %in% Manuf_repeat] <- 'Others'

# Aggregating GDP for various extraction steps (transposing to aggregate on rows)
# Aggregate function does not keep original order, use "reorder" to return to the original order
reorder <- unique(Countries_repeat)
myMat<-data.frame (t(rbind(GDP_Sub3,Countries_repeat)))
myMat[, 1] <- as.numeric(as.character( myMat[, 1] ))
GDP_Sub3_Agg<- aggregate(myMat$GDP_Sub3, by=list(Countries_repeat=myMat$Countries_repeat), FUN=sum)
colnames(GDP_Sub3_Agg)<-c("ISO3","GDP_Sub3")
GDP_Sub3_Agg <-GDP_Sub3_Agg[match(reorder,GDP_Sub3_Agg$ISO3),]
myMat<-data.frame (t(rbind(GDP_Sub3a,Countries_repeat)))
myMat[, 1] <- as.numeric(as.character( myMat[, 1] ))
GDP_Sub3a_Agg<- aggregate(myMat$GDP_Sub3a, by=list(Countries_repeat=myMat$Countries_repeat), FUN=sum)
colnames(GDP_Sub3a_Agg)<-c("ISO3","GDP_Sub3a")
GDP_Sub3a_Agg <-GDP_Sub3a_Agg[match(reorder,GDP_Sub3a_Agg$ISO3),]

myMat<-data.frame (t(rbind(GDP_Long,Countries_repeat)))
myMat[, 1] <- as.numeric(as.character( myMat[, 1] ))
GDP_Long_Agg<- aggregate(myMat$GDP_Long, by=list(Countries_repeat=myMat$Countries_repeat), FUN=sum)
colnames(GDP_Long_Agg)<-c("ISO3","GDP_Long")
GDP_Long_Agg <-GDP_Long_Agg[match(reorder,GDP_Long_Agg$ISO3),]

myMat<-data.frame (t(rbind(GDP_Short,Countries_repeat)))
myMat[, 1] <- as.numeric(as.character( myMat[, 1] ))
GDP_Short_Agg<- aggregate(myMat$GDP_Short, by=list(Countries_repeat=myMat$Countries_repeat), FUN=sum)
colnames(GDP_Short_Agg)<-c("ISO3","GDP_Short")
GDP_Short_Agg <-GDP_Short_Agg[match(reorder,GDP_Short_Agg$ISO3),]

myMat<-data.frame (t(rbind(GDP_less1,Countries_repeat)))
myMat[, 1] <- as.numeric(as.character( myMat[, 1] ))
GDP_less1_Agg<- aggregate(myMat$GDP_less1, by=list(Countries_repeat=myMat$Countries_repeat), FUN=sum)
colnames(GDP_less1_Agg)<-c("ISO3","GDP_Less1")
GDP_less1_Agg <-GDP_less1_Agg[match(reorder,GDP_less1_Agg$ISO3),]

myMat<-data.frame (t(rbind(GDP_Init,Countries_repeat)))
myMat[, 1] <- as.numeric(as.character( myMat[, 1] ))
GDP_Init_Agg<- aggregate(myMat$GDP_Init, by=list(Countries_repeat=myMat$Countries_repeat), FUN=sum)
colnames(GDP_Init_Agg)<-c("ISO3","GDP_Init")
GDP_Init_Agg <-GDP_Init_Agg[match(reorder,GDP_Init_Agg$ISO3),]

myMat<- merge(GDP_Init_Agg, GDP_less1_Agg)
myMat<- merge(myMat, GDP_Short_Agg)
myMat<- merge(myMat, GDP_Long_Agg)
myMat<- merge(myMat, GDP_Sub3a_Agg)
myMat<- merge(myMat, GDP_Sub3_Agg)
myMat <-myMat[match(reorder,myMat$ISO3),]
write.csv(myMat, file="GDP_Aggregates.csv")
#Saving evolution of sectoral VA for countries of interest
matList <- list(GDP_Init[Manuf], GDP_less1[Manuf], GDP_Short[Manuf], GDP_Long[Manuf],
        GDP_Sub3a[Manuf], GDP_Sub3[Manuf])
names(matList) <- c("Init", "Extract_1", "Short", "Long", "Sub3a", "Sub3")
write.csv(matList, file="VAManuf.csv")
#Exports are direct and indirect: induced by demand from Protecting. Different from Balance of Payments
Exports <- list(X_Init[Manuf, Y_extr], X_less1[Manuf, Y_extr], X_Short[Manuf, Y_extr], X_Long[Manuf, Y_extr],
        X_Sub3a[Manuf, Y_extr], X_Sub[Manuf, Y_extr])
names(Exports) <- c("Init", "Extract_1", "Short", "Long", "Sub3a", "Sub3")
VA_inExp <- list( (VA_Init[Manuf]*X_Init[Manuf, Y_extr]), (VA_Init[Manuf]*X_less1[Manuf, Y_extr]),
(VA_Short[Manuf]*X_Short[Manuf, Y_extr]),
         (VA_Long[Manuf]*X_Long[Manuf, Y_extr]), (VA_Sub3a[Manuf]*X_Sub3a[Manuf, Y_extr]),
(VA_Sub3[Manuf]*X_Sub[Manuf, Y_extr]))
names(VA_inExp) <- c("Init", "Extract_1", "Short", "Long", "Sub3a", "Sub3")
write.csv(VA_inExp, file= "VA_to_Protecting.csv")
write.csv(Exports, file="Exports_to_Protecting.csv")

#LAST STEP: Final demand modified in proportion of change in GDP
```

```
#First, disaggregate the GDP to return to sectoral dimension WARNING: depends on number of sectors: Change accord-
ingly
myMat<-myMat[rep(seq_len(nrow(myMat)), each=3),]
myMat<-as.data.frame(myMat)

myMat[ , -1] <- myMat[, -1]/myMat$GDP_Init
Final_3Mod<-Final_3*myMat$GDP_Sub3
Final_3aMod<-Final_3a*myMat$GDP_Sub3a
# New GDP after Final Demand is modified
X_Sub3Mod <- L_Suba%*%Final_3Mod
GDP_Sub3Mod<-(VA_Sub3)*rowSums(X_Sub3Mod)
X_Sub3aMod <- L_Suba%*%Final_3aMod
GDP_Sub3aMod<-(VA_Sub3a)*rowSums(X_Sub3aMod)
write.csv(GDP_Sub3Mod, file="GDP_Sub3_FDModified.csv")
write.csv(GDP_Sub3aMod, file="GDP_Sub3a_FDModified.csv")

#END program
```