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The US-Mexico bilateral trade relation through a value added lens

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Abstract: We use the World Input-Output Database and build on Wang et al. (2013) gross exports decomposition to analyze the bilateral trade relation between Mexico and the United States from a value added perspective. Once we take into account that gross commercial flows are clouded by failing to account for imported content, we find that contrary to what gross flows suggest, Mexico has a value added commercial deficit in manufacturing with the United States. Similar patterns can be observed at the sectoral level with significant differences between the gross and value added sectoral trade balances: an improvement of most sectoral US trade balances, particularly for those sectors importing significant amounts of intermediate goods.
Keywords: Global value chains, World input-output tables, International fragmentation of production, Trade imbalances
JEL Classification: E1, F2, F14, F15, F23.

Resumen: Utilizamos la Matriz Insumo-Producto Mundial y con base en la descomposición de exportaciones brutas en Wang et al. (2013) analizamos la relación comercial bilateral entre México y Estados Unidos desde una perspectiva de valor agregado. Al tomar en cuenta que los flujos comerciales brutos explican de manera difusa el contenido por país de la creciente cantidad de bienes intermedios importados, encontramos que contrariamente a lo que los flujos comerciales brutos indican, México tiene un déficit comercial en valor agregado en el sector manufacturero con Estados Unidos. A nivel de sectores se observa un comportamiento similar de diferencias significativas entre los balances comerciales brutos y los de valor agregado, principalmente en aquellos sectores que importan grandes cantidades de bienes intermedios, observándose balances más favorables para Estados Unidos de los que se obtienen con los flujos brutos.
Palabras Clave: Cadenas globales de valor, Matriz Insumo-Producto Mundial, Fragmentación internacional de la producción, Desequilibrios comerciales

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1. Introduction

The emergence of complex global production arrangements increasingly fragmented across borders in the form of global value chains (GVCs) has profoundly altered the nature of international trade, away from trade in final goods towards trade in tasks and activities, as well as the nature and patterns of the gains from trade. A direct consequence of this production fragmentation has been the increased importance of intermediate goods that cross borders several times along the value chain. This has significantly diminished the information content of gross trade flows for understanding the nature of bilateral or multilateral trade relationships and the gains of its insertion in international trade. For example, gross trade imbalances have been a major contributing factor for igniting the recent wave of anti-globalization in many countries. To the extent that these imbalances fail to quantify and acknowledge the complexity of productions arrangements, the conclusions derived from an analysis of gross trade flows can yield to misleading conclusions regarding the patterns and benefits of trade. On the other hand, an analysis based on value added trade flows that correctly takes into account the complex production arrangements among countries and the rest of the world would contribute to a clearer understanding of trade relationships. This paper seeks to analyze the bilateral Mexico-United States relationship from a value added perspective by using recently available methodologies and data sets in the form of global input-output tables that allow for obtaining data on the value added contributed by each country to GVCs to get a clearer picture of trade flows related to activities within GVCs. This document is empirical in nature and extends the use of these datasets and methodologies in the context of the bilateral US-Mexico trade relationship in the spirit of Los et al. (2015), Timmer et al. (2015), Koopman et al. (2008), and Wang et al. (2013).

Over the last two decades, world trade and production have become increasingly organized around global value chains. Previously, international trade, to a larger extent, focused on transactions of goods and services for final consumption. Still, processes of trade liberalization and progress in information and communication technologies significantly lowered transportation costs and, hence, favored the cross-border shipment of intermediate goods. Indeed, this has led to a greater leveraging of differences in production costs between countries and has propitiated a fragmentation of the productive process at a global scale, in which different productive stages are located across different countries, based on their respective comparative advantages (Los et al., 2015; Antràs et al., 2012; Feenstra, 1998). Thus, GVCs have encouraged greater specialization and a more efficient use of resources as compared to a situation in which the entire productive process is carried out in a single country. This has positively affected productivity in the different countries they are located in, as well as their welfare levels (Amiti and Wei, 2009).

The fact that global value chains are intensive in intermediate goods and services has also increased the complexity of the linkages among different industries within a given country and across different countries. In most economies, significant amounts of imports are incorporated as inputs in the production of goods and services that are subsequently re-exported. Moreover, the increased complexity has raised the relevance of indirect exports to third countries through other countries' trade flows. Indeed, global value chains can become so complex that a country's imports can contain "returned" value added that was originated in the importing country. In a context in which exports contain a large number of imported products, gross international trade flows are not informative on the performance of a country as an exporter or on the gains it reaps from inserting in global value chains. The fact that a country has a gross trade deficit, overall or in a given sector against another country, does not mean that its output is being displaced or substituted by foreign goods or that it is losing employment, as this deficit could reflect the import of intermediates that are necessary for domestic production, and the generation of domestic employment.

This is of particular relevance in the context of the Mexico – US relation in which the geographic proximity, differentials in production costs and trade openness have led to the emergence of important production partnerships in many sector that have allowed a reduction of costs and increase of competitiveness and welfare for both economies (Caliendo & Parro, 2015). However, the productive linkages between Mexico and the United States have been traditionally analyzed in terms of the evolution of the size and composition of gross bilateral trade flows. This is unfortunate considering that the size of intermediate trade flows between these two countries, the importance of cross-country production arrangements, and the easiness with which goods can cross borders between these countries may lead to a significant distortion of the economic information embedded in gross trade flows. Because official export statistics record transactions in gross terms, the value added contributed by other countries through imported content is registered in the value of exports potentially leading to an overestimation of the value added actually traded by the original exporter. During the last years, a heated debate has emerged in the United States questioning the “fairness” and benefits of this country’s trade relationship with its North American partners, and in particular with Mexico, characterizing this last relationship as an asymmetric one that has allowed Mexico to take advantage of the United States. A central argument for this characterization has been the size of the gross bilateral trade deficit of the United States with Mexico and in fact, the reduction of this deficit was identified as a central objective in the US goals for NAFTA renegotiation. Such characterization fails to recognize the production arrangements and clusters formed within the economic bloc and the high degree of imported content embedded in exports. This situation provides an excellent example of why it is of the upmost importance to count with methodologies that allow accurate representations of production and trade arrangements.

There has been a growing literature in the quantification of sources of value added in either a country’s exports or output by acknowledging production linkages between different countries and sectors. Hummels et al. (2001) proposed the concept of vertical specialization or foreign content or foreign value added in a country’s trade as "the imported input content of exports, or equivalently, foreign value-added embodied in exports" and provided an approach to compute vertical specialization shares based on a country’s input-output table. Johnson and Noguera (2012) combine input-output and bilateral trade data to quantify cross-border production linkages and develop a measure of trade in value added, “value-added exports”, which measures the amount of domestic value added embodied in final expenditure in each destination. The emergence of global input-output tables has sparked a growing literature on global value chains that has increasingly allowed analyzing trade in value added terms. For example, Timmer et al. (2015) explain the construction of the World Input-Ouput

Database (WIOD) and use it to characterize economic linkages in automotive value chains around the world. Los et al. (2015) uses the WIOD to quantify the importance of the external sector and exporting in the Chinese economy. Koopman et al. (2014) also use the WIOD to develop a comprehensive methodology to decompose a country's exports in various components of domestic and foreign value added as well as to take into account double counting components in gross international trade flows arising from the multiple crossing of borders of the same value added. Wang et al. (2013) extend this methodology to decompose exports at a sectoral level. Ignatenko, et al. (2019) use another global input-output dataset, the Eora MRIO, to compute different measures of GVC participation for 189 countries and illustrate global patterns of supply chains as well as their evolution over time.

This paper's main contribution is the use of these methodologies and dataset to study the bilateral Mexico-US trade relationship from a value added point of view in order to generate a more accurate representation of value added flows, rather than gross trade flows. Our results present bilateral trade measures in a manner consistent with the concept of "value added exports" of Johnson and Noguera, 2012. Just as gross exports break down gross output sold across destinations, value-added exports break down GDP sold across destinations. This value-added export measure is more in line with the concept of exports in international models that are written in value-added terms (Johnson, 2014). Furthermore, by providing a clearer view of how countries are linked together via international production arrangements, the paper contributes to break down mercantilist ("us" versus "them") views of trade. While De la Cruz, et. al. (2011) estimate foreign value-added in Mexico's manufacturing exports taking into account the high import content of production in the Maquiladora using an input-output approach in the vein of Hummels et al. (2001), this document is the first, to our knowledge, to use a global input-output dataset to analyze, not only the foreign content in Mexican exports, but also the different sources of value added embedded in bilateral trade flows between Mexico and the US.

Our results show that by taking into account the intermediate trade and production linkages, both between Mexico and the US, as well as with the rest of the world, some of the conclusions that one could derive from the analysis of gross flows are significantly changed.

In particular, the sign of the bilateral trade imbalance in manufacturing goods reverts from that derived from gross trade flows. That is, the US trade deficit in manufacturing with Mexico is actually a surplus in value added terms once we acknowledge that Mexican exports to the United States contain significantly more US value added than the Mexican value added contained in US exports. This overstates Mexican exports in gross terms relative to their value added counterparts due to a sizable foreign value added component. While this result fails to acknowledge other possible sources of trade gains, such as increased variety or improved technology and productivity, it highlights the potential for reaching misleading conclusions on the nature of trade relationships from a mere analysis of gross flows.

The paper will be outlined as follows: Section 2 describes the data, section 3 the methodology employed for quantifying the metrics to assess the Mexican-US bilateral trade relationship by developing a method for the decomposition of sources of valued added for each country's exports; section 4 presents the results; and section 5 concludes.

2. Data

In a GVC world, the production process is globally fragmented and, thus, countries import and then re-export goods pertaining to the same process. This implies that gross exports currently contain large proportions of imported intermediate goods and, as a result, they do not capture a country's contribution to GVCs or, alternatively, its value added embedded in global production. Moreover, the measurement of this value added is further complicated by the complex production linkages between countries and industries implied by the GVCs; e.g., a country's imported inputs to produce final goods for exports could contain value added originated in this country.

In this context, the measurement of the sources of value added in Mexico's and US exports, computed in Section 3, requires the use of data on global input-output tables that track, for each industry and each country, bilateral shipments of gross output for intermediate use and final demand separately and that, as a result, enable to account for the complex production linkages between countries and industries. These global tables are provided by the WIOD, which was constructed by a group of eleven European research institutions and funded by the European Commission (see Timmer et al., 2015).

The WIOD comprises a time series of World Input-Output tables (WIOTs), which provide data on the transactions taken place in the global economy across industries, final consumers and countries. This is graphically illustrated in Table 1, which shows a schematic representation of a WIOT. As shown in this table, columns in WIOTs contain information on the inputs that each industry requires to produce its own output, broken down by industry and country; e.g., the column cell shaded in blue contains the amount of output of industry N in country P required to produce a given amount of industry 1's output in country 1. Rows in WIOTs contain data on the distribution of each industry's output over its different uses (i.e., its uses as intermediate or final good), also broken down by industry and country; e.g., the cells shaded in yellow and green contain data on the amount of output from industry 1 in country 1 used as an input by industry N in country P and the amount of industry 1's output in country 1 used for consumption or investment in country M, respectively.[1]

Table 1. Schematic Representation of a World Input-Output Table

			Intermediate use by country-industry							**Final use by countries**			**Total use**
			Country 1			…	Country P			Country 1	…	Country P	
			Industry 1	…	Industry N	…	Industry 1	…	Industry N		…		
Supply from country-industry	Country 1	Industry 1											
		…											
		Industry N											
	…	…											
	Country P	Industry 1											
		…											
		Industry N											
Value added by labor and capital													
Gross output													

Source: Timmer et al. (2015).

[1] Note that, for each industry, the gross output must equal the sum of all its uses.

Note that, by tracking bilateral purchases of gross output separately for intermediate and final uses for each industry and each country, the WIOD constitutes a useful tool for analyzing GVCs, as illustrated by a number of studies. For instance, Baldwin and Lopez-Gonzalez (2015) use the WIOD to study global patterns in what they call “global supply chain trade;” i.e., trade in intermediate goods used as inputs in domestic production processes. In turn, employing this database, Los et al. (2014) study whether the production process fragments mainly through the formation of production networks between countries within a region. Moreover, Timmer et al. (2015) use the database to study the fragmentation and the regional distribution of value added in global automotive production. Finally, Wang et al. (2013) employ the WIOD to compute the domestic value added embedded in gross exports at the bilateral, sector and bilateral sector levels.

There are two releases of the WIOD. The 2013 release provides annual time series of WIOTs over 1995-2011, covering 40 countries and 35 sectors, mostly at the 2-digit ISIC Rev. 3. The 2016 release enlarges the sample to 43 countries and 56 sectors, mostly at the 2-digit level of ISIC Rev. 4 from 2000 to 2014. These two releases are used, in Section 3, to compute the Mexican value added embedded in US manufacturing consumption and production over 1995-2014; the 2013 release is used to compute this value added for 1995-2011, and the 2016 release is used for 2012-2014. In this regard, it is worth mentioning that in order to make the two releases comparable, the WIOTs contained in the 2016 release are broadly aggregated to the sectoral level with which the 2013 release is presented.

3. Methodology

The objective of this section is twofold. First, we will introduce the traditional input-output approach developed by Leontief (1936) and explain its limitations. Second, motivated by Koopman et al. (2014) and Wang et al. (2013), we construct a backward-linkage approach to decompose gross exports into value added terms, which will be useful to compute the value added bilateral trade balance between the United States and Mexico.

3.1 Introduction to the basic Input-Output approach

In his seminal article, Leontief (1936) developed a methodology to compute the value added generated by an industry using input-output matrices. Johnson and Noguera (2012), in turn, extended this approach to a multi-country analysis. In this section, we introduce this input-output accounting framework.

We assume the existence of *P* countries and *N* industries. Each industry's production takes place using both domestic and foreign inputs. Moreover, this production can be used as an intermediate good for other industries, or as a final good to be consumed —both inside and outside the country. For a particular good, we define *s* as the exporting country, *r* as the destination country (trading partner), *u* as the exporting industry, and *v* as the destination industry. The efficient markets conditions assume that the quantity of output used as inputs or final goods must equal the quantity of output produced:

$$y_s(u) = \sum_r f_{sr}(u) + \sum_r \sum_v b_{sr}(u,v) \tag{1}$$

where $y_s(u)$ stands for industry u output in country *s*. Also, $f_{sr}(u)$ is the value of production of industry *u* for final consumption in destination country *r*, while $b_{sr}(u,v)$ represents industry *u* output that is used as inputs by industry *v* in country *r*. Let us note that this production can be used both inside the producing country (if $r = s$) and outside the country (if $r \neq s$).

We can express this multi-country input-output system using matrix notation:

$$\begin{bmatrix} \boldsymbol{y}_1 \\ \boldsymbol{y}_2 \\ \vdots \\ \boldsymbol{y}_P \end{bmatrix} \equiv \begin{bmatrix} \boldsymbol{A}_{11} & \boldsymbol{A}_{11} & \cdots & \boldsymbol{A}_{1P} \\ \boldsymbol{A}_{21} & \boldsymbol{A}_{22} & \cdots & \boldsymbol{A}_{2P} \\ \vdots & \vdots & \ddots & \vdots \\ \boldsymbol{A}_{P1} & \boldsymbol{A}_{P2} & \cdots & \boldsymbol{A}_{PP} \end{bmatrix} \begin{bmatrix} \boldsymbol{y}_1 \\ \boldsymbol{y}_2 \\ \vdots \\ \boldsymbol{y}_P \end{bmatrix} + \begin{bmatrix} \sum_r \boldsymbol{f}_{1r} \\ \sum_r \boldsymbol{f}_{2r} \\ \vdots \\ \sum_r \boldsymbol{f}_{Pr} \end{bmatrix} \tag{2}$$

where each $\boldsymbol{y}_s$ is a N×1 vector containing the output levels of each industry in country s. $\boldsymbol{A}_{sr}$ is a N×N matrix whose elements $a_{sr}(u,v)$ represent the requirement coefficients that industry *v* in country *r* demands from industry *u* in country *s*. Finally, $\boldsymbol{f}_{sr}$ represents a N×1 vector containing country *r* demand for country *s* final goods.

Equation (2) can be expressed in a reduced form as follows:

$$\boldsymbol{y} = \boldsymbol{A}\boldsymbol{y} + \boldsymbol{f} \tag{3}$$

From which, in turn, we can obtain the input-output identity introduced by Leontief (1936):

$$\boldsymbol{y} = (\boldsymbol{I} - \boldsymbol{A})^{-1}\boldsymbol{f} \tag{4}$$

$\boldsymbol{I}$ is a *NP*×*NP* identity matrix, and $(\boldsymbol{I} - \boldsymbol{A})^{-1}$ is the Leontief inverse matrix, which we define as $\boldsymbol{L}$.

Lastly, by multiplying both sides of equation (4) by a NP×NP diagonal matrix $\boldsymbol{V}$, whose elements contain the value added to gross output ratios of each sector *u* in for every country, we obtain the following expression:

$$\boldsymbol{VA} = \boldsymbol{V}(\boldsymbol{I} - \boldsymbol{A})^{-1}\boldsymbol{f} \tag{5}$$

where $\boldsymbol{VA}$ is a NP×1 vector which contains the value added by each sector *u* in country *s* to fulfill final demand $\boldsymbol{f}$.

3.2 Backward-linkage decomposition of gross exports

As gross trade flows incorporate large amounts of imported intermediate content gross flows, they are less informative on a country's performance as an exporter or on the gains it reaps from its integration into the global economy. As discussed earlier, the increased complexity of global value chains, in which a good's production processes takes place within several countries, hinders the analysis of international trade using gross flows as significant amounts of imported value added are incorporated as inputs in the production of goods and services that are subsequently re-exported. Moreover, the emergence of global value chains has raised the relevance of indirect exports to third countries through other countries' trade flows, as well as "returned" value added that was originated in the importing country.

Koopman et al. (2014) use the WIOD to provide an accounting and analytic framework to decompose the value of gross exports into a number of terms in order to keep track of all production linkages and provide a clearer picture of the bilateral of multilateral trade relations at a country level. Wang et al. (2013) extend this framework so that the export decomposition holds at the bilateral and sectoral levels. Among the main results from this approach is the computation of measures for the domestic and foreign value added content in exports, the amount of local value added embedded in exports that eventually returns to be absorbed in the exporting country, as well as pure double counting terms arising from the fact that value added has crossed borders multiple times.

Wang's approach tracks domestic value added in exports according to where it is ultimately absorbed, allowing to identify a number of relevant economic relationships such as domestic valued added that eventually returns to be consumed by the original exporter, domestic value added ultimately absorbed by third parties other than the direct importer, etc. However, this approach does not provide the same level of tractability for foreign value content in exports. For the purposes of this paper, it would be useful to keep that level of tractability for foreign value added, as this would allow us to identify if there are differences in bilateral content depending on the market for final consumption. In this regard, we construct a novel framework that makes it possible to track the foreign content embedded in gross exports by contributor. In other words, this new approach allows tracking each country's contribution of value added embedded in gross trade flows.

We will illustrate this issue by trying to decompose exports from country *s* to trading partner *r* assuming a global economy consisting of only two countries (*s* and *r*) and one good. Figure 1a shows schematically this decomposition in which exports of final goods from *s* to *r* are shown as a red square. The nodes at the lower levels of the tree depict the input requirements at various stages of production, so that the final exports require a set of inputs from the two countries, which in turn require inputs, and so on for an infinite number of production stages.

Note that this scheme amounts to multiplying $\boldsymbol{f}_{s,r}$ by the Leontief matrix[2]. Thus, the value added decomposition of final exports of country *s* to trading partner *r* is given by:

$$\boldsymbol{VA}_{s,r}{}^{f} = \boldsymbol{V} * \boldsymbol{L} * \boldsymbol{f}_{s,r} \tag{6}$$

where $\boldsymbol{f}_{s,r}$ is defined as a vector with zeros in all rows except those corresponding to country *s* which contain the value of final good exports of country *s* to trading partner *r* and $\boldsymbol{V}$ and $\boldsymbol{L}$ are defined as in the previous section. Thus, each row in vector $\boldsymbol{VA}_{s,r}{}^{f}$ contains the value added contribution of each industry/country to the production of final good exports of country *s*. Note that the value added contributed by each sector in each country *s* includes not only the value added embedded in the final goods exports of that sector, but all the value added embedded in all final goods exports. That is, it includes the value added by each sector that was eventually exported either directly or indirectly through other sectors in country *s*. For example, the value added contributed by the textile sector is not only the one embedded in textiles goods for final consumption abroad, but also the value added contributed to an exported automobile through, say, carpets.

Since we are interested in decomposing all exports from *s* to *r* and not only final goods exports, it would seem that we should multiply the value of *s* exports of inputs used in trading partner's *r* output ($\boldsymbol{A}_{sr}\boldsymbol{x}_r$) by the Leontief matrix. However, note that a subset of these intermediate exports has already been accounted for in equation (6). These cases are represented by all blue nodes connected to white nodes within the red area in Figure 1a. Nevertheless, it is important to highlight that many exports remain unaccounted for (blue nodes connected to white nodes in the green areas in Figures 1a and 1b). Also, note that decomposing these exports is not as straightforward as multiplying a final demand vector by the Leontief matrix as was done before. The next paragraphs provide further information regarding how to address this issue.

We will follow an iterative approach to try to account for these instances. Note that an industry also exports value added through its participation in other global value chains whose

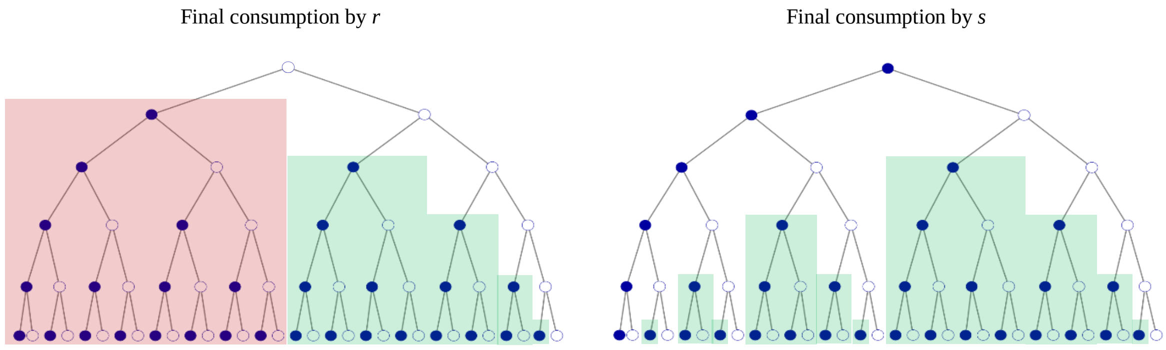
[2] The Leontief matrix is (NP x NP), while $\boldsymbol{f}_{s,r}$ is (N X 1). Therefore, it amounts to pre-multiplying a vector (NPX1) with the positions corresponding to country s are equal to $\boldsymbol{f}_{s,r}$ and zeros elsewhere.

final product is not necessarily a final export by the country *s*. Thus, for example, an industry exports value added if its products are used as inputs in the production of final consumer goods by other countries. It also exports value added if its products are used as an input that is used for the production of a final good demanded in the same country *s*. We will denote this value added exported through inputs in global value chains that do not end in an export of final goods of the country *s* as $\boldsymbol{VA_{s,r}}^{\boldsymbol{i}}$**.**

Figure 1. Schematic representation of global value chain production processes in a two country and one good economy

a) Production process to fulfill country *r* demand of final goods

b) Production process to fulfill country *s* demand of final goods



Source: Prepared by the authors.

In addition to exports contained in the red area of Figure 1a, which have already been accounted for in equation (6), it is of interest to account for the value added embedded in the exports of intermediates contained in the shaded green areas, that is, the added value, in all stages of production, required to produce inputs of *s* required by *r*. It should be noted that once an export from *s* to *r* has been identified, all the previous steps in that chain must be accounted for, since we want to quantify all the production required to produce said export. Returning to the *N* countries and *P* sectors framework, $\boldsymbol{VA_{s,r}}^{\boldsymbol{i}}$ is defined formally as:

$$\boldsymbol{VA_{s,r}}^{\boldsymbol{i}} = \boldsymbol{V} * \boldsymbol{L} * \boldsymbol{A_{sr}} * (\boldsymbol{I} - \boldsymbol{J})^{-1} \boldsymbol{f_i} \quad (7)$$

where $\boldsymbol{f_i} = \boldsymbol{f} - \boldsymbol{f_f}$; $\boldsymbol{J} = \boldsymbol{A} - \boldsymbol{A_{sr}}$ and $\boldsymbol{A_{sr}}$ is the *NP*×*NP* input requirement matrix with zeros in every position except in those corresponding to the production of country *s* for use of trading partner *r*. The derivation of equation (7) is presented in the Annex 1, following an iterative algorithm.

Thus, the valued added exported by country *s* to trading partner *r* is equal to the value added contained in the set of final goods exported from *s* to trading partner *r* plus the value added embedded in the exports of intermediate inputs required in the production of other final goods either at country *s* or abroad:

$$\boldsymbol{VA_{s,r}}^{\boldsymbol{x}} = \boldsymbol{V} * \boldsymbol{L}[\boldsymbol{f_f} + \boldsymbol{A_{sr}}(\boldsymbol{I} - \boldsymbol{J})^{-1}\boldsymbol{f_i}] \qquad (8)$$

where $\boldsymbol{VA_{s,r}}^{\boldsymbol{x}}$ is an NPx1 vector in which the *i*-th row represents the value added that the *i*-th industry/country contributed to country *s* exports to the trading partner *r*. If *r* is defined as all countries other than *s*, the rows in $\boldsymbol{VA_{s,r}}^{\boldsymbol{x}}$ represent the value added contributed by each industry/country to country *s* total exports. Likewise, the $\boldsymbol{VA_{s,r}}^{\boldsymbol{x}}$ positions corresponding to the country's industries represent the value added that each sector of this country eventually exports, regardless of whether said export was direct through final goods or indirectly through other global value chains.

By using equation (8) and summing the rows of $\boldsymbol{VA_{s,r}}^{\boldsymbol{x}}$ corresponding to all industries of a given country, we can calculate how much value added embedded in the US gross exports to Mexico was produced within the US, how much was provided by Mexico and how much by third countries. Ultimately, summing all these terms, we would get the total gross exports from the United States to Mexico, as follows:

$$X_{US,MX} = DVA_{US,MX}^{US} + FVA_{US,MX}^{MX} + \sum_{i \neq MX}^{N} FVA_{US,MX}^{i} \qquad (9)$$

where:

$DVA_{US,MX}^{US}$: is the US domestic value added embedded in its gross exports to Mexico.

$FVA_{US,MX}^{MX}$: is the Mexican value added embedded in the US gross exports to Mexico.

$FVA^{i}_{US,MX}$: is the country *i* value added embedded in the US gross exports to Mexico.

Similarly, we can decompose the Mexican exports to the United States following the same criteria:

$$X_{MX,US} = DVA^{MX}_{MX,US} + FVA^{US}_{MX,US} + \sum_{i \neq US}^{N} FVA^{i}_{MX,US} \tag{10}$$

where:

$DVA^{MX}_{MX,US}$: is the Mexican domestic value added embedded in its gross exports to the US.

$FVA^{US}_{MX,US}$: is the US value added embedded in the Mexican gross exports to the US.

$FVA^{i}_{MX,US}$: is the country *i* value added embedded in the Mexican gross exports to the US.

Thus, the US gross bilateral trade balance with Mexico (B) is:

$$B = X_{US,MX} - X_{MX,US} \tag{11}$$

Rearranging based on the decomposition described above, the gross trade balance may be expressed as:

$$B = \underbrace{\left(DVA^{US}_{US,MX} - DVA^{MX}_{MX,US}\right)}_{(I)} + \underbrace{\left(FVA^{MX}_{US,MX} - FVA^{US}_{MX,US}\right)}_{(II)} + \underbrace{\left(\sum_{i \neq MX}^{N} FVA^{i}_{US,MX} - \sum_{i \neq US}^{N} FVA^{i}_{MX,US}\right)}_{(III)} \tag{12}$$

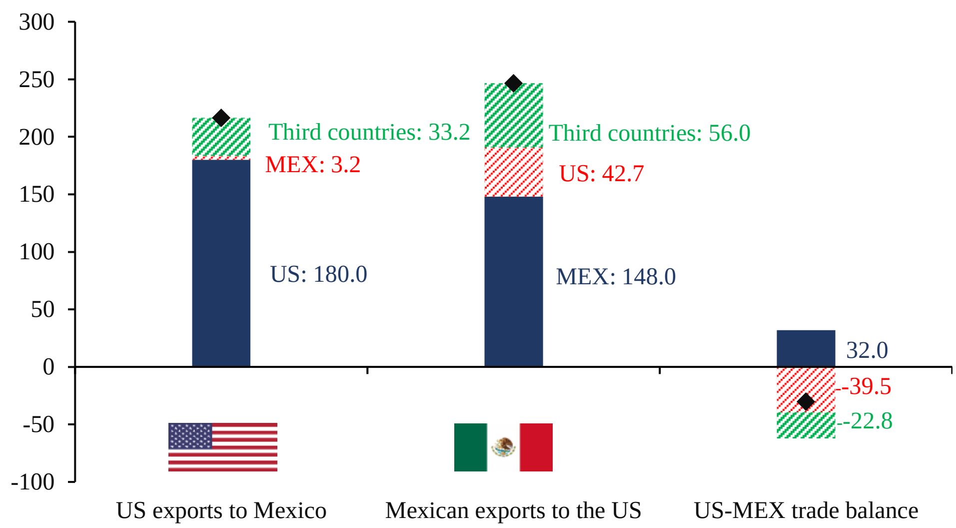
Equation (12) shows that the gross bilateral trade balance between the United States and Mexico (B) equals the sum of three terms on the right-hand side of the equation: (I) the domestic value trade balance; (II) the foreign value added trade balance coming from the direct trading partner; (III) the foreign value added trade balance coming from third countries.

4. Results

In this section we contrast the US-Mexico bilateral trade relationship using domestic value added vs gross flows**.** Based on equation (12), Figure 2 illustrates the decomposition of the bilateral manufacturing gross exports flows between the US and Mexico for 2014. The left-side column shows that out of the 216.4 USD billion manufacturing exports to Mexico, 180 billion corresponded to US domestic content, 3.2 billion to Mexican content and 33.2 billion to content from third countries. Conversely, in 2014 Mexico exported 246.7 USD billion in manufacturing in gross value to the US, 148 billions of which were Mexican content, 42.7 billions were US content and 56 billions content from third countries. Note that the blue columns represent the domestic content in each country's bilateral exports, the red areas represent the foreign value content in each country's exports from the direct trading partner, and the green area represent the foreign value content coming from other trading partners. The breakdown of each country's exports by value added source allows for decomposing the gross bilateral trade balance into the sum of balances of sources of value added. As a result, while the United States had a gross manufacturing trade deficit with Mexico of 30.3 USD billion, this value becomes a 32 USD billion surplus once we only take into account each country's domestic content; i.e. more value added was created in the United States than in Mexico due to the bilateral trade relationship. This result has been overlooked in the gross balance by the fact that the balance of foreign value added in bilateral exports is negative for the US. That is, Mexican exports contain a larger amount of US value added than the Mexican value added embedded in US exports to Mexico (the negative red area in the third column of Figure 2), and the content of value added from third countries is also larger in Mexican exports to the United States than in US exports to Mexico (negative green area in the third column of Figure 2).

Figure 2. US-Mexico manufacturing gross exports and trade balance decomposition (2014)

USD billion



Note: Black diamonds represent the gross manufacturing exports and trade balance.

Source: Authors' own estimates using data from the World Input-Output Database and the US Trade Department.

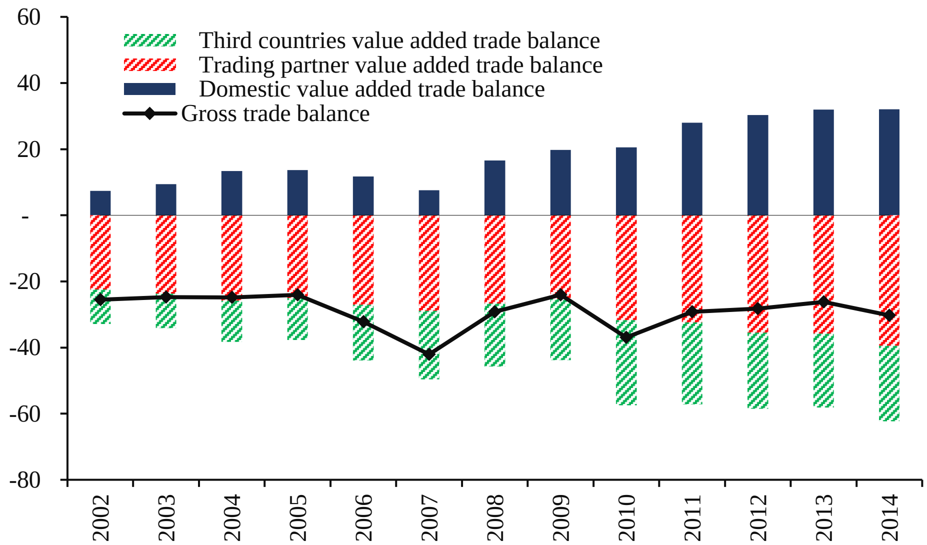
Figure 3 shows that, while the US gross manufacturing trade deficit has remained significant since 2002, its value added surplus has increased consistently throughout time. Equation (12) terms (II) and (III) explain the source of mismatch between the gross and value added trade balances as:

- The balance of returned value added from the direct trading partner (term II). It refers to the content of the direct trade partner (United States or Mexico) in the exports of both countries. Thus, the gross balance overestimates the US deficit, as the US value added content in Mexican exports is significantly higher than the Mexican content in US exports. Figure 3 shows that this term has increased its relevance across time.

- The balance of the foreign value added unrelated to the bilateral relation (term III). This term measures the intensity of third countries' value added content and increases the US gross trade deficit insofar as the foreign value added from other countries contained in Mexican exports is higher than the content in the US exports. The importance of this term has slightly increased throughout the period.

Figure 3. US-Mexico manufacturing gross trade balance decomposition

USD billion



Note: Black diamonds represent the manufacturing gross trade balance.

Source: Authors' own estimates using data from the World Input-Output Database and the US Trade Department.

Table 2 shows the comparison of US gross and domestic value added trade balances with Mexico for different sectors such as agriculture, mining and manufacturing. Similar patterns can be observed at the sectoral and aggregate levels: once we exclude the foreign value added from the analysis, significant differences between the gross and domestic value added trade balances arise, particularly for those sectors importing significant amounts of intermediate goods to be used as inputs. For instance, the United States has a trade surplus with Mexico in electronics in terms of value added, rather than the deficit indicated by gross trade flows. Similarly, US trade deficits in transport and electrical equipment decreases substantially after restricting the analysis to the domestic value added trade balances actually exchanged in these sectors' bilateral exports. It is important to note that sectoral exports contain value added from other industries as the bilateral sectoral gross balance is decomposed by using equations (9) and (10).

Table 2. US-Mexico sectorial trade balance (2014)

	Gross trade balance	Domestic value added trade balance
All commodities	-54.07	9.80
Agriculture	-3.00	-2.48
Mining	-20.82	-19.74
Manufacturing	-30.25	32.02
Electronics	-11.04	17.84
Transport equipment	-59.46	-32.97
Chemicals	19.12	17.20
Machinery	4.02	5.64
Electrical equipment	-8.54	-0.15
Basic metals	1.01	0.67
Manufacturing n.e.c.	24.64	23.79

Source: Authors' own estimates using data from the World Input-Output Database and the US Trade Department.

Thus, our methodology for decomposing gross exports into the components of local content not only includes value added generated in the same exporting sector, but also the contribution from all industries within the local economy to the production of exports of a particular sector. In this sense, a sector's exports represent a direct exports' vehicle for the sector itself, but also an indirect exports' vehicle for the value added of other sectors. Table 3 presents the share of local value added contained in bilateral manufacturing exports of Mexico and the United States that was exported indirectly (that is, the value added of a sector contained in the exports of another sector). It can be observed that in most sectors the US exports serve as vehicles of indirect exports to a greater degree, relative to Mexican exports.

Table 3. Domestic value added indirectly exported through an industry different from the one that generated it (2014)

Percentage of total domestic value added

Industry	In US exports	In Mexican exports
Food and beverages	64.00	45.32
Basic metals	63.54	51.03
Textiles and apparel	58.76	34.07
Transport equipment	58.60	42.39
Wood	57.56	46.05
Paper	57.09	47.11
Machinery	50.61	42.67
Non metal minerals	48.91	38.56
Electrical equipment	45.64	49.04
Chemicals	35.69	50.80
Electronics	19.37	40.82

Source: Authors' own estimates using data from the World Input-Output Database and the US Trade Department.

Finally, Table 4 presents a comparative analysis of the US trade manufacturing balance with its main trade partners. A clear difference can be seen in the nature of the US trade relation with the NAFTA members and countries that are not part of the agreement. Thus, in most cases, the United States exhibits significant trade deficits outside of NAFTA both in gross terms and in value added. On the contrary, the balances in the value added with other NAFTA members represent a significant surplus for the US, once the high content of the imported value added in the exports among its members is accounted for considering the complex productive linkages within the block.

Table 4. US manufacturing trade balance with selected economies (2014)

USD billions

	Gross trade balance	Value added trade balance
Canada	53.4	83.0
Mexico	-30.2	32.0
NAFTA	**23.1**	**115.0**
Germany	-73.8	-47.3
China	-368.1	-300.1
Korea	-30.7	-12.7
India	-23.6	-15.9
Japan	-75.2	-52.9
United Kingdom	-1.5	5.7

Source: Authors' own estimates using data from the World Input-Output Database and the US Trade Department.

5. Conclusions

The complexity of global production arrangements has eroded the economic information content in gross trade flows. This has given rise to concerns that gross trade data distort perceptions about the nature of international integration and the role of particular countries in international markets, which in turn leads to tensions in the world trade system. The fragmentation of production processes and the high content of imported inputs requires the use of data sources and methodologies that allows the tractability of transactions between countries and industries similarly to how domestic transactions occur. This paper uses the World Input-Output Database (WIOD) and recent methodologies in the Global Value Chains literature to analyze the Mexico-US bilateral economic relation from a value added perspective. Despite some general limitations of input-output models, our results provide a strong case for the need to analyze value added instead of gross trade balances in the bilateral US-Mexico trade relationship arising from the fact that such analysis yield qualitatively opposite conclusions. In particular, by taking into account all intermediate trade linkages of both Mexico and the United States with each other and the rest of the world, the sign of the bilateral trade imbalance in manufacturing goods reverts from that derived from gross trade flows. That is, the US trade deficit in manufacturing with Mexico is actually a surplus in value added terms once we acknowledge that Mexican exports to the United States contain significantly more US value added than the Mexican value added contained in US exports to Mexico. This causes Mexican exports to be overstated in gross terms relative to their value added counterparts due to a sizable foreign value added component. Similar patterns can be observed at the sectoral level. That is, once we exclude the foreign value added from the analysis, significant differences between the gross and domestic value added trade balances arise, mostly towards an increase of the sectoral US trade balances, particularly for those sectors importing significant amounts of intermediate goods such as electronics and transportation equipment. Furthermore, the nature of the relationship of the United States with its North American trade partners seems to be markedly different due to the strong productive integration amongst these economies. In this regard, the United States maintain a value added trade surplus in manufacturing with both Mexico and Canada while it keeps trade deficits with other important trading partners both in gross and in value added terms.

6. References

Amiti, M., & Wei, S.-J. (2009). Service Offshoring and Productivity: Evidence from the US. *The World Economy, 32(2).*

Antràs, P., Chor, D., Fally, T., & Hillberry, R. (2012). Measuring the Upstreamness of Production and Trade Flows. *The American Economic Review, 102(3),* 412-416.

Baldwin, R., & Lopez-Gonzalez, J. (2015). Supply-chain Trade: A Portrait of Global Patterns and Several Testable Hypotheses. *The World Economy, 38(11),* 1682-1721.

Caliendo, L., & Parro, F. (2015). Estimates of the Trade and Welfare Effects of NAFTA. *The Review of Economic Studies 82(1),* 1-44.

De La Cruz, J., Koopman, R. B., Wang, Z., & Wei, S. J. (2011). Estimating Foreign Value-added in Mexico's Manufacturing Exports (pp. 1-33). US Internat. Trade Commission, Office of Economics.

Feenstra, R. C. (1998). Integration of Trade and Disintegration of Production in the Global Economy. *Journal of Economic Perspectives, 12(4)*, 31-50.

Hummels, D., Ishii, J., & Yi, K.-M. (2001). The nature and growth of vertical specialization in world trade. *Journal of International Economics, 54(1)*, 75-96.

Ignatenko, A., Raei, F., & Mircheva, B. (2019). Global Value Chains: What are the Benefits and Why Do Countries Participate? *IMF Working Paper WP/19/18*.

Johnson, Robert C. (2014). "Five Facts about Value-Added Exports and Implications for Macroeconomics and Trade Research." Journal of Economic Perspectives, 28 (2): 119-42.

Johnson, R. C., & Noguera, G. (2012). Accounting for intermediates: Production sharing and trade in value added. *Journal of International Economics, 86(2)*, 224-236.

Koopman, R., Wang, Z., & Wei, S.-J. (2008). How Much of Chinese Exports is Really Made In China? Assessing Domestic Value-Added When Processing Trade is Pervasive. *NBER Working Paper No. 14109*.

Koopman, R., Wang, Z., & Wei, S.-J. (2014). Tracing Value-Added and Double Counting in Gross Exports. *The American Economic Review, 104(2)*, 459-494.

Leontief, W. W. (1936). Quantitative Input and Output Relations in the Economic Systems of the United States. *The Review of Economics and Statistics, 18(3)*, 105-125.

Los, B., Timmer, M. P., & de Vries, G. (2015). How important are exports for job growth in China? A demand side analysis. *Journal of Comparative Economics, 43(1)*, 19-32.

Los, B., Timmer, M. P., & de Vries, G. J. (2014). How global are global value chains? A new approach to measure international fragmentation. *Journal of Regional Science, 55(1),* 66-92.

Timmer, M. P., Dietzenbacher, E., Los, B., Stehrer, R., & de Vries, G. J. (2015). An Illustrated User Guide to the World Input–Output Database: the Case of Global Automotive Production. *Review of International Economics, 23(3)*, 575-605.

Wang, Z., Wei, S.-J., & Zhu, K. (2013). Quantifying International Production Sharing at the Bilateral and Sector Levels. *NBER Working Paper No. 19677*.

Annex 1

In this section we derive equation (7), i.e. the value added embedded in intermediate exports from country *s* to *r*, that were not used in the production process of its final exports, by using an iterative approach. We make use of Figure 1 to explain the intuition. First, we want to identify all exports from country *s* at upstream stages of production and compute the embedded value added by multiplying them by the Leontief matrix. By doing so, we are calculating all output at downstream stages of production, including those corresponding to country's s exports used as inputs to produce the upstream set of exports. This step corresponds to the largest green areas in Figures 1a and 1b. Note, however that there are still country's s exports unaccounted for in downstream stages of production. We identify those exports in the immediate previous stage and multiply this amount by the Leontief matrix and so on.

Formally, let $\boldsymbol{f_i}$ be a vector containing all countries' final goods and services demand excluding the exports of final goods and services from country *s* to *r* so that $\boldsymbol{f_i} = \boldsymbol{f} - \boldsymbol{f_{s,r}}$. Country *s* exports used as inputs for the production of $\boldsymbol{f_i}$ can be represented as:

$$\boldsymbol{f^s}_{\boldsymbol{n}} = \boldsymbol{A_{sr}} * \boldsymbol{f_i} \tag{1a}$$

Note that $\boldsymbol{f^s}_{\boldsymbol{t}}$ represents the exports used as inputs in the final stage of production *t* for the final output vector $\boldsymbol{f_i}$. $\boldsymbol{A_{sr}}$ is the requirement coefficients matrix with zeros in every entry except in those corresponding to the production of *s* used by *r*. This expression allows us to identify the blue node at the top of the largest green areas in Figure 1a and 1b. This term will be multiplied by the Leontief matrix to decompose its value added components.

To account for the remaining exports by country *s* at downstream stages, note that the production of *r* at stage *t* is equal to:

$$\boldsymbol{f^r}_{\boldsymbol{t}} = \boldsymbol{A} * \boldsymbol{f_i} - \boldsymbol{A_{sr}} * \boldsymbol{f_i} \tag{2a}$$

This can be expressed as:

$$\boldsymbol{f^r}_{\boldsymbol{t}} = [\boldsymbol{A} - \boldsymbol{A_{sr}}] * \boldsymbol{f_i} \tag{3a}$$

In turn, the exports of inputs from country *s* in the previous stage $(t-1)$ results from multiplying $\boldsymbol{f^r}_{\boldsymbol{t}}$ by $\boldsymbol{A_{sr}}$, similarly to equation (1a).

$$\boldsymbol{f^s}_{\boldsymbol{t-1}} = \boldsymbol{A_{sr}} * \boldsymbol{f^r}_{\boldsymbol{t}} \tag{4a}$$

Iterating this process for infinite stages allows us to identify all the remaining intermediate exports from *s* to *r* that have not been accounted for in the production of final good exports by country *s*.

We define $\boldsymbol{E_{s,r}}$ as the sum of these intermediate exports at the various stages.

$$\boldsymbol{E_{s,r}} = \sum_{i}^{\infty} \boldsymbol{f^s}_{\boldsymbol{t-i}} \tag{5a}$$

Equation (5a) can be expressed as:

$$\boldsymbol{E_{s,r}} = \boldsymbol{A_{sr}} * \boldsymbol{f_i} + \boldsymbol{A_{sr}} * \boldsymbol{J} * \boldsymbol{f_i} + \boldsymbol{A_{sr}} * \boldsymbol{J^2} * \boldsymbol{f_i} + \boldsymbol{A_{sr}} * \boldsymbol{J^3} * \boldsymbol{f_i} + \cdots \tag{6a}$$

where $\boldsymbol{J} = \boldsymbol{A} - \boldsymbol{A_{sr}}$. Factoring (6a) we get:

$$\boldsymbol{E_{s,r}} = \boldsymbol{A_{sr}} * [\boldsymbol{I} + \boldsymbol{J} + \boldsymbol{J^2} + \cdots] * \boldsymbol{f_i} \tag{7a}$$

Since $[\boldsymbol{I} + \boldsymbol{J} + \boldsymbol{J^2} + \boldsymbol{J^3} + \cdots]$ can be expressed as $(\boldsymbol{I} - \boldsymbol{J})^{-\boldsymbol{1}}$:

$$\boldsymbol{E_{s,r}} = \boldsymbol{A_{sr}}(\boldsymbol{I} - \boldsymbol{J})^{-\boldsymbol{1}} \boldsymbol{f_i} \tag{8a}$$

Finally, multiplying both sides of equation (8a) by $\boldsymbol{V}$**,** which is a diagonal matrix whose entries contain the value added to gross output ratios for each industry, and by the Leontief matrix $\boldsymbol{L}$:

$$\boldsymbol{VA_{s,r}}^{\boldsymbol{i}} = \boldsymbol{V} * \boldsymbol{L} * \boldsymbol{A_{sr}} * (\boldsymbol{I} - \boldsymbol{J})^{-\boldsymbol{1}} \boldsymbol{f_i} \tag{9a}$$