

Who produces for whom in the world economy?¹

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Abstract: For two decades, the share of trade in inputs, also called vertical trade, has been dramatically increasing. In reallocating trade flows to their original input-producing industries and countries, this paper suggests a new measure of international trade: “value-added trade” and makes it possible to answer the question “who produces for whom?”. In 2004, 27% of international trade was vertical trade. The industrial and geographic patterns of value-added trade are very different from those of standard trade. Value-added trade is relatively less important in regional trade but the difference is not more important for Asia than for America. JEL Classification: F15, F19

Résumé: La part du commerce en produits intermédiaires dans le commerce international, appelé aussi “commerce vertical”, n’a cessé d’augmenter depuis vingt ans. Cet article propose une nouvelle mesure du commerce international “le commerce en valeur ajoutée” qui réalloue les flux commerciaux aux pays et aux secteurs produisant les intrants. Les répartitions géographique et sectorielle du commerce en valeur ajoutée sont très différentes de celles du commerce « standard ». La différence entre le commerce en valeur ajoutée et le commerce standard est plus importante dans le cas du commerce régional mais ce n’est pas plus le cas en Asie qu’en Amérique.

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Introduction

The expansion of international trade since the end of the 1980s has largely been supported by the emergence of a new international production scheme based on the cross-border production (variously named delocalization, disintegration of production, fragmentation, global production sharing, international outsourcing, slicing up the value chain, processing trade, etc. as Feenstra (1998) reminds). Different stages of production are spread across a range of sites in multiple countries. This vertical specialization of production is based on a new international division of labour that is moving away from the traditional division, where production is split up between primary and manufactured goods. The segmentation of production is becoming increasingly subtle, perhaps in order to make the best of the “kaleidoscope” of each country’s comparative advantages, as explained in Bhagwati and Dehejia (1994).

This new international division of labour has logically induced an acceleration of trade flows as a growing number of inputs including intermediate goods, are crossing several borders. The multiplication of input trade has been facilitated by cuts in tariff and nontariff barriers within the framework of bilateral and multilateral trade agreements: according to Yi (2003), vertical specialization is especially sensitive to trade costs, as it implies an increase in the number of borders crossed by each good.

In this context, it is well known that international trade statistics fail to offer a good picture of trade integration and the global division of labour. They cannot answer the question “who produces for whom?”. Let us take a different example from the canonical Barbie doll and Nike shoe to illustrate the point, extracted from Benhamou (2005). The firm Burberry sends bottles of French perfume to Shanghai to be decorated with a Scottish pattern before bringing them back to be sold on the French market. Standard trade statistics suggest that France is exporting perfume bottles to China and China is exporting perfume bottles to France. Yet France does not export anything for Chinese consumption, as the perfumes are consumed in France. China simply exports decoration for French consumption. Suppose the pigments used for the decoration of the perfume bottles are imported by China from Japan. This Japan-China trade flow does not mean that China consumes Japanese products, as the final consumer is in France. Unravelling these long supply chains is impossible using simply trade statistics.

Likewise, East Asia and also Europe have experienced a growing regionalization of their trade². We could wonder say if this process is due to a regional self centred development or the vertical production. Probably, the extent of regionalization is exaggerated by the importance of vertical trade: Asian trade as a whole is still very dependent on final demand from the other continents, especially America. And only a value added trade measure can illustrate this dependency and allow to answer to the question “who produces for whom in the world economy?”. This could modify the vision we have of regionalisation process based on the degree of trade intensity to a vision based on the importance of local final market.

For that, we have to consider all the stages of production of a final good in order to track the value-added coming into its production from each sector and each country. Inputs in the first, second, third and subsequent stages must be isolated before being reallocated to their original industries and countries. This can be done only thanks to a coherent worldwide set of intermediate delivery matrices and bilateral trade matrices. This advocates the study of trade flows using “value-added trade”.³ This paper’s contribution is to use coherent trade and input-output data from the GTAP to. It computes value-added trade for 66 regions and 55 sectors in 1997, 2001 and 2004. It also computes value-added trade for 113 regions in 2004.⁴The GTAP database includes the necessary information and is presented in its whole in Dimaranan (2006).

In a first section, we define vertical trade and value added trade and the existing approaches. The second section presents the data base and the method of computing value-added trade. In a third section, our results on vertical trade and value-added trade are compared to results obtained by other methods. This section shows the extent to which standard trade statistics give a distorted picture of the relative openness of different sectors. A much larger part of the output of the services sector is exported than what is suggested by standard trade statistics: they undervalue the vulnerability of service workers to international competition. It also shows the different degree of participation of various countries in vertical trade, for example, as re-exporters of imported inputs. The openness rate of many countries is overvalued by standard measures of

2 Kwan (2001), Chortareas and Pelagidis (2004).

3 It has long been recognized that trade and GDP are not directly comparable, because trade is not measured in terms of exchanged value-added: Irwin (1996), Feenstra (1998), Cameron and Cross (1999).

4 Similar exercises using 1997 and 2001 GTAP data can be found in: Belke and Wang (2005), Daudin, Riffart, Schweisguth and Veroni (2006) and Johnson and Noguera (2010). All these researchers seem to have developed their methods independently.

trade. The fourth section discusses bilateral vertical trade, including regionalization. Looking at value-added trade decreases the extent of regionalization of world trade, but less so for Europe than for America and Asia. It also allows the identification of the ultimate producers of imports. It shows that American producers are not as much as competing with Chinese workers but with others situated in America and Europe as well. A Technical Appendix is added at the end of the article and a Statistical Appendix with detailed tables and descriptions have been put online.

1 Vertical trade

1.1 What is it?

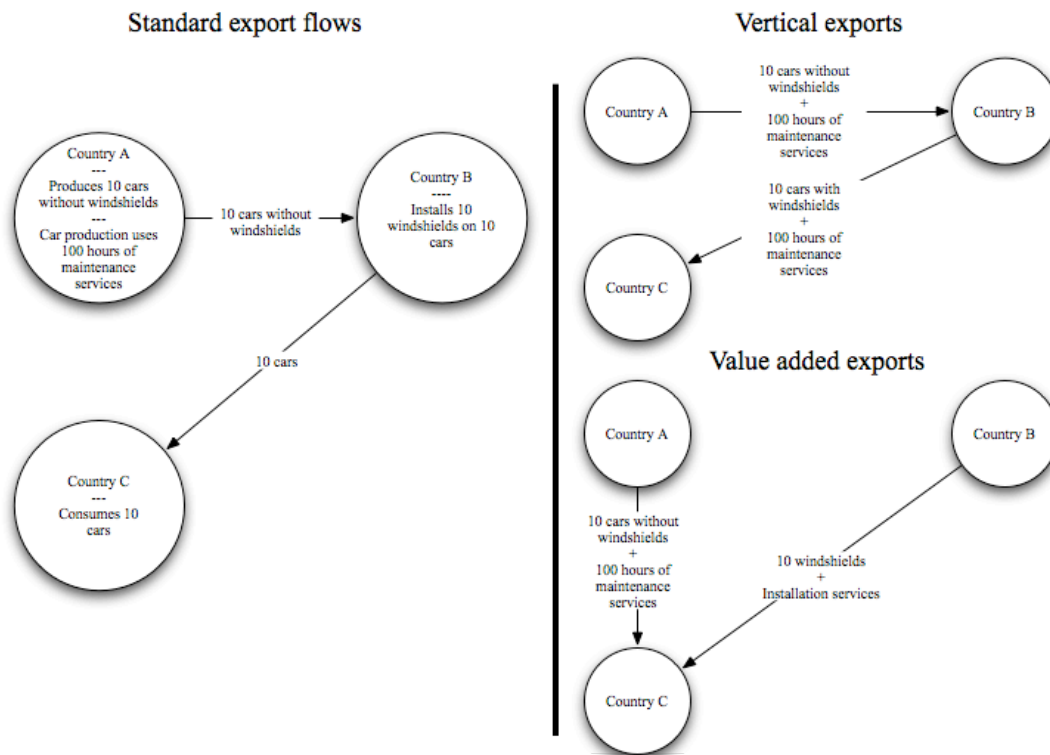
This paper follows the definition given by Hummels, Rapoport and Yi (1998). There is vertical specialization of trade (or “vertical trade” for short) as soon as:

- the production of a good follows a sequential process that can be broken down into several stages;
- at least two countries take part in this production process;
- at least one country imports inputs to produce the goods, at least some of which are exported in turn.

Based on this definition, two different measures of trade can be identified. The first, which we call “standard trade”, measures trade flows based on their market value when they cross borders. When exported goods contain a high proportion of imported inputs, their market value can be very high compared to their locally produced value-added. This measure can lead to a very high trade-to-GDP ratio, sometimes exceeding 100% as in Singapore (165%), Luxembourg (135%), Malaysia (115%), Malta (101%) and Estonia (108%). The other measure, called “value-added trade”, measures trade net of vertical trade and reallocates the value-added produced at the different stages of the production process to each of the participating countries and industries. Value-added trade thus measures only the trade flows between the producer and the final user.

Let us take the example of three countries: A, B and C.

Figure 1: Three ways to look at the same export flows



The left side of the figure shows total export flows as they appear in standard trade statistics (for shorthand, “standard trade”). First, country A exports 10 cars without windshields to country B. Then, country B installs the windshields and exports the finished goods to C to be consumed. The exported goods are classified as exports of manufacturing goods (motor vehicles and parts), but they contain 100 hours of maintenance services.

The top right figure shows the calculation of vertical exports. “Cars without windshields” are counted twice in standard trade statistics: once when they are exported from A to become inputs in B and once when they are exported from B for consumption in C. These flows indicate the integration of the production process between countries A and B.

The bottom right figure shows “value-added” exports as it appears in our data. The value-added export flows shows that no final user in B utilizes goods from A. B is just used as an intermediate (or transit) country for A. All the final users of country A’s exports are in country C. So the only value-added exports that B realizes with C are the windshields that are produced in B and used as a final product in C. That means that country A’s exports do not depend on the final demand of country B, but on the final demand of C. They

depend on B solely as a place of transformation. Furthermore, standard trade flows suggest that country A does not export services but only manufacturing goods. Yet its services production is being consumed, once it is embedded in cars, in country C. In that sense, country A is exporting services too.

Value-added export flows can also change our assessment of regionalization. Imagine that country A and country B are in the same region, but not country C. In this example, standard export flows suggest that intra-regional export flows are nearly as important as extra-regional export flows. Yet value-added export flows suggest that intra-regional export flows are nil in the sense that no one in country A or B is consuming cars produced in the region. Both countries are producing for C's consumption. A depends on B as a transformation centre for its exports to C. This is a different case of regionalization than one in which country A actually depends on B as a final market for its goods. In our example, the regionalization is based only on vertical trade.

1.2 How can vertical trade be measured?

In his survey of literature, Feenstra (1998) presents three ways of measuring the Vertical trade. The first is to use firm surveys, as in the work of Hanson, Mataloni Jr and Slaughter (2005). But these are only available for a limited number of countries (notably, the United States and Japan) and present a number of limitations. They have been used to study trade in intermediate inputs by multinational firms.

A second method is to use a fine industrial classification of trade.⁵ For example, Athukorala and Yamashita (2006) have measured vertical trade for most countries in the world in the context of the five-digit SITC, Rev 3 classification, by treating some goods belonging to categories 7 (machinery and transport equipment) and 8 (miscellaneous manufactured articles) as component inputs. They find that world trade in components increased from 18.5 percent to 22 percent of world manufacturing exports between 1992 and 2003. This method cannot be extended to measure the value-added trade.

The third and most traditional method is to use input-output tables.⁶ The most extensive use of this

⁵ E.g., Fontagné, Freudenberg and Ünal-Kesenci (1996), Ng and Yeats (1999), Yeats (2001) (this paper also use data coming from special favourable treatment for re-imported domestically-produced components), Ng and Yeats (2003), Egger and Egger (2005).

⁶ E.g., Fontagné (1991), Campa and Goldberg (1997).

method has been by Yi and his various co-authors (these papers are subsequently referred as “Yi et al.”).⁷ They calculated international vertical specialization trade, defined as the share of imported inputs in exports, using input-output matrices for 10 OECD and 3 non-OECD countries.⁸ In their computations, Yi et al. take into account imported goods directly used as inputs for the production of exports, but also imported inputs used for the production of domestic inputs used in the production of exports: they call all these flows “VS” for vertical trade. Hummels, Ishii and Yi (1999, 2001) extrapolate their results to the rest of the world. They found that the ratio of VS to world merchandise exports was equal to 18% in 1970 and 23.6% in 1990.

Looking at VS from the point of view of the partner countries, purely domestically-produced exports can also be part of vertical trade if they are subsequently used by partner countries as inputs in their own exports: Yi et al. call this flow “VS1”. Computing VS1 is more difficult than computing VS. VS can be computed using solely the intermediate delivery matrix of the reporting country, whereas VS1 requires matching bilateral trade flow data with intermediate delivery matrices for all trading partners.⁹ By construction, VS in the exports of country A is equal to VS1 in the exports of all other countries to country A. For the world as a whole, VS is equal to VS1. One can further distinguish the part of VS1 that comes back to the country of origin: VS1*. VS1* is defined as the exports that are, further down the production chain, embedded in re-imported goods that are either consumed, invested, or used as inputs for domestic final use. VS1* is the domestic content of invested or consumed imports. A typical example is trade in motor vehicles and parts between the United States and Mexico. When the United States imports cars from Mexico for its own consumption, motors made in the US are part of VS1*.

A country’s vertical trade is equal to twice the sum of VS and VS1* (as they must be removed from both exports and imports). Subtracting this sum from total standard trade yields total value-added trade. At the world level, removing double counting, value-added trade is equal to world trade minus VS and VS1*.

$$\textit{World value-added trade} = \textit{Standard world trade} - \textit{vertical trade} = X - (VS + VS1^*)$$

This relation is not true at the level of specific bilateral trade relations, as, for example, value-added

⁷ Ishii and Yi (1997), Hummels, Rapoport and Yi (1998), Hummels, Ishii and Yi (1999), Hummels, Ishii and Yi (2001); Yi (2003); Chen, Kondratowicz and Yi (2005).

⁸ Hummels, Rapoport and Yi (1998), Hummels, Ishii and Yi (2001).

⁹ VS1 is computed from some case studies in Hummels, Rapoport and Yi (1998) and from input-output tables in Hummels, Ishii and Yi (1999).

trade between two countries could be higher than standard trade if all trade is conducted through an intermediary country.

$$\text{Value-added exports from country A to country B} = \text{Standard exports from country A to country B} - (VS + VS1) + \text{Value-added from A embedded in the exports of other countries to B (also called Indirect value added trade)}$$

Similarly, value-added exports in an industry could be higher than standard exports in this sector if all exports are embedded as inputs in the exports of another industry.

$$\text{Value-added exports for an industry} = \text{Standard exports for this industry} - (\text{value-added from other domestic industries embedded in these exports} + VS + VS1^*) + \text{value-added embedded in the exports of other domestic products}$$

The method in this paper is similar to that of Hummels et al., but we compute VS for all the countries in three years: 1997, 2001 and 2004. Furthermore, because we use world wide input-output tables reconciled with bilateral trade statistics, we can also compute VS1 and VS1* and reallocate vertical trade to its initial producer. That cannot be done by Hummels et al. They de facto assume that the domestic content in imported inputs VS1* is nil.

Our method and our data are the same as that of Johnson and Noguera (2010).¹⁰ We believe our papers complement each other. The presentation of their method is more formal than ours and might be clearer to some readers. We use data for 1997, 2001 and 2004, whereas they use data only for 2004 with 87 regions. We are interested in regionalization processes, which they do not consider. Their method is superior to ours in one aspect: they adjust the GTAP data in the case of China and Mexico to take into account the specificities of the processing trade. We do not do that, though we recognize the specificity of processing trade is an important issue for our computations.¹¹ Ideally, it would need to be treated on a global scale rather than for two countries: this is a terrain for future research. Not taking this into account leads to an

10 For what it is worth, we claim precedence, as our first publication using this method was Daudin, Riffart, Schweisguth and Veroni (2006). It was, alas, published in a little-read language.

11 See the discussion *infra*. However, the resulting difference can be important for specific countries. For 2004, we find a ratio of world value-added exports to standard exports equal to 73%, which is the same as their result. In China, they find 59%, we find 65%. The biggest difference is for Mexico: they find 52%, we find 72%. (Table 1 in Johnson and Noguera (2010))

underestimation of the importance of vertical trade.¹² The fact that we still find interesting results confirms the importance of taking into account vertical trade to understand the world division of labour.

2 How to compute trade flows in value added?

2.1 The GTAP database

Computing international trade flows in value-added requires the use of input-output tables and in particular the use of intermediate deliveries matrices reconciled with bilateral trade data. In the 1930s, Leontief (1936) computed the first input-output tables and laid the foundations of input-output (I-O) analysis. This branch of economics has in turn nourished general equilibrium modelling, allowing for the construction of computable economic models that rely on the Leontief inverse matrix, as in Hanson, Mataloni Jr and Slaughter (2005). Such models can also be used for the study of international trade. For this purpose, I-O tables must be reconciled with bilateral trade data. This has been done by the Global Trade Analysis Project (GTAP). For additional information, refer to <http://www.gtap.agecon.purdue.edu>

In this paper, we work with versions 5 (for 1997 data), 6 (for 2001 data) and 7 (for 2004 data) of the GTAP database. These three versions cover the same number of industries: 57 sectors (or commodities). Yet the geographical precision has considerably increased between version 5 and version 7. The 1997 year includes only 66 “regions” (countries and zones). The 2001 version includes 87 “regions” and lastly, 2004 includes 113 “regions”. So we calculate an aggregated database with 66 regions and 57 sectors to compare the evolution of vertical trade and regionalization process over these three respective years (see online appendix). We use the 2004 version to carry out the analysis of regional integration in more detail. The database provides aggregated final demand and input-output tables. In each input-output table, two full

¹² True, there is an underestimation for the “normal” sector and an overestimation for the “processing” sector. However, on the whole, there must be an underestimation as long as a larger share of “processed” production is exported. Here is the formal proof in the case of the import content of exports.

Let us call a the share of production exported, b the share of imported inputs and normalize the size of the economy to 1. We have a processing sector of size p_1 (with associated shares a_1 and b_1) and a normal sector of size p_2 (with associated shares a_2 and b_2). We have $p_1 + p_2 = 1$. We want to show that: $p_1 a_1 b_1 + p_2 a_2 b_2 - ab \geq 0$ with $a_1 > a_2$ and $b_1 > b_2$

We have $a = p_1 a_1 + p_2 a_2$ and $b = p_1 b_1 + p_2 b_2$

Hence $ab = p_1^2(a_1 b_1 - a_2 b_1 - a_1 b_2 + a_2 b_2) + p_1(a_2 b_1 + a_1 b_2 - 2a_2 b_2) + b_2 a_2$

Hence: $p_1 a_1 b_1 + p_2 a_2 b_2 - ab = p_1^2(a_2 b_1 + a_1 b_2 - a_1 b_1 - a_2 b_2) + p_1(a_1 b_1 - a_2 b_1 - a_1 b_2 + a_2 b_2) = p_1(1 - p_1)(a_1 - a_2)(b_1 - b_2)$, which is positive. QED.

intermediate deliveries matrices are available: one for domestic inputs and one for imported inputs from the rest of the world. It also provides information on bilateral international trade by industry (including service trade).

Despite the quality of this database, it is still imperfect. Original trade and input-output data come from national statistical offices and in spite of standardization efforts, statistical conventions differ among countries. Furthermore, some national statistical offices are too understaffed to produce reliable data.¹³ The GTAP team (McDougall, 2006) has imposed some assumptions on input-output data in order to reconcile them with trade data and to correct discrepancies. Data that exclusively concerns a single country, like input-output tables, are less reliable than trade data, as they cannot benefit from double checking with data from partner countries. For that reason, the I-O tables bear the brunt of the fitting procedure. The amplitude of these changes can sometimes be very important.¹⁴ Moreover, the input-output data used in the GTAP are not systematically updated between the different versions.¹⁵ As a consequence, comparisons between different years can be misleading, as the underlying structure of the economy is assumed to have stayed the same. Finally, some regions are poorly detailed, particularly in the 1997 and 2001 versions, e.g., the developing countries in the 1997 version. In the 2004 version, a considerable number of African and European countries have been added in the database. Africa still remains aggregated, but improvements are expected in the next versions. As a result, regional African trade appears smaller than it is, even in the 2004 version. Clearly, the more aggregated the countries of a continent, the smaller its absolute intra-regional trade appears to be.

It could be argued that these defects make the GTAP database a markedly inferior source for the computation of vertical trade than the data used up to now in the existing literature. However, the originality of our paper is that it re-allocates input trade flows to their initial producers. The only way to do that is to use

13 For example, we have stressed the importance of intra-firm trade. This kind of trade can bias our methodology if firms set their transfer prices in order to redirect their profits to countries where the tax burden is lower. According to IMF rules, transfer prices must correspond to market prices in the country of origin and prices set by firms can be modified by customs and the tax authority. Nonetheless, some biases may persist.

14 The largest changes between the initial and the fitting I-O tables tend to be found in small economies, such as Cyprus, Malta, Botswana and the composite region of the “Rest of SADC” in GTAP 6. In contrast, the changes are relatively small in the largest industrialised countries, including Japan, the United States and the United Kingdom..

15 Considerable effort has been put into updating data for some big countries in the last version. The I-O data for the United States, Canada and Mexico came from 1990 in the 2001 version and from 2002 or 2003 in the 2004 version. Data for the United Kingdom, France and Germany came from, respectively, 1990, 1992 and 1995 in the 2001 version and from 2000 in the 2004 version. Data from Italy still comes from 1992 in the 2004 version.

reconciled input-output and trade data and the GTAP is the best source of such information, as the community of compatible general equilibrium economists recognizes. One can only hope better quality data will arise in time.

2.2 Theoretical foundation of the calculation¹⁶

2.2.1 A closed economy

In a closed economy with n industries and products, equilibrium between output and final demand requires that for each product, output is equal to the sum of intermediate deliveries and of final demand:

$$P = A P + FD \quad (1)$$

in which P is a $n \times 1$ vector of output, FD is a $n \times 1$ vector of final demand and A is a $n \times n$ matrix of input coefficients taken from the intermediate deliveries matrix. This matrix is composed of elements a_{ij} , defined as the amount of product i required for the production of one unit of product j .

Assuming that the matrix A is fixed¹⁷, this yields the following relation:

$$P = (I-A)^{-1} FD \quad (2)$$

In which I is the $n \times n$ identity matrix and $(I-A)^{-1}$ the Leontief inverse matrix derived from the input coefficients matrix A . This relation is a well-known result in input-output analysis that links the final demand of each product and the production. It gives the total direct and indirect effects of an increase in final demand on the production of each industry.¹⁸

Furthermore, each output vector P is itself associated with a value-added vector VA :

$$VA = P - \text{diag}(P) A' I \quad (3)$$

where $\text{diag}(P)$ is the $n \times n$ matrix having the elements of P on its diagonal and 0 elsewhere, A' is the transpose of matrix A and I is the identity column vector filled by 1s. Each element of $\text{diag}(P) A' I$ gives the

16 This is discussed in greater depth in Daudin, Riffart, Schweisguth and Veroni (2006).

17 This assumption is needed to derive the I-O model. It means that all inputs are required in a fixed proportion of the output. This implies a production function with constant returns to scale.

18 $(I-A)^{-1}$ is derived from the expression $I+A1+A2+A3+\dots$, where I is used to calculate the direct effect linked to the increase in final demand, $A1$ is the first-order matrix used to calculate the production of inputs required by the increase of final demand, $A2$ is the second-order matrix used to calculate the production of inputs required by this increase of input demand, $A3$, etc. The sufficient condition to derive the A matrix is that all the leading principal minors be positive (Hawkins Simon Conditions). A minor of a matrix is the value of a determinant. The principal leading minors of an $n \times n$ matrix are evaluated on what is left after the last m rows and columns are deleted, where m runs from $(n-1)$ down to 0.

value of the required input to produce each element of P .¹⁹

Hence, substituting (1) into (2), the value-added vector VA associated with the final demand vector FD is equal to:

$$VA = (I - A)^{-1} FD - \text{diag}((I - A)^{-1} FD) A' I \quad (4)$$

2.2.2 Opening up a single economy

Before moving to the study of value-added trade, let us compute VS (the imported inputs used in exports).

Let a $n \times 1$ vector Im give the imports used for the production of each sector.

Let X be a $n \times 1$ vector of exports (part of final demand). Following (2), the production of all the inputs for X requires a total domestic production of $(I-A)^{-1}X$. VS , the amount of imports required to produce X can hence be defined as :

$$VS = Im - ((I-A)^{-1}X)$$

2.2.3 Value-added trade

We can transpose this writing to the world as a whole using an inter-country input-output table. To do this, the world is considered in the same way as a single closed economy with c countries, each one containing n sectors. We assume that each sector in each country produces a very specific product, which is produced nowhere else and which is not substitutable with any other product. The construction of the appropriate matrixes is detailed in the appendix and discussed in Hoen (2002).

Applied to the world, the previous equations (1), (2) and (3) can be rewritten as:

$$P^* = (I - A^*)^{-1} FD^*$$

$$VA^* = P^* - \text{diag}(P^*) A^{*' } I \quad (5)$$

$$VA^* = (I - A^*)^{-1} FD^* - \text{diag}((I - A^*)^{-1} FD^*) A^{*' } I \quad (6)$$

Where

P^* is the $nc \times 1$ vector of output by country and by industry,

FD^* is the $nc \times 1$ vector of final demand by country and by industry,

¹⁹ In contrast, $A P$ gives the vector of output used as inputs for further production.

A^* is the $nc \times nc$ input coefficients matrix showing all the inter-industrial and inter-regional trade of inputs all over the world (See Technical Appendix for its construction). A^* being a fixed matrix, A^* can be transposed into $A^{*'}$,

and VA^* is the $nc \times 1$ vector of value added, provided by country and by industry.

Equation (6) allows the computation of the value-added production required by the consumption or investment of any final product. It is possible to use this formula to compute the effects of an increase in final demand on the value-added sector:

$$\Delta VA^* = (I - A^*)^{-1} \Delta FD^* - \text{diag}((I - A^*)^{-1} \Delta FD^*) A^{*'} I \quad (7)$$

Assuming that fd_i^a and va_j^b are items of the vectors FD^* and VA^* , with a and b for the countries and i and j for the products or industries, a one unit change in a final product i_0 of a country a_0 , $fd_{i_0}^{a_0}$ will generate an increase in the value added va_{j,i_0}^{b,a_0} of any sector j of any country b .

If $b \neq a_0$, va_{j,i_0}^{b,a_0} will be considered as a value-added export from the sector j of the country b to the sector i_0 of the country a_0 . The total export in value added from country b to country a_0 can be written as

$$X_{VA}^{b,a_0} = \sum_{i_0=1}^n \sum_{j=1}^n va_{j,i_0}^{b,a_0}, \forall b \neq a_0$$

If $b = a_0$, va_{j,i_0}^{b,a_0} will be domestic value-added production from sector j to sector i_0 in country a_0 .

2.2.4 Exports that are ultimately consumed at home

Let us call all non- a_0 countries ROW . We can treat the ROW as a single economy with $n(c-1)$ sectors. This economy exports $n(c-1) \times 1$ vector X_{ROW} to country a_0 . Out of these exports, X_{ROW}^* are ultimately used for final usage in country a_0 . This excludes those that are re-exported as inputs by country a_0 . Let us call the imports from a_0 used in the production of each sector Im_{ROW} .

Using similar notation to 2.2.2. we can define $VS1^*$, the amount of imports from country a_0 used in exports for final usage in country a_0 :

$$VS1^* = Im_{ROW} \cdot (I - A_{ROW})^{-1} X_{ROW}^*$$

From the point of view of country a_0 , $VS1^*$ are its own exports that it consumes or invests.

2.3 Calculation and limitations

2.3.1 Input-output coefficient

In our case, the exact matrix A^* is unknown. As far as we know, no statistical institute diffuses the use of imports (as inputs to specific sectors or final consumption) by one country from another country. We follow the procedure of “limited information multi-country input-output models”, as described in Hoen (2002). To approximate A^* , we use the domestic and imported intermediate delivery matrices and the geographical origin of trade by product as reported by the GTAP. The imported intermediate delivery matrix provides the amount of imported inputs in each sector. The trade data provides the share of each trade partner in imports. We approximate the elements $a_{i,j}^{a,b}$ of matrix A^* with $a_{i,j}^{a,b}$ being the coefficient of imported inputs by the sector i of country a in product j from country b and defined as (see appendix):

$$a_{i,j}^{a,b} = c_{i,j}^{a,row} * \left(\frac{m_j^{a,b}}{m_j^{a,row}} \right)$$

in which $c_{i,j}^{a,row}$ is the coefficient of imported inputs by the sector i of country a in product j from the rest of the world, $m_j^{a,b}$ is the import of country a from country b in product j and $m_j^{a,row}$ is the total imports of country a in product j from the rest of the world. In the case where $a=b$, $a_{i,j}^{a,a}$ is the amount of inputs used by sector i produced by sector j in country a . It is given by the domestic input coefficient matrix of country a .

The underlying assumption is that, for a specific importing country and a specific partner, the share of an imported product used as input by a sector is the same as is the product imported from the rest of the world²⁰. This hypothesis is very common and is used for example in Campa and Goldberg (1997) and Feenstra and Hanson (1997).

This is a severe approximation, because we know, for example, that the origin of inputs used in exports is probably different from the origin of inputs used in domestic consumption. Multinational firms producing in process-heavy countries, like China, are more likely to import more foreign goods as inputs and export

²⁰ This key assumption can be illustrated by an example. A given country imports 100 of grain, of which 30 from the US. Of the 100, 20 are used as input to make bread, 70 to make beer and 10 go to final consumption. According to our assumptions, of the 30 US grain, 6 will go to make bread, 21 to make beer and 3 will be consumed.

more than the average of the industry as a whole. This practice is encouraged by the existence of fiscal support for process activities, e.g., duty-drawbacks systems like in China and Vietnam or more generally “Export Processing Zones” (more than 3,500 exist in 130 countries²¹). This can also be encouraged by higher quality requirements in foreign markets. This issue has long been recognized, as in Hummels and al (1998) and has been extensively studied in the case of China.²² Koopmans, Wang and Wei (2008) show that the method we use underestimates by 50% the amount of imported content in Chinese exports. Implementing their method for China and the other countries in our data would require using more detailed trade statistics than those available in the GTAP and extends beyond the ambitions of this paper. Rather than trying to measure vertical trade finely, the goal of this paper is to give a first approximation of the effects of reallocating input trade to its original producer. It must be kept in mind that this paper underestimates vertical trade throughout, especially for developing Asian countries (see *supra*, note 12). The extent of the underestimation will depend both on the exporting country and the exporting sector.

2.3.1 Taking into account margin services

Data on foreign trade flows also need some price amendments. First, we look at all flows at what the GTAP calls “market prices”, i.e., prices inclusive of export or import taxes or subsidies, but exclusive of domestic taxes or subsidies. We are not studying the complex issues linked to the effect of vertical trade on tariff escalation, for example. Volumes of imported goods are measured by the GTAP — for example, in the intermediate deliveries tables — in import market prices. Such prices include production prices, transport costs and insurance costs as well as taxes levied on imports. However, to make the link between imports and production in the country of origin, we must measure the volumes of imported goods used as intermediate deliveries or as final demand at production prices. To transform import prices into production prices, we apply a constant ratio along the different usage of each good. This is equivalent to assuming that goods produced by a specific industry in a specific country bear the same transport cost and the same export or import taxes or subsidies, whatever their use in the importing country. This seems reasonable, except that our

21 Singa Boyenge (2007). Countries with more than 500,000 workers in EPZs are: China (40 M), Indonesia (6 M), Bangladesh (3.4 M), Mexico (1.2 M), Philippines (1.1 M), Vietnam (1 M), Pakistan (0.9 M), UAE (0.6 M) and South Africa (0.5 M).

22 Chen, Cheng, Fung and Lau (2005), Dean, Fung and Whang (2008), Koopman, Wang and Wei (2008).

industry aggregation is not very fine.

The difference between import market prices and export market prices includes transport, maintenance and insurance costs. It is called ‘margin services utilization’ in the GTAP database. The database does not indicate whether margin services linked to a trade flow were provided by a firm in the importing country, a firm in the exporting country or a firm in a third country. The only data available are the share of each country in the total supply of transport services linked to total international trade flows. Following Robert A. McDougall’s precious advice from the GTAP diffusion list, we have assumed that each country supplies a constant share of the transport services used in international trade flows.²³ According to this assumption, France, which contributes to 4.8% of the transport services used in international trade, contributes 4.8% of the transport services used in trade between Germany and France and to 4.8% of the transport services used in trade between Germany and the United States and between the United States and, for example, Canada. This methodology is thus biased, as it overestimates the trade openness of the transport sector and its relative importance in international trade. Nonetheless, this bias does not bear serious consequences on our core results, which concern the comparison between apparent and value-added trade flows and such measures are equally influenced by the above-mentioned treatment of transport services. Moreover, there is less bias in this method than when using a measure of international trade flows at import prices, as the latter include all transport costs (while we subtract those allocated to the importing country) and import and export duties.

3 Value-added trade in general

3.1 Comparing with previous measures

Before developing our own results, we compare them with the results of Yi et al. Our frameworks are very similar: we use the same definition of vertical trade and work from intermediate delivery matrices. However, Yi et al. do not use reconciled trade / input-output data and cannot reallocate vertical trade flows to their original producers and so do not compute value-added trade.

Yi et al. calculated the share of imported inputs in merchandise exports (VS) for 10 OECD countries

²³ We thank Robert A. McDougall for this suggestion. We bear full responsibility for the choice we have made, however.

and 4 emerging countries, including inputs for inputs, using OECD input-output tables up to the end of the 1990s.²⁴ To compare with their results, we computed the same share using the same method for the same countries. For most countries, the data is for 1997, but we supposed that the comparison stays valid with a 2-year gap. That is the case for France, Germany and Australia. Comparison was not possible for four countries, as the latest data from Yi et al. refer to the beginning of the 1990s (Canada, Korea, Ireland and Italy). Nevertheless, for informational purposes we prefer to show all the results in Table 1.

We do not diverge systematically in any way from the results by Yi et al. and the rank of countries, classified according to the vertical trade content in their exports, remains the same. The difference between Yi et al.'s results and ours is larger than two percentage points for only two countries (Netherlands, Denmark). And if we keep in mind that these countries are large traders, the gap is really not so high. The difference is smaller than two percentage points for five countries: France, Germany, Japan, the United Kingdom and the United States. As indicated in McDougall (2006, table 19-4) and Walmsley (2006, table 11.A.1.), the differences are not correlated with the amount of change resulting in the Input-Output table from the trade / Input-Output reconciliation process, nor do they seem to be linked with the origin of the Input-Output tables in the GTAP.

24 Hummels, Ishii and Yi (1999) Tables 2 and 3, Hummels, Ishii and Yi (2001), pp 84-85, Chen, Kondratowicz and Yi (2005), p 42, Table 2.

Table 1: Share of imported inputs (VS) in merchandise exports: comparing our results with those of Yi et al.

		Yi et al.'s results for the following year	Authors' results for 1997	Difference
Netherlands	1997	40.7%	44.9%	4.2%
Denmark	1997	28.6%	35.0%	6.4%
UK	1997	27.2%	25.6%	-1.6%
France	1995	27.1%	25.9%	-1.2%
Germany	1995	22.4%	23.3%	0.9%
Australia	1995	15.7%	13.8%	-1.9%
USA	1997	12.3%	11.6%	-0.7%
Japan	1997	11.3%	10.0%	-1.3%
Korea	1993	30.1%	33.0%	-2.9%
Italy	1992	22.5%	31.3%	8.8%
Canada	1990	27.0%	32.1%	5.1%
Ireland	1990	27.8%	46.0%	18.2%

Sources: Hummels, Ishii and Yi (2001), Chen, Kondratowicz and Yi (2005), authors' calculations based on GTAP5 data for year 1997.

Hummels et al. provide estimation for the share of VS in merchandise exports in 1970 and 1990. Table 2 presents the results, together with other information. The combined results suggest that, as a share of merchandise trade, vertical trade increased by 55% from 1970 to 2004. Of course, this estimation of the growth of vertical trade is very flimsy, as the data are not really comparable (not even between different GTAP years) and are based on a quite limited sample before 1997. Still, it is probably the best one available for the time being.

Table 2: Evolution of various measures of vertical trade through time

	1970	1990	1997	2001	2004
	(Hummels et al.)	(Hummels et al.)	(66 regions)	(87 regions)	(113 regions)
Share of VS in merchandise exports	18%	23.6%	25.8%	27.4%	28.0%
Average annual growth rate of the share of VS in merchandise exports		1970-1990 +1.6%	1990-1997 +1.3%	1997-2001 +1.6%	2001-2004 +0.7%
Share of all VS in all exports			23.5%	24.8%	25.7%
Share of vertical trade in world exports			25.5%	26.8%	27.5%

Sources: Hummels, Ishii and Yi (2001), authors' calculations based on GTAP data for 1997, 2001 and 2004.

3.2 Industrial classification

Table 3 and table 4 give the share of imported inputs in exports (VS), the share of exports used as inputs for further exports (VS1), the share of domestic content of invested or consumed imports in exports (VS1*) and value-added trade per industry. (For a more detailed industrial breakdown, see table 12 and table 13 online.) As expected, exports of raw materials and semi-finished products are very often used as inputs in further exports: VS1 is over 40% for plant fibres, minerals nec and metals. Finished goods are intensive in imported inputs: VS is higher than 30% for petroleum and coal products, electronic equipment, motor vehicles and parts exports. Electronic equipment has both a high VS and a high VS1, suggesting higher vertical specialization. VS1* is not very important (1,8 % in average) but yet it is interesting to compare it to value-added trade: VS1* is especially high in wood and papers industry, chemical and metals, metal and transport products, suggesting that these industries produce goods as inputs for re-imported assembly production in other countries. It is probably underestimated and dominated by the trade of the United States

and other large economies.

Table 3: Vertical and value-added trade per industry (2004)

Sectors	Total exports (billions US\$)	Import content of exports	Exports consumed or invested domestically	VA from other domestic sectors embedded in exports	VA embedded in other domestic sectors' exports	Ratio of VA exports over standard exports	Exports used as inputs in further exports
	X	VS/X	VS1*/X	as a share of X	as a share of X		VS1/X
	(1)	(2)	(3)	(4)	(5)	100%-(2)-(3)- (4)+(5)	
Agriculture	239	14%	1.3%	30%	58%	112%	17%
Raw materials	688	11%	1.3%	16%	26%	98%	36%
Primary sector	927	12%	1.3%	19%	34%	102%	31%
Farm industries	453	21%	0.4%	49%	10%	39%	10%
Textiles et al.	561	30%	0.7%	37%	7%	39%	18%
Wood and paper	361	22%	1.9%	35%	27%	67%	22%
Chemicals and metals	1,971	30%	1.8%	34%	16%	50%	37%
Metal and transport products	1,315	30%	1.5%	35%	9%	42%	21%
Other manufactures	2,662	33%	1.0%	32%	5%	39%	26%
Utilities	80	19%	8.8%	33%	287%	326%	14%
Secondary sector	7,404	30%	1.4%	35%	13%	47%	26%
Communication and trade	1,056	20%	3.3%	24%	93%	146%	24%
Business services	727	13%	4.6%	21%	109%	170%	24%
Other services	274	10%	1.8%	25%	58%	121%	8%
Tertiary Sector	2,056	16%	3.5%	23%	94%	151%	22%
All sectors	10,387	26%	1.8%	31%	31%	73%	26%

Source: Authors' calculations based on GTAP7 data for 2004.

Table 4: Industry breakdown of trade (2004)

Sector	Share of total exports	Share of total value-added exports	Ratio of VA exports over standard exports	Standard openness rate (exports/industry's GDP)	Value-added openness rate (Value-added exports/industry's GDP)
Agriculture	2.3%	3.6%	112%	19%	21%
Raw materials	6.6%	8.9%	98%	67%	66%
<i>Primary sector</i>	8.9%	12.5%	102%	41%	41%
Farm industries	4.4%	2.4%	39%	41%	16%
Textiles et al.	5.4%	2.9%	39%	111%	43%
Wood and paper	3.5%	3.2%	67%	42%	28%
Chemicals and metals	19.0%	13.1%	50%	90%	45%
Metal and transport products	12.7%	7.3%	42%	100%	42%
Other manufactures	25.6%	13.9%	39%	123%	48%
Utilities	0.8%	3.5%	326%	3%	9%
<i>Secondary sector</i>	71.4%	46.3%	47%	66%	31%
Communication and trade	10.2%	20.4%	146%	14%	20%
Business services	7.0%	16.4%	170%	10%	18%
Other services	2.6%	4.4%	121%	3%	3%
<i>Tertiary Sector</i>	19.8%	41.2%	151%	8%	12%
All sectors	100.0%	100.0%	73%	27%	20%

Source: Authors' calculations based on GTAP7 data for 2004.

At the industry level, value-added trade cannot be computed as total trade minus vertical trade. In addition to the “usual” vertical trade effect (imports used in exports), value-added trade is reallocated to its initial producer industry. As a result, some sectors have more value-added trade than they have export trade: that means they are mainly traded as inputs in other goods. This is especially strong for the tertiary sector: total value-added exports in business services are 70% higher than standard exports. This is also true for utilities and some agricultural raw materials. Industries with a high share of VS or VS1 have a small value-added trade compared to standard trade (metal and transport products and “other manufactures”, including electronics). The share of the secondary sector in total value-added trade (46%) is much smaller than its share in total standard trade (74%). On the other hand, the value-added trade share of the primary sector is higher: 13% against 9%. This is also the case for the value-added share of the tertiary sector: 41% against 20%. This is not a surprise and serves to check that our method gives the expected results.

Standard trade statistics give a wrong idea of the relative dependence on international demand of different sectors. The openness rate of the secondary sector is equal to 66% of the sectoral value added, yet a large part of secondary exports are formed by embedded tertiary or primary sectors’ value-added. As a result, openness rate of the secondary sector in value added is equal to only 31% of the secondary sector’s value-added. *A contrario*, the openness rate in value-added of the tertiary sector is equal to 12% though the tertiary exports are equal to only 8% of the tertiary value-added. This must be taken into account in order to understand who produces for whom in the world economy.

Table 5 provides the evolution through time of the ratio of value-added exports to total exports by sector. The input-output tables are not strictly comparable, which makes this a bit difficult to interpret. If this is to be believed, it shows that value-added exports in services have tended to increase compared to standard exports, whereas value-added exports in industry have tended to decrease.

Table 5: Ratio of VA exports over standard exports, 1997, 2001 and 2004

Sector	1997	2001	2004
Agriculture	118%	121%	113%
Raw materials	98%	87%	100%
<i>Primary sector</i>	<i>105%</i>	<i>99%</i>	<i>103%</i>
Farm industries	41%	45%	40%
Textiles et al.	45%	46%	39%
Wood and paper	70%	68%	68%
Chemicals and metals	57%	55%	50%
Metal and transport products	44%	43%	42%
Other manufactures	44%	42%	39%
Utilities	264%	376%	329%
<i>Secondary sector</i>	<i>51%</i>	<i>51%</i>	<i>47%</i>
Communication and trade	121%	129%	145%
Business services	183%	161%	169%
Other services	185%	179%	121%
<i>Tertiary Sector</i>	<i>147%</i>	<i>146%</i>	<i>151%</i>
All sectors	74%	73%	73%

Note: For 2004, this table is not exactly comparable to Table 4, col 4. Table 4 uses GTAP7 with a 113-region partition of the world. This table uses a 66-region partition of the world coherent with the GTAP database of 1997. See Online Statistical Appendix for a detailed description. Source: Authors' calculations based on GTAP data for 1997, 2001 and 2004.

3.3 Value-added trade at the country level

Table 6 displays some measures of vertical trade and value-added trade by continent in 2004. Table 7 gives the measure of vertical trade by continent for 1997, 2001 and 2004. In Europe, this share declined from 29.2% to 27.8%. Asia's vertical trade has been growing the fastest. In 1997, 26.3% of Asian trade was vertical trade, which increased to 33.3% in 2004. In the last section, we will study the relationship between the rise of Asian vertical trade and growing Asian regionalization.

Table 6: Vertical and value-added trade per region, 2004

Continent	Total trade (in billions \$)	Import content of exports as a share of total trade	Exports consumed or invested domestically	Share of vertical trade in total trade	Share of exports used as inputs for further exports	Ratio of standard trade to GDP	Ratio of value-added trade to GDP
	(I+X)	$2*VS/(I+X)$	$(2*VS1^*)/(I+X)$	$2*(VS+VS1^*)/(I+X)$	(VS1/X)	(I+X)/(2*GDP)	$\frac{[(I+X)-2*(VS+VS1^*)]}{(2*GDP)}$
Asia Pacific	5,489	32.2%	1.0%	33.6%	26.9%	28.6%	19.1%
America	4,414	16.9%	4.5%	21.4%	23.2%	15.4%	12.1%
Europe and peripheries	9,62	27.1%	1.2%	28.2%	25.6%	37.0%	26.5%
Africa and Middle-East	1,251	17.3%	0.5%	17.9%	28.6%	39.6%	32.5%
World	20,774	25.7%	1.8%	27.5%	25.7%	26.9%	19.5%

Note 1: Europe and peripheries includes Turkey, Russia and the former USSR. Asia Pacific includes Oceania and excludes the Middle East. Africa and Middle East includes Iran and the countries of the Arabian Peninsula (Western Asia). Trade inside blocks of the GTAP database is not taken into account.

Note 2: In this table as in the next ones, imports are computed at export prices.

Source: Authors' calculations based on GTAP7 data for 2004.

Table 7: Share of vertical trade in total trade - $2*(VS+VS1^*)/(I+X)$, 1997-2004 (66-region)

Continent	1997	2001	2004
Asia Pacific	26.3%	29.6%	33.3%
America	20.1%	20.4%	21.3%
Europe and peripheries	29.2%	29.7%	27.8%
Africa and Middle-East	17.0%	17.9%	16.9%
World	25.5%	26.6%	27.2%

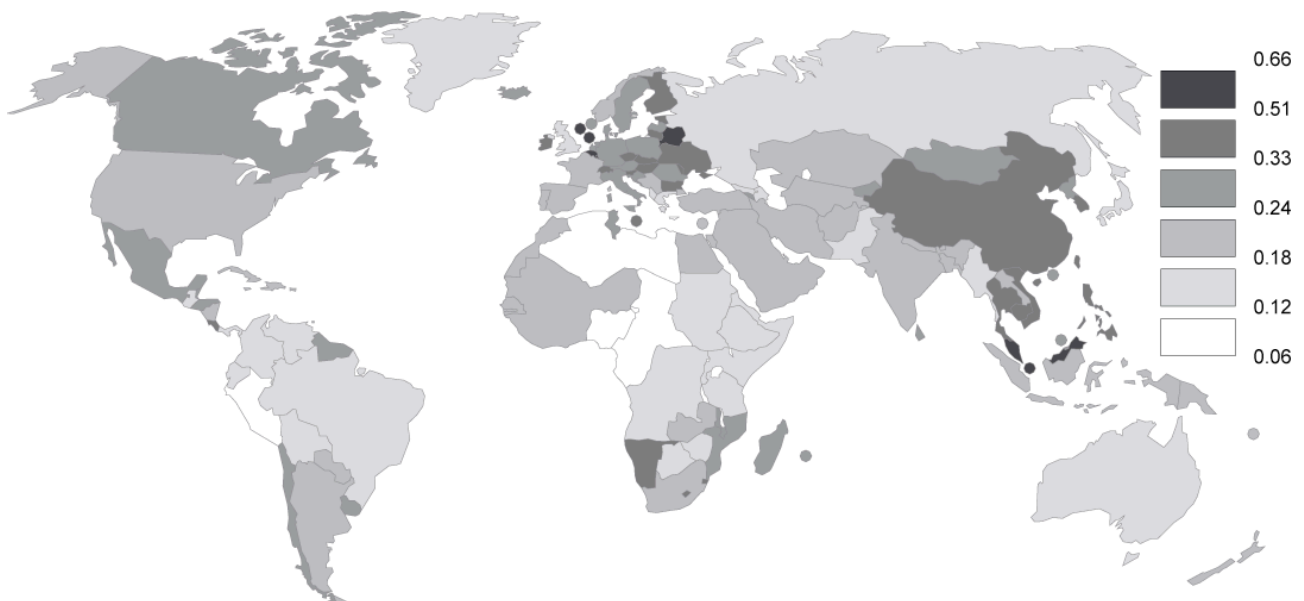
Note: These results are not comparable to Table 6. Table 6 uses GTAP7 with a 113-region partition of the world. This table uses a 66-region partition of the world coherent with the GTAP database of 1997. See Online Statistical Appendix for a detailed description.

Source: Authors' calculations based on GTAP data for 1997, 2001 and 2004.

The data for individual countries is presented in table 14 online. Map 1 gives the share of vertical trade in total trade ($2*(VS+VS1^*)/(I+X)$) for each country in the world. The exports of small countries have a bigger share of imported inputs. The imported input content of exports reaches 40% in some Asian and European countries (67% in Singapore). Dutch and Hong Kong trade are already modified in the GTAP

to remove transit trade: this explains the relatively small values of their imported inputs in exports (27.7% and 31.8% respectively according Gehlhar (2006)). Eastern Europe and South-East Asia have the highest shares of vertical trade. Keeping this picture in mind is important when answering the question, “who produces for whom?” in the world economy. Standard trade statistics particularly overestimate the dependence of some countries on world trade for their own consumption and for demand for their products: this is the case for small open economies, China and parts of Eastern Europe.²⁵

Map 1: Share of vertical trade in total trade - $2*(VS+VS1^*)/(I+X)$, 2004



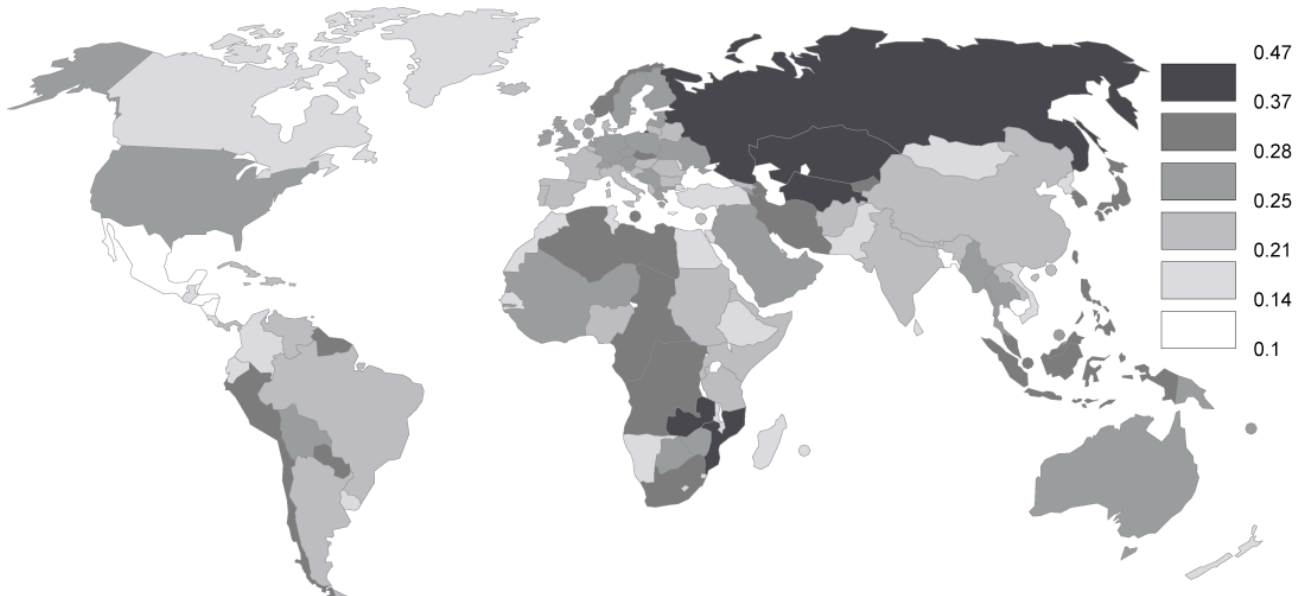
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Map 2 gives the share of exports used as inputs for further exports for every country in the world. There are two types of countries that participate indirectly in vertical trade through the production of inputs for further exports: primary producers

²⁵ Because trade balances are not changed in value-added trade compared to standard trade: in absolute terms, differences in imports and exports between standard and value-added trade are exactly the same.

(former Soviet Union, Brunei, the Middle-East, etc.) and producers of industrial inputs for processing countries (Japan, the United Kingdom, the United States, etc.). Mexico, Canada, Turkey and Vietnam, on the other hand, ship relatively more often to the final consumer of their goods.²⁶

Map 2: Share of exports used as inputs for further exports (VS1/X), 2004



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4 What role for vertical trade in regionalization?

4.1 Bilateral value-added and vertical trade

In line with the definitions given in Section 1.2, the difference between standard exports and value-added exports can come from a difference in VS (imported inputs embedded in exports) or VS1 (exports used as inputs for further re-exports) or in the value-added from the region of origin embedded in the exports of other countries to the region of destination, which we have called indirect value-added trade. Table 8 shows the decomposition of this difference for all trade flows between the four regions.

²⁶ The geographical breakdown of the domestic content of consumed or invested imports (VS1*) is less interesting, as our data and method underestimate it.

Table 8: Ratio of VS, VS1 and indirect VA exports over standard exports, 2004

in % of total exports		To Asia Pacific	To America	To Europe and peripheries	To Africa and Middle East	To other regions (i.e. extra-regional destinations)	To the whole world
From Asia Pacific	VS (a)	32.1%	29.3%	28.7%	26.2%	28.7%	30.3%
	VS1 (b)	37.2%	11.6%	24.5%	17.5%	17.9%	26.9%
	Indirect VA exports (c)	22.4%	25.1%	34.5%	23.3%	29.1%	26.0%
	VA exports (100-a-b+c)	53.1%	84.2%	81.3%	79.5%	82.5%	68.8%
From America	VS (a)	15.6%	22.7%	15.3%	13.7%	15.2%	19.0%
	VS1 (b)	31.2%	19.0%	26.5%	15.4%	27.4%	23.2%
	Indirect VA exports (c)	24.1%	9.0%	30.7%	22.8%	27.3%	18.1%
	VA exports (100-a-b+c)	77.3%	67.3%	88.9%	93.8%	84.6%	75.9%
From Europe and peripheries	VS (a)	24.7%	25.6%	27.6%	27.2%	25.6%	27.0%
	VS1 (b)	30.0%	13.0%	27.6%	19.3%	20.7%	25.6%
	Indirect VA exports (c)	33.4%	32.4%	21.4%	25.2%	31.4%	24.4%
	VA exports (100-a-b+c)	78.7%	93.8%	66.2%	78.7%	85.1%	71.9%
From Africa and Middle East	VS (a)	14.3%	15.3%	16.9%	23.0%	15.5%	16.1%
	VS1 (b)	34.9%	16.2%	30.4%	23.5%	29.1%	28.6%
	Indirect VA exports (c)	23.3%	31.5%	33.7%	20.5%	28.9%	28.1%
	VA exports (100-a-b+c)	74.1%	100.0%	86.3%	74.1%	84.3%	83.4%
From other regions (i.e., extra-regional origins)	VS (a)	19.4%	26.4%	22.2%	24.6%	23.1%	NA
	VS1 (b)	31.4%	12.6%	26.1%	18.1%	22.3%	NA
	Indirect VA exports (c)	28.2%	28.8%	33.0%	24.2%	29.4%	NA
	VA exports (100-a-b+c)	77.3%	89.7%	84.7%	81.5%	84.0%	NA
From the whole world	VS (a)	26.1%	24.9%	26.0%	24.4%	NA	25.7%
	VS1 (b)	34.5%	15.2%	27.2%	18.7%	NA	25.7%
	Indirect VA exports (c)	25.1%	20.9%	24.8%	23.9%	NA	23.9%
	VA exports (100-a-b+c)	64.5%	80.7%	71.6%	80.7%	NA	72.5%

Notes: For the regions, see note 1 in Table 6.

VS in the exports from region A to region B is the share of inputs imported by all countries in A from the whole world (including other countries in A) in exports from A to B.

VS1 in the exports from region A to region B is the share of A exports re-exported by B to the whole world (including A or other countries in B).

The equivalent numbers for intra-regional exports are: 27.7% (VS), 28.4% (VS1), 19.5% (indirect VA exports) and 63.4% (VA exports).

Source: Authors' calculations based on GTAP data for 2004.

Table 8 shows that VS and indirect VA exports both contribute unambiguously to decrease the ratio of VA exports to standard exports relatively more in intra-regional trade than in extra-regional trade for all regions. The ratio of VS to standard exports is the highest in intra-regional exports for all regions and the ratio of indirect VA exports to standard exports is the lowest. VS1 contributes in the same way on the whole, but not for all individual regions. On the contrary, for all regions the ratio of VS1 to standard exports is the highest for exports to Asia. In other words, exports to Asia contain a high share of goods re-exported to other countries. This confirms the role of Asia as the main assembling platform in the international division of the production chain.

4.2 Value-added trade and regionalization

Considering that the ratio of VA exports to standard exports is lower for intra-regional trade and extra-regional trade, it might be that regionalization depends on vertical exports rather than on VA exports. Table 9 shows some basic measures of the openness rate and the degree of regionalization (measured as the ratio of regional exports to total exports) in the different regions of the world. According to this indicator, the most regionalized region is Europe (70%). It is also the most open. The least regionalized region is Africa and the Middle East (8.9%). However, the ratio of regional trade to total trade is very sensitive to the size of the region and the dimension of the constituent countries and therefore cannot be easily interpreted as a real measure of the intensity of regionalization. As noted in Iapadre (2006), regional trade would be greater in America if the US were split into fifty states.

Table 9: The extent of regionalization and relative size of the regions, 2004

In %	Europe and peripheries	America	Asia Pacific	Africa and Middle East	World
Total exports / GDP	37.1	13.7	30.5	42.5	26.9
Total exports / world exports	46.5	18.9	28.1	6.5	100
Regional exports / total exports	70.0	50.0	46.4	8.9	100
Regional exports / value-added exports	64.5	44.3	35.8	7.9	100

Note: For the regions, see note 1 in Table 6.

Source: Authors' calculations based on GTAP data for 2004.

To go further than these rough measures of regionalization, we need to use a regionalization indicator that is not affected by the size of the different countries. A number of indicators have been suggested to

measure the “geographic neutrality” of trade.²⁷ This paper takes the Symmetric Trade Introversion Index (STJ) used by Ledio Iapadre and the Regional Integration Knowledge System of the United Nation University of Bruges and generalizes it to the bilateral case. We call the resulting index the “Trade Intensity Bilateral Index” between region *i* and region *j* (See Technical Appendix for its construction). The $TIBI_{ij}$ ranges between -1 and 1. -1 means that region *i* does not export at all to region *j*. 1 means that region *i* exports only to region *j*. 0 means that exports from region *i* to region *j* respect geographic neutrality. The $TIBI_{ii}$ is equal to the STJ_i , which measures the amount of regionalization for region *i*. Its main advantage compared to the relative exports intensity index (REI) developed by the CEPII²⁸ is that it solves three problems: range variability, range asymmetry and dynamic ambiguity. In other words, it means that the value of the TIBI index does not depend on the size of the region (no range variability), that the range of the index is symmetric around zero (no range asymmetry) and that a change in the index between region *i* and region *j* is always in the opposite direction to the change in the complementary index measuring the intensity of trade between region *i* and all non-*j* regions (no dynamic ambiguity).

Table 10: Trade Intensity Bilateral Index of exports, 2004

		To Asia Pacific	To America	To Europe and peripheries	To Africa and Middle East
From Asia Pacific	standard (a)	0.64	0.04	-0.59	-0.05
	value-added (b)	0.47	0.13	-0.47	-0.02
From America	standard (a)	-0.14	0.65	-0.52	-0.14
	value-added (b)	-0.04	0.48	-0.41	-0.07
From Europe and peripheries	standard (a)	-0.63	-0.54	0.75	0.03
	value-added (b)	-0.50	-0.45	0.63	0.02
From Africa and Middle East	standard (a)	0.32	-0.10	-0.29	0.27
	value-added (b)	0.31	-0.06	-0.25	0.14

Note: For the regions, see note 1 in Table 6.

Source: Authors' calculations based on GTAP data for 2004.

Table 10 shows the TIBI between regions measured in terms of standard and value-added trade in 2004.

It shows that the trade of all continents is regionalized, both in the standard and value-added measures.

27 The ‘geographic neutrality’ means that exports from region *i* to region *j* are simply a function of the value of exports from region *i* and the value of exports to region *j*. No other factors – distance, currency union, free trade areas, common languages, colonial ties – play any role in determining bilateral world trade.

28 See Deutsch and Savage (1960), Drysdale and Garnaut (1982), Freudenberg, Gaulier and Ünäl-Kensenci (1998), p. 66-68, Gaulier and Ünäl-Kesenci (2004)

Europe and its peripheries is the most integrated region and Africa the least. Conversely, trade intensity is most often negative between regions, with three exceptions: Asian exports to America, African exports to Asia Pacific and European exports to Africa and Middle East. None of these are surprising. America is an important market for Asian goods, Asia is dependant for its primary products on Africa and Africa and the Middle East are traditional markets for European exports.

Table 10 allows a comparison of the difference between the “standard” and the “value-added” TIBI. A negative (positive) difference means that the share of value-added bilateral exports in this region’s total value-added exports is smaller (larger) than the share of standard bilateral exports in this region’s total standard exports. There is a general reversion to the mean: value-added trade is more geographically neutral than standard trade. This is to be expected, as value-added trade is less sensitive to trade barriers than vertical trade. Asian exports to America are the only exception. Past studies on Asian exports have shown that America is an important final market for Asian goods, so this exception is not surprising.

There is one counterintuitive result in Table 10. Past studies such as that of Athukorala and Yamashita (2006) have argued that Asian regionalization is very dependant on vertical trade. If that were true, one would expect Asian regional trade intensity to be much smaller in value-added than in standard trade. This is indeed the case: the regional TIBI for Asia is 0.64 in standard trade and 0.47 in value-added trade. What is counterintuitive is that it is not more the case for Asia than for America, even though the ratio of VA regional exports to standard regional exports is much higher for America than for Asia (as is confirmed in Table 8). The regional TIBI for America is 0.65 in standard trade and 0.48 in value-added trade. That is because the TIBI takes into account relative trade shares (as shown by its formula in the appendix). Table 8 shows that the ratio of Asian regional value-added trade over Asian regional standard trade is smaller than the ratio of American regional value-added trade over American regional standard trade (respectively 53.1% and 67.3%), but it is also the case for the Asian exports to the whole world and its American equivalent (respectively, 68.8% and 75.9%). That is equally true for the ratio of VA exports from the rest of the world to Asia over standard exports from the rest of the world to Asia and its equivalent American statistics (respectively 77.3% and 89.7%). The counter-intuitive result in Table 10 reflects the fact that Asia is an assembling platform for the whole world, whereas America is not.

Europe is in a different situation. Its regional TIBI is less reduced when moving from standard trade to value-added trade, even though the ratio of its regional VA exports to regional standard exports is very close to America's ratio. That is because the ratio between Europe's value-added trade with the rest of the world and Europe's standard trade with the rest of the world is lower than America's.

To sum up, looking at value-added trade suggests that Europe is, by a larger measure than what is suggested by standard trade, the most regionalized region in the world. Due to different mechanisms, both Asia and America are even less regionalized compared to Europe in value-added trade than they are in standard trade measures.

4.3 Two extensions to these results

4.3.1 Evolution of vertical trade and regionalization from 1997 to 2004

Trade in inputs has increased faster between regions than within regions. For the world as a whole, between 1997 and 2004, the ratios of VS and VS1 to standard exports have risen faster for extra-regional trade than for intra-regional trade (respectively in percentage points, 2.5 (VS-extra), 1.9 (VS1-extra), 0.9 (VS-intra) and 1.4 (VS1-intra)). However, in the meantime, the share of indirect value-added trade has also risen faster for extra- than intra-regional trade (3.5 and 1.2 percentage points respectively). The rise in indirect value-added trade has partially offset the growth of vertical trade (VS and VS1). As a result, on the whole, the ratio of value-added trade to standard trade has decreased at the same speed for intra-regional trade and extra-regional trade (1.0 and 0.9 percentage point, respectively).

Table 11 confirms this result. It presents the evolution of the TIBI index between 1997 and 2004 for intra-regional trade. The table shows that regionalization intensified everywhere in that period. For all regions, the standard TIBI and value-added TIBI have increased by the same amount. The rise of vertical trade (see Section 3.1) has apparently not influenced measures of regionalization. It has been growing as fast for intra-regional trade as for extra-regional trade.

Asia is one example of this trend, despite the commonly held view that the Asian regionalization process is unusually dependant on vertical trade. While it is true that the ratio between Asian regional value-

added trade and Asian regional standard trade has decreased by 9.2 percentage points between 1997 and 2004 (from 62.3% to 53.1%), the ratio between all Asian value-added exports and all Asian standard exports has decreased by a very similar amount, by 8.7 percentage points between 1997 and 2004 (from 73.2% to 64.5%). The rise of vertical trade in Asia does not concern Asian regional trade disproportionately more than it does Asian trade with the rest of the world.

Table 11: Trade Intensity Bilateral Index of exports, regional trade, 1997-2004

		1997	2001	2004	1997-2004
In Asia Pacific	standard (a)	0.55	0.59	0.63	+0.08
	value-added (b)	0.38	0.41	0.45	+0.08
In America	standard (a)	0.56	0.56	0.65	+0.09
	value-added (b)	0.37	0.35	0.47	+0.10
In Europe and peripheries	standard (a)	0.69	0.69	0.74	+0.05
	value-added (b)	0.57	0.55	0.62	+0.05

Note: For the regions, see note 1 in Table 6.

This table uses a 66-region partition of the world coherent with the GTAP database of 1997. As a result, the figures for 2004 differ slightly from Table 10, because we use a geographical split consistent with the GTAP5 database (containing data for year 1997). See Online Statistical Appendix for a detailed description.

The index for Africa and Middle East is not presented because the low number of African countries available in the GTAP5 database does not allow a meaningful calculation.

Source: Authors' calculations based on GTAP data for 1997, 2001 and 2004.

4.3.2 Looking at bilateral trade more closely

Dividing the world *a priori* into four regions is a bit blunt. Table 16, Table 17 and Table 18 (online) give the same information for a finer regional classification. This allows a clearer view of which regions are integrated. The highest case of geographic non-neutrality is for trade between the USA and the rest of North America (mainly Canada and Mexico), reflecting a very intense trade relationship (TIBI of 0.91). This geographic non-neutrality is only marginally reduced when measured in value added (TIBI of 0.85). Sub-Saharan Africa, Oceania and the Rest of America (Central and South America and the Caribbean) are the most introverted regions (TIBI of 0.79). This is still the case in value added, but with a lower TIBI (0.68). The region for which standard trade gives the most distorted answer to the question “who produces for whom” (measured as the absolute changes in TIBI between value-added trade and standard trade) is Asia-Pacific and in particular the Asian dragons (Korea, Taiwan and Singapore). Looking at the standard measure of TIBI, the Asian dragons' exports to China plus Hong-Kong have a large TIBI (0.71), while their exports

to the US indicate geographic neutrality (TIBI of 0.01). In value added, the Asian dragons' exports to China have a smaller, but still high, TIBI (0.58), while their exports to the United States have a higher TIBI (0.14 points). The TIBI of China and Hong-Kong's exports to the US is slightly reduced when considering value-added trade (0.27, against 0.29 with the standard TIBI). But the TIBI of all other Asian region exports to the US is increased when considering value-added trade, with Japan's exports to the United States having the largest extra-regional TIBI for the US (0.29).

This confirms that many exports from China and Hong-Kong to the US are actually transformed inputs from the rest of Asia. The focus of US politicians on the trade deficit with China seems less relevant when looking at value-added figures. The bilateral trade deficit of the US with China is reduced from 128 billion US dollars in standard trade (which is 23% of the total US deficit) to 90 billion (16%) in 2004.

Conclusion

This paper seeks to make a contribution to the debate on globalization, vertical trade and regionalization. Since the end of the 1980s, globalization has been linked with the development of new international production processes based on a new international division of labour. In this context, it has become increasingly difficult to understand the international division of labour using standard trade statistics. If one wants to understand the international production process well enough to be able to answer the question, "who produces what and for whom?", one must reallocate the value-added contained in trade in final goods to each country that has participated in its production. We do this using the GTAP database for 1997, 2001 and 2004.

The most obvious way to improve the results of this paper would be to improve the data it uses. Although it would certainly be difficult to improve the quality of the GTAP database, nevertheless, we have made a simplifying assumption that might have important consequences: that, inside each sector, all production had the same imported content and the same pattern of use. As is obvious in the case of the affiliates of multi-national firms, inside sectors some firms are more intensive in imported inputs and export more than others. Taking this into account would increase our estimate of vertical trade and hence decrease our estimate of value-added trade. By making this assumption, this paper has underestimated the effect of the international fragmentation of production on the patterns of the international division of labour.

Still, our results are worth discussing. This study offers the first analysis of the effect of vertical trade on trade patterns for a database covering the entire world and the whole range of industries. Our results are compatible with the previous results of Yi and his co-authors. We go further, computing the share of imported inputs in exports (VS), the share of exports used as inputs in further exports (VS1), the domestic content of imports (VS1*) and value-added trade for 113 countries or groups of countries and 55 sectors. While the estimations do have shortcomings, their implications for how to answer the question “who produces for whom in the world economy”, have gained in importance, as vertical trade has grown as a share of total trade between 1997 and 2004, especially for Asia.

Services are much more dependent on external demand than is suggested by the standard trade statistics. Standard trade statistics give a misleading idea of the relative dependence on international demand of different sectors. Even though industrial exports account for 67% of industrial value-added, a large part of these exports embed tertiary or primary productions. As a result, only 32% of the world industrial value-added is actually consumed by foreign consumers. *A contrario*, 11% of world service value-added is consumed by foreign consumers, compared to service standard exports of only 7% of value-added. Standard trade statistics undervalue the vulnerability of service workers to international competition.

On the whole, however, a look at the different degrees of participation of various countries in vertical trade, for example, as re-exporters of imported inputs, shows that standard measure of trade overvalue the openness rate of many countries.

Looking at value-added trade decreases the extent of regionalization of world trade, but less so for Europe than for America and Asia. The ratio of value-added exports to standard exports is smaller for regional trade, but between 1997 and 2004 the rise of vertical trade in the world, especially in Asia, has not been a factor in the rising regionalization of standard trade. This paper confirms that Asia relies more heavily on extra-regional final markets than standard trade statistics suggest. However, this is also the case for the other continents. One surprising result that could not have been deduced from looking at regional trade statistics is that taking into account value-added trade flows does not reduce Asian regionalization more than it does American regionalization. This is because, among other things, goods that are transformed for re-exports form a larger share of exports from Europe and America to Asia than they do of Europe and

America's regional exports.

By answering the question “who produces for whom”, value-added trade helps to identify the ultimate producers of imports. This is important for trade policy makers: American producers might believe that their products are competing with Chinese goods produced by low-wage workers, whereas in fact an important portion of these “Chinese” goods was produced in high-wage economies situated not only in Asia, but also in America and Europe.

1. Technical Appendix

1.1. Inter-country Input-Output Analysis: construction of A*

From the input-output tables of countries and the bilateral international trade data by industry, we get:

- one vector of output P* defined as the alignment in column of the output vector of every country. In our aggregated database, its dimension is (66x57,1) or (3762,1);

- one vector of final demand FD* defined as the alignment in column of the final demand vector of every country. Its dimension is (66x57,1);

- an “extended” input coefficients matrix A* which shows the intersectoral relations between different regions of the world and inside regions. The dimension is (66x57,66x57). A* can be seen as the domestic input coefficients matrix of the world economy where each pair (product i* country a) in column or row is treated as a different item. But contrary to vectors P* and FD* which directly come from GTAP data, the A* matrix has to be approximated.

The big input coefficients matrix A* is presented as follows (Figure 2). In column, for each recipient country we find the geographical and industrial origins of the input imported. Each element $a_{i,j}^{a,b}$ represents the amount of imported inputs required by the production of one unit of product i in country a in product j from country b (See text Section 3.3.1). In row, for each exporting country we find the geographical and industrial destination of the input exported: $a_{i,j}^{a,b}$ represents the amount of product j produced in country b exported to produce one unit of product i in country a. The blocks on the main diagonal represent the intermediate deliveries exported by a country to itself. They are the domestic input coefficients matrix of the national input-output tables. This extended matrix A* of input coefficients is used in equations (6) and (7). For a more thorough discussion on the A matrix building, it is possible to refer to Hoen (2002).

Figure 2: Presentation of A* with 3 countries and 4 sectors

Country	1			2			3		
	Sector			Sector			Sector		
	1	2	3	1	2	3	1	2	3
1	$a_{i,j}^{1,1}$								
2				$a_{i,j}^{2,2}$					
3	$a_{i,j}^{1,3}$						$a_{i,j}^{3,3}$		

1.2. Constructing the Trade Intensity Bilateral Index (TIBI)

Let us start with the index developed by the CEPII based on research on the structure of world trade in the 1960s and 1970s: the relative bilateral intensity of exports.²⁹ Its logic is similar to the index of comparative advantages used by Balassa (1965). It is equal to:

$$\text{Relative Export Intensity}_{ij} (\text{REI}_{ij}) = (X_{ij} / X_i) / (X_j / X) \tag{6}$$

Where X_{ij} are the exports from region i to region j , X are total world exports, X_i are total exports from region i and X_j are total exports to region j . REI_{ij} is the ratio between the share of exports to region j in the total exports of region i ($X_{ij} / X_i = S_{ij}$) and the share of exports to region j in total world exports ($X_j / X = W_j$). All REI_{ij} would be equal to one if all exports respected geographic neutrality, i.e., if exports from region i to

²⁹ See Deutsch and Savage (1960), Drysdale and Garnaut (1982), Freudenberg, Gaulier and Ünal-Kesenci (1998), pp. 66-68, Gaulier and Ünal-Kesenci (2004).

region j were simply a function of the value of exports from region i and the value of exports to region j and no other factors (distance, currency union, free trade areas, common languages, colonial ties) played any role in determining bilateral world trade.³⁰

Iapadre has shown that this kind of index has three problems: range variability, range asymmetry and dynamic ambiguity. We follow his solutions to solve these problems.

Range variability means that the maximum value of the index depends on the size of the regions under study. To solve that issue, we replace the denominator by the share of exports to region j in total exports from all non-i regions (the “rest of the world”) rather than in total world exports:

$$I^1_{ij} = (X_{ij}/ X_i.) / (X_{rj}/X_r.) \quad (7)$$

Where X_{rj} is the amount of exports to region j in exports from the rest of the world excluding region i and $X_r.$ is the total exports of the rest of the world excluding region i. $X_{rj}/X_r.$ is the share of exports to region j in exports from the rest of the world excluding region i. Now the index can take any value from 0 to infinity.

Range asymmetry means that the range is not symmetric around neutrality. I^1 ranges from 0 to 1 if trade is less important than expected and from 1 to infinity if trade is more important than expected. To solve that issue, we use the following index, which varies between -1 and 1 and has neutrality at 0 rather than 1:

$$I^2_{ij} = (I^1_{ij}-1)/(I^1_{ij}+1) \quad (8)$$

Dynamic ambiguity means that a change in the index might be in the same direction as the change in the complementary index measuring the intensity of trade between region i and all non-j regions. To solve that issue, we first define this complementary index:

$$I^3_{ij} = (1-(X_{ij}/ X_i.)) / (1-(X_{rj}/X_r.)) \quad (9)$$

And we study as the “basic” index the ratio between I^1 and I^3 , which we transform to correct for range asymmetry. Our final index, the “Trade Intensity Bilateral Index” is equal to:

$$TIBI_{ij} = (I^1_{ij}/ I^3_{ij}-1) / (I^1_{ij}/ I^3_{ij}+1) \quad (10)$$

30 This is similar to the definition offered in Frankel (1998). Yet this measure does not correct for distance to measure regionalization. Looking at REI is similar to a measure of bilateral resistance in a gravity equation. See for example Anderson and Wincoop (2003).

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