World Input-Output Database

Trade Performance in Internationally Fragmented Production Networks: Concepts and Measures

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Trade Performance in Internationally Fragmented Production Networks: Concepts and Measures*

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Abstract

In this note, we outline two perspectives on the value added content of international trade. We distinguish two perspectives: the "direct trade flow (DTF)" perspective and the "global value chain (GVC)" perspective. We argue that both have their particular interpretations. The direct trade flow perspective is useful to analyse the domestic value added content of exports. The GVC perspective is useful for analysing the importance of foreign demand for income generation in the domestic economy. In addition, the GVC perspective can be used to trace the development of global production networks.

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1. Introduction

The fragmentation of production across national boundaries is a defining feature of the modern international economy. This calls for new measures to analyse trade patterns. Figures on gross exports do not give much information anymore about the actual value added by the exporting country: if a country has to import a large amount of intermediate inputs to assemble its export products, the value added is much less than the gross export value. In the end, it is the domestic value added content that matters, as this amounts to the compensation for domestic labour and capital due to demand from abroad.[1]

Recently, following a well-known article by Hummels et al. (2001), various measures linking value added and exports have been proposed in the literature. In this note, we discuss the two main perspectives: the "direct trade flow" perspective and the "global value chain (GVC) income" perspective. The results obtained by the computations associated with these perspectives should be interpreted differently. The choice for one specific perspective should depend on the particular policy question at hand.

The expositions are based on a single hypothetical example of a simple trade network, depicted in Figure 1. It depicts the flows of three types of intermediate inputs (mining products, business services and manufactured steel) that are used by the car industry to manufacture final products. These final products are produced in two countries (A and C). In this hypothetical case, A sells cars to consumers in A itself and in B. C's car industry sells on its domestic market and to D. It is important to note that 1000 dollars of value added are created in this system (400 in A, 300 in B and 300 in C). These 1000 dollars are reflected in the total value of the sales to consumers, in the bottom row. [2]

The flow of gross exports and imports is given in Table 1. The conventional bilateral trade balances (based on gross exports and imports) for this system are given in Table 2.

[1] It is important to stress from the outset that throughout this note, we consider both trade in goods and services. Financial flows, such as repatriation of profits, are not considered. It is the value added that crosses industry and country borders embodied in products that we try to measure.

[2] Please note that real-world global trade networks are much more intricate than the simplified example that is used for illustrative purposes in this note. These networks are much less "linear". It is much harder to denote an industry as "upstream" or "downstream", because of feedback loops (such as the business services industry in C using C's business services as an intermediate input). These loops often also have an international dimension, which complicates the computations outlined in the sections below.

Table 1: Gross exports from country in row to country in column

To / From	A	B	C	D	Total
A		400	0	0	400
B	200		400	0	600
C	0	100		100	200
D	0	0	0		0

Table 2: Gross trade balances (bilateral, surpluses/deficits for countries in rows)

	A	B	C	D	Total
A		200	0	0	200
B	-200		300	0	100
C	0	-300		100	-200
D	0	0	-100		-100

2. The "direct trade flow" (DTF) perspective

The first approach to studying links between value added and trade in the context of increasing production fragmentation aims to measure the *domestic value added (DVA) content of exports*.[3] Since the value of gross exports equals the value of imported intermediate inputs plus domestic value added in these exports, this approach is in fact equivalent to computing the vertical specialization index introduced by Hummels et al. (2001), multiplying this index by gross exports and subtracting the result from the gross export figure.[4] The Hummels et al. measure of vertical specialization is defined as the value of imports required to produce one unit of exports. The higher this vertical specialization index, the lower the domestic value added content of a unit of exports.

[3] In launching a new initiative, OECD-WTO (2012) labeled this approach 'trade in value added', a label that usually refers to a different concept (see Section 3).

[4] In most input-output tables, the value added block does not only contain a row for value added (at basic prices), but also additional rows for "taxes minus subsidies on products", "direct purchases abroad by residents", etc. In these cases, the value of gross exports equals the sum of the value of imported intermediate products, value added at basic prices and these additional cost components.

A typical question would be: how much DVA is contained in exports from C to B? In the case described this would be 100, as all value of the exports is created in C itself. This is because C's business services industry does not use any imported intermediate inputs. More complex is the question how much of B's DVA is contained in exports from B to C. B is using imported intermediates (from A and C) and hence the value added by B to its exports is less than its gross export value. Gross exports of steel by B are 600. Of this value, 300 is added by B, so exports of domestic value added by B amount to 300. If we assume that the DVA content of a single product produced in a single country does not depend on the country of destination, then B exports 100 of DVA to A (200/600*300) and 200 to C (400/600*300).[5] Note that this concept relates to direct trade flows between countries: the DVA that is contained in products that leave a port in B and arrive at a port in C.

This calculation can also be done for multiple products. For example, A exports mining products and cars to B: how much of A's value added is contained in A's exports to B? In the case described above, the answer would be 200+100=300, i.e. the value added in A's mining exports to B's steel industry, plus the value added by A's car industry to produce cars sold to consumers in B. To arrive at 100 for the second part, we assume again that value added per dollar of output is identical for A-cars sold in A and A-cars sold in B. The results for all bilateral trade flows are given in Table 3. Combining Tables 1 and 3 we can derive the value added content of exports (as a share of gross exports), see Table 4.[6]

By considering the difference between exports of value added from A to B and exports of value added from B to Aare equal to imports of value added from B to A, we can derive value added in net trade between these countries. The full set of bilateral value added in net trade figures is documented in Table 5. These numbers are difficult to interpret, however. Take the example of country D. D has a gross trade deficit of 100, but in value added terms using this direct trade flow perspective its deficit is substantially smaller. The reason is that in this approach only the value added by the direct exporter (country C) is considered and not the value added in the production stages further upstream. In this case the value added by B's steel industry and A's mining industry is not taken into account.[7] We thus conclude that the direct trade flow perspective is useful for examining domestic value added content of export flows, but should not be used to examine the value added content of imports or of net trade.

[5] DVA contents in products can vary across countries of destination. For China and Mexico, for example, we know that goods produced for exports have a different domestic value added content than goods for domestic use (Hummels et al., 2001, Koopman et al, 2008, Yang et al., 2009, and Johnson and Noguera, 2012)

[6] Since D does not export anything, the DVA contents of its exports are not defined.

[7] In the recent literature, the direct trade concept is used in the recent literature on testing the Heckscher-Ohlin-Vanek (HOV) theorem (e.g. Trefler and Zhu, 2010), which relates empirical trade patterns to differences in national endowments of production factors. To this end, production factor contents (in physical terms rather than in terms of their compensation) in net trade are considered. For the purposes of testing the HOV theorem, all factor contents in net trade must be considered, including factors deployed in third countries. In this context, the factor contents of C's exports to D (and consequently, D's imports from C) would also contain factor inputs in A's mining and in B's steel industries.

Table 3: Value added in exports, DTF perspective

To / From	A	B	C	D	Total
A	(100)	300	0	0	300
B	100	(0)	200	0	300
C	0	100	(166.7)	33.3	133.3
D	0	0	0	(0)	0

*The values between parentheses (in the shaded cells) indicate domestic value added that does not cross a border. If these numbers would also be included in row-wise sums, domestic value added of the exporting country would be obtained.

Table 4: Value added content in exports (%), DTF perspective

To / From	A	B	C	D	Total
A		75%	0	0	75%
B	50%		50%	0	50%
C	0	100%		33.3%	66.7%
D	-	-	-		-

Table 5: Value added in net trade (bilateral, surpluses/deficits for countries in rows), DTF perspective

	A	B	C	D	Total
A		200	0	0	200
B	-200		100	0	-100
C	0	-100		33.3	-66.7
D	0	0	-33.3		-33.3

We would like to stress that the domestic value added content of exports can be measured on the basis of a national input-output table (giving a detailed account of the values of domestic interindustry flows, plus a vector or matrix of the use of imported intermediate inputs by using industry).[8] The bilateral measures require a split of the exports by country of destination but still do not require a full world input-output table.

Koopman et al. (2010) do not only compute value added in exports. They also decompose this value into three components: value added contained in exports that (i) end up in final products in the importing country (i.e., value added in B's steel exports to A that get embodied in A's cars sold on the domestic market), (ii) end up in final products used in the exporting country (i.e. value added in B's steel exports to A that get embodied in A's cars exported to B itself), and (iii) end up in third countries (i.e., value added in B's steel exports to C that get embodied in C's cars sold to consumers in D). For this type of calculations, a full world input-output table is needed. Some pitfalls should be avoided. An example of such a pitfall is including part of the value added in A's mining industry twice, when computing A's DVA in exports to B. This problem emerges when A's mining products exports are unduly considered as exports of final products, because this approach fails to take into account that exported cars contain some value added generated in the mining industry.

3. The global value chain (GVC) perspective

The direct trade flow perspective focuses on the value added content of particular trade flows originating from a country. In contrast, the GVC perspective takes final consumption of goods in a country as a starting point and traces the value that has been added by different countries in the various production stages. In this perspective, the *exports of value added* is defined as the amount of value added produced in a given source country that is ultimately *embodied* in final products absorbed abroad (Johnson and Noguera, 2011; Bems et al., 2011).

The hypothetical example depicted in Figure 1 can serve as an illustration. The value added in C business services is embodied in cars sold to consumers in all four countries considered. Although there are no products physically crossing the "border" between C and A, C still exports value added to A, according to this concept. This is due to the fact that the C business services industry adds value that ends up in cars driven by A consumers.[9] If e.g. demand for cars in A is dropping this will have a negative effect on the value added generated (and hence income) in C although there is no direct trade link between the two. This simplified example shows that the GVC perspective requires world input-output tables: without information about the production structure of B and information about the countries to which C supplies, it would be impossible to arrive at the value added generated in B that is consumed in A.

[8] See Dietzenbacher (2012), who proves that it does not matter for vertical specialization indices whether national input-output tables or international input-output tables are used.

[9] Note that this is analogous to the well-known concept of 'carbon footprints': if factories in country A emit pollutants associated with the production of intermediate inputs required for consumption in country B, these are considered part of country B's carbon footprint.

The exports in value added of C to D can be computed in a stepwise fashion. First (assuming identical value added to output ratios for C cars sold in C itself and in D as before), 33.3 dollars of value added C car industry value added end up with D consumers ($1/6^{th}$ of 200). Next, value added generated further upstream in C should be considered. As mentioned above, the value added in C business services is finally embodied in cars purchased in all four countries. How much of this value added can be attributed to the cars sold in D? For each dollar of output of the C car industry, 2/3 dollars of B steel are needed (output of C's car industry equals the 400 dollar of intermediate inputs plus 200 dollars of value added it creates itself).[10] For each dollar of B's steel in its turn, 1/6 dollars of C business services are needed. Each of these contain 1 dollar of C's value added. Hence, we have that the 100 dollars of cars sold in D require $100 \cdot (2/3) \cdot (1/6) \cdot 1 = 11.1$ dollars of C's business services value added. Hence, the total C exports in value added to D amount to 33.3 + 11.1 = 44.4 dollars.

The bilateral exports of value added are given in Table 6. Note that although A does not deliver directly to either C or D, there is an export of value added from A to these countries, indirectly through B. This indicates the basic difference between the DTF and the GVC perspective. Although there is no direct trade flow from A to D, any change in final demand in D will have an impact on the value added generated in A. This is picked up in the GVC approach, but not in the DTF approach as described above.

Table 6: Exports of value added (GVC perspective)

To / From	A	B	C	D	Total
A	(133.3)	133.3	111.1	22.2	266.6
B	50	(50)	166.7	33.3	250
C	16.7	16.7	(222.2)	44.4	77.7
D	0	0	0	(0)	0

*The values between parentheses (in the shaded cells) indicate domestic value added that does not cross a border. If these numbers would also be included in row-wise sums, domestic value added of the exporting country would be obtained.

Based on Table 6 we can define imports of value added by A from B as the exports of value added from B to A. By subtracting the imports from the exports, net trade in value added is derived, see Table 7. Comparing the results in Table 7 to those for conventional trade balances in Table 2 shows that the

[10] These input coefficients (defined as the values of intermediate inputs required per value unit of output) are contained in the well-known input coefficients matrices directly derived from input-output tables.

values summed over countries-of-destination are identical for the two indicators. B, for example, remains a net exporter and the extent to which its exports exceed imports does not change. This is a fundamental property of the GVC concept (see Johnson and Noguera, 2012) and makes it a useful indicator for analysing net trade in value added.

Table 7: Net trade in value added (bilateral, surplus/deficits for countries in rows) (GVC perspective)

	A	B	C	D	Total
A		83.3	94.3	22.2	200
B	-83.3		150	33.3	100
C	-94.3	-150		44.4	-200
D	-22.2	-33.3	-44.4		-100

The bilateral trade patterns in value added terms are different from those in gross terms, however. In the example, B has a surplus with D if the trade in value added concept is used, while it has neither a surplus nor a deficit in conventional gross trade terms. B's trade surplus with C is reduced significantly when considering trade in value added. A comparison of the results for trade in value added (Table 3) and value added in trade (Table 2) shows that the two concepts are very different, and not only in conceptual terms.

Trade in value added indicators are important when studying the domestic effects of global macroeconomic shocks such as the 2008 crisis (e.g. Bems et al., 2011) as well as for measuring income elasticities in a country to consumer demand in other countries. The GVC perspective is also useful when one wants to study how much various countries contribute to the value of a particular product, say a mobile phone produced in China as it allows one to trace the value added in all stages of production. Hence, it can be seen as an indicator of revealed competitiveness. Timmer et al. (2012) define *GVC income* as the income generated in a country by carrying out activities related to the production of manufacturing goods in any stage of the production process. Compared to traditional competitiveness indicators like a country's share in world exports, this new metric has three advantages. First, it indicates to what extent a country can compete with other nations in terms of *activities* related to global manufacturing, rather than competing in manufacturing products as measured by exports of *products*. These activities take place in manufacturing industries, but also in services industries. Second, it measures the share of a country in internationally contested markets. It is a reflection of an economy's strength to compete in both domestic and global markets. Third, income and employment effects of trade in tasks for separate groups of workers (such as low- and high-skilled) can also be determined in this unified framework. Timmer et al. (2012) argue that this approach leads to insightful conclusions

about international competitiveness of countries in a world characterized by internationally fragmented production networks.

5. Concluding remarks

In this note we highlighted two perspectives on the value added content of trade. By outlining the basic ideas behind these methods, illustrating these by means of a simplified example and giving very brief accounts of potential uses of these concepts, we hope this note adds to the understanding of the concepts, in particular among non-specialists. Since both perspectives boil down to a specific decomposition of value added (GDP) as generated in a country to trading partners and to itself, it is very important that the input-output data used to compute the indicators accurately reflect national GDP levels and their division over industries. The basic philosophy behind the WIOD database (i.e., start from National Accounts data and treat these as hard constraints in the treatment of trade data that are not always in line with these) suits this purpose very well.

We hope that in future discussions a common language is being developed to avoid further confusion. Therefore we propose to always indicate the perspective taken when measuring value added trade. The terms “direct trade flow” (DTF) and “Global value chain” (GVC) perspective will hopefully serve this purpose.

References

Bems, R., R. Johnson and K.-M. Yi (2011). "Vertical Linkages and the Collapse of Global Trade". *American Economic Review Papers and Proceedings*, Vol. 101(3), pp. 308-312.

Dietzenbacher, E. (2012). “Fragmentation in an Inter-Country Input-Output Framework”. WIOD Working Paper 5, University of Groningen.

Hummels, D., J. Ishii and K.-M. Y (2001). "The Nature and Growth of Vertical Specialization in World Trade". *Journal of International Economics*, vol. 54(1), pp. 75-96.

Johnson, R., and G. Noguera (2012). “Accounting for Intermediates: Production Sharing and Trade in Value Added”. *Journal of International Economics*, Vol. 86(2), pp. 224-236

Koopman, R., W. Powers, Z. Wang and S.-J. Wei (2010). “Give Credit where Credit is Due: Tracing Value Added in Global Production Chains”. NBER Working Paper 16426.

Koopman, R., Z. Wang and S.-J. Wei (2008). “How Much of Chinese Exports is Really Made in China? Assessing Domestic Value-Added When Processing Trade is Pervasive”. NBER Working Paper 14109.

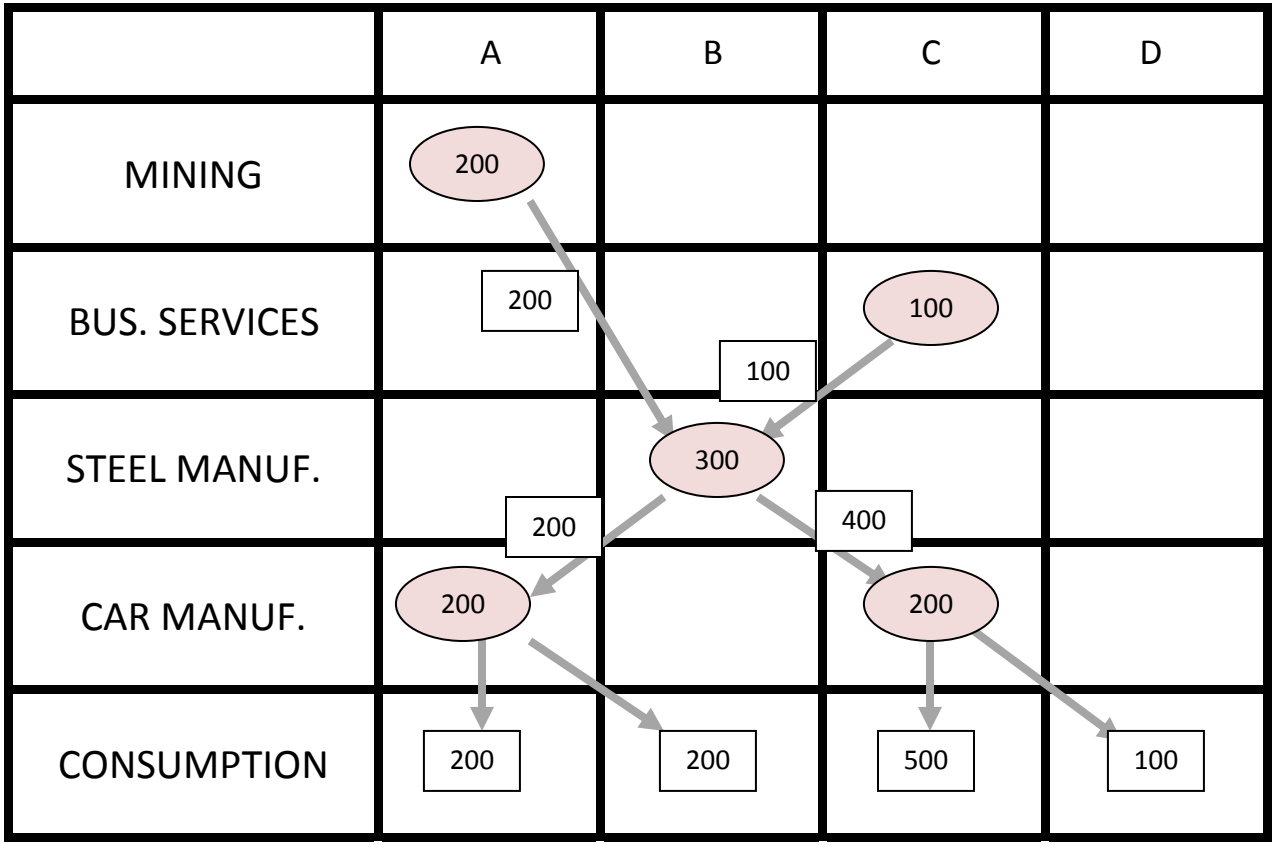
OECD-WTO (2012). “Trade in Value Added: Concepts, Methodologies, and Challenges”. Mimeo, OECD.

Timmer, M.P., A. Erumban, B. Los, R. Stehrer and G.J. de Vries (2012). “Slicing Up Global Value Chains: New Measures of European Competitiveness”. Mimeo, University of Groningen.

Trefler, D., S.C. Zhu (2010). “The Structure of Factor Content Predictions”. *Journal of International Economics*, Volume 82(2), pp. 195-207.

Yang, C., E. Dietzenbacher, J. Pei and X. Chen (2009). “The Bias in Measuring Vertical Specialization”. Paper presented at the 17th International Input-Output Conference, Sao Paulo, Brazil (July 13-17).

Figure 1: Stylized Network of Fragmented Production Chains



Values in rectangular boxes refer to the value of the transactions among industries and between industries and consumers as indicated by arrows.

Values in shaded ellipses indicate value added created in the industry to which the cell refers.