World Input-Output Database

Trade in Value Added and the Value Added in Trade

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Trade in Value Added and the Value Added in Trade☆

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Abstract

This paper discussed two measures of value added flows between countries: "Trade in value added" accounts for value added of one country directly and indirectly embodied in final consumption of another country. "Value added in trade" measures the value added embodied in gross trade flows. The paper shows that both measures result in the same overall net trade of a country which equals its trade balance in gross terms which however does not hold for bilateral relations. These value added flows can further be broken down by various production factors including capital and labor income by educational attainment categories. Using the recently compiled World Input-Output Database (WIOD) selected results comparing EU-27, US, Japan and China based on both concepts regarding value added flows across countries are presented. For example, the US trade deficit with China is reduced by about 25% but would increase with respect to EU-27 by about 20%. These imbalances are further broken down by factor incomes.

JEL: F1, F15, F19

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1. Introduction

It is sometimes at least implicitly argued that a countrys trade deficit might be lower when measured in value added terms rather than in gross terms. This is often motivated by case studies for high-tech products such as the iPod (Varian, 2007; Linden et al., 2009) or iPhone (Xing and Detert, 2010). Such case study approaches however face some limitations as the particular components of a product under consideration are themselves made of other - maybe imported - components which makes it difficult to trace back a product to the ultimate producer. Therefore, for example, Varian (2007) concludes: "Ultimately, there is no simple answer to who makes the iPod or where it is made. The iPod, like many other products, is made in several countries by dozens of companies, with each stage of production contributing a different amount to the final value.". Another strand of literature examines value added trade based on input-output techniques which are variants or generalizations and further developments of the vertical specialization measures as suggested by Hummels et al. (2001) and many other papers following this approach. In most cases this literature is focused on the US trade deficit in general and with China in particular arguing that the US deficit with China is reduced by about 15-20 when measured in value added terms. Recent contributions in measuring value added trade based on input-output techniques include Hummels et al. (2001), Daudin et al. (2011), Johnson

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and Noguera (2012), and Koopman et al. (2010) and, with a focus on the factor content of trade and testing the Heckscher-Ohlin-Vanek predictions, Trefler and Zhu (2010). In both cases the literature both includes a focus on a country's total trade and its bilateral relations.[1]

In this paper we build on the above mentioned contributions and distinguish carefully between two concepts of value added flows across countries: The first - "trade in value added" - accounts for the value added of one country directly and indirectly contained in final consumption of another country. The typical question would be: 'How much value added of other countries is contained in the consumption of the country under examination?' The second concept - "value added in trade" - calculates the value added contained in gross trade flows between two countries. The typical question would be: 'How much of value added from other countries is contained in the gross imports of one country?' or 'How much of foreign value added does the gross exports of a country embody?'

Though these two concepts measure different flows of value added across countries we show that a country's trade surplus or deficit is the same in both cases and, furthermore, equals this country's net trade when measured in gross terms. After succinctly defining both concepts this can be shown analytically. However, this result at the macro level does not carry over when considering bilateral relations. In this case the concept of "trade in value added" results in different levels of bilateral surpluses or deficits as measured in gross terms. Defining bilateral "value added in trade" is less straightforward. We therefore require that such a measure should satisfy two properties: First, adding up a country's bilateral trade surpluses or deficits over all partner countries should result in this country's overall trade surplus or deficit. Second, a country's bilateral trade surplus (deficit) with another country must this other country's bilateral deficit (surplus), i.e. it's mirrored. Under these two requirements it turns out that the bilateral "value added in trade" surplus or deficit equals a country's bilateral net trade in gross terms.

In Section 2 we define these two concepts and show analytically that these result in the same net trade figures of a country's overall trade in gross terms. We also discuss the differences when looking at bilateral trade relations. Furthermore, we extend both approaches to be applied for value added components (e.g. capital and labor income and the latter broken down by educational attainment categories) and physical factor inputs (e.g. employment). Section 3 gives a short overview of the data used for the empirical part which relies on a recently compiled and unique world input-output database (WIOD). Section 4 then provides selected empirical results to highlight similarities and differences of these two concepts and important patterns of trade across countries. These results point towards the underlying questions concerning trade patterns, factor rewards and the factor content of trade. However, it is not the intention of this paper and would go beyond the scope of it provide detailed explanations. The focus of this paper is on the measurement issue and the differences and similarities of the two concepts mixed up in the literature. Section 5 concludes.

2. Trade in value added and value added in trade

In this section we propose measures for "trade in value added" and "value added in trade" and discuss how these relate to each other. We start discussion with a country's overall trade and then go on to consider these approaches in bilateral relations. For clarity we discuss these concepts in a three country setting without loss of generality. An empirical application can then be found in Section 4.

2.1. Measuring "trade in value added"

We start with the proper measure of "trade in value added". The basic question asked here is how much of value added of a particular country r is contained in consumption of another country s. Based on an

[1] In the "factor content of trade" literature the important contributions include Choi and Krishna (2004) and Lai and Zhu (2007). With respect to trade in intermediates these papers accept the result by Staiger (1986). All of them build upon Helpman (1984).

input-output approach the basic relationship to start with is

$$\mathbf{x} = \mathbf{A}\mathbf{x} + \mathbf{f} = \mathbf{L}\mathbf{f}$$

$\mathbf{x}$ denotes a $CG \times 1$ vector of gross output (with C being the number of countries and G the number of products considered). $\mathbf{A}$ is a $CG \times CG$ matrix of technical input-output coefficients with each element denoting the input used in a particular industry in one country per unit of gross output. $\mathbf{f}$ denotes the $CG \times 1$ vector of final demand. The second part rearranges this equation such that gross output is written as a function of the Leontief inverse, $\mathbf{L} = (\mathbf{I} - \mathbf{A})^{-1}$, and the final demand vector. For three countries and using partitioned matrices this equation can be written as follows:

$$\begin{bmatrix}\mathbf{x}^r\\ \mathbf{x}^s\\ \mathbf{x}^t\end{bmatrix} = \begin{bmatrix}\mathbf{A}^{rr} & \mathbf{A}^{rs} & \mathbf{A}^{rt}\\ \mathbf{A}^{sr} & \mathbf{A}^{ss} & \mathbf{A}^{st}\\ \mathbf{A}^{tr} & \mathbf{A}^{ts} & \mathbf{A}^{tt}\end{bmatrix}\begin{bmatrix}\mathbf{x}^r\\ \mathbf{x}^s\\ \mathbf{x}^t\end{bmatrix} + \begin{bmatrix}\mathbf{f}^r\\ \mathbf{f}^s\\ \mathbf{f}^t\end{bmatrix} = \begin{bmatrix}\mathbf{L}^{rr} & \mathbf{L}^{rs} & \mathbf{L}^{rt}\\ \mathbf{L}^{sr} & \mathbf{L}^{ss} & \mathbf{L}^{st}\\ \mathbf{L}^{tr} & \mathbf{L}^{ts} & \mathbf{L}^{tt}\end{bmatrix}\begin{pmatrix}\mathbf{f}^{rr} + \mathbf{f}^{rs} + \mathbf{f}^{rt}\\ \mathbf{f}^{sr} + \mathbf{f}^{ss} + \mathbf{f}^{st}\\ \mathbf{f}^{tr} + \mathbf{f}^{ts} + \mathbf{f}^{tt}\end{pmatrix}$$

$\mathbf{x}^c$ ($c = r, s, t$) denotes the $G \times 1$ vector of gross output in country c, $\mathbf{L}^{cd}$ the respective $G \times G$ submatrix of the Leontief inverse and $\mathbf{f}^{cd}$ the $G \times 1$ vector of final demand of country d in country c. It is important to distinguish between demand for final products which are produced in country c and thus includes exports, i.e. the $G \times 1$ vector $\mathbf{f}^c = \mathbf{f}^{cr} + \mathbf{f}^{cs} + \mathbf{f}^{ct}$, and the $CG \times 1$ vector denoting country c's final demand (domestically and imported), i.e. $\mathbf{f}^{*c} = \left((\mathbf{f}^{rc})', (\mathbf{f}^{sc})', (\mathbf{f}^{tc})'\right)'$. Pre-multiplying this equation with a $1 \times CG$ vector of value added coefficients, i.e. value added per unit of gross output $\mathbf{v}$, results in value added and will be used to calculate trade in value added terms. (Note, for notational reasons, vectors $\mathbf{v}$ and its subvectors $\mathbf{v}^c$ denote row vectors.)

Value added exports of country r to all other countries include value added created in country r to satisfy final demand in countries s and t.[2] Selecting the appropriate terms in the above equation gives:

$$\begin{aligned} t^r_{\text{TiVA},X} &= \begin{bmatrix}\mathbf{v}^r & \mathbf{0} & \mathbf{0}\end{bmatrix}\begin{bmatrix}\mathbf{L}^{rr} & \mathbf{L}^{rs} & \mathbf{L}^{rt}\\ \mathbf{L}^{sr} & \mathbf{L}^{ss} & \mathbf{L}^{st}\\ \mathbf{L}^{tr} & \mathbf{L}^{ts} & \mathbf{L}^{tt}\end{bmatrix}\begin{pmatrix}\mathbf{0} + \mathbf{f}^{rs} + \mathbf{f}^{rt}\\ \mathbf{0} + \mathbf{f}^{ss} + \mathbf{f}^{st}\\ \mathbf{0} + \mathbf{f}^{ts} + \mathbf{f}^{tt}\end{pmatrix}\\ &= \mathbf{v}^r\mathbf{L}^{rr}(\mathbf{f}^{rs} + \mathbf{f}^{rt}) + \mathbf{v}^r\mathbf{L}^{rs}(\mathbf{f}^{ss} + \mathbf{f}^{st}) + \mathbf{v}^r\mathbf{L}^{rt}(\mathbf{f}^{ts} + \mathbf{f}^{tt}) \end{aligned}$$

As we are only interested in value added created in country r we set the value added coefficients for the other countries to zero. Further, as we are not interested in how much value added is created in r to satisfy country r's final demand itself, we set the entries of country r's final demand vector, $\mathbf{f}^{*r}$, to zero. In particular this excludes subvector $\mathbf{f}^{sr}$ which would appear in the second term (in the second line of the equation above) as $\mathbf{v}^r\mathbf{L}^{rs}\mathbf{f}^{sr}$. This would include value added created in r needed to satisfy final demand imports of r from s thus capturing re-imports of country r value added which we do not count as value added exports. The first term in the second line therefore is value added created in country r to satisfy final demand imports (in gross terms) of countries s and t from country r. The second terms captures value added created in country r to satisfy country s domestic demand and demand via imports in gross terms from country t. As production of these final demand goods also uses intermediate inputs from r these embody value added created in r and therefore count as country r's value added exports. An analogous interpretation holds for the third term. In the general case for many countries we can write this expression as $t^r_{\text{TiVA,X}} = \mathbf{v}^r\mathbf{L}\mathbf{f}^{-r}$, where $\mathbf{v}^r$ denotes the value added coefficients vector with non-negative entries for country r and zeros for the other countries, and $\mathbf{f}^{-r}$ the consumption vector of all countries except r.

[2] This is the definition used in Johnson and Noguera (2012).

Value added imports of country r from all other countries should account for value added created in countries s and t to satisfy final demand of country r. Again selecting the appropriate terms the equation has to be written as:

$$\begin{aligned} t^r_{\text{TiVA},M} &= \begin{bmatrix}\mathbf{0} & \mathbf{v}^s & \mathbf{v}^t\end{bmatrix}\begin{bmatrix}\mathbf{L}^{rr} & \mathbf{L}^{rs} & \mathbf{L}^{rt}\\ \mathbf{L}^{sr} & \mathbf{L}^{ss} & \mathbf{L}^{st}\\ \mathbf{L}^{tr} & \mathbf{L}^{ts} & \mathbf{L}^{tt}\end{bmatrix}\begin{pmatrix}\mathbf{f}^{rr}+\mathbf{0}+\mathbf{0}\\ \mathbf{f}^{sr}+\mathbf{0}+\mathbf{0}\\ \mathbf{f}^{tr}+\mathbf{0}+\mathbf{0}\end{pmatrix} \\ &= (\mathbf{v}^s\mathbf{L}^{sr}+\mathbf{v}^t\mathbf{L}^{tr})\mathbf{f}^{rr}+(\mathbf{v}^s\mathbf{L}^{ss}+\mathbf{v}^t\mathbf{L}^{ts})\mathbf{f}^{sr}+(\mathbf{v}^s\mathbf{L}^{st}+\mathbf{v}^t\mathbf{L}^{tt})\mathbf{f}^{tr}\end{aligned}$$

The first term (in the second line) accounts for value added created in country s and t to satisfy country r's domestic demand, the second term denotes value added created in both countries to satisfy country r's demand for final products imported from country s, and analogously for the third term. In general notation this can be written as $t^r_{\text{TiVA,M}} = \mathbf{v}^{-r}\mathbf{L}\mathbf{f}^r$ with an analogous definition of the vectors as above.

Net trade in value added is defined as the difference between value added exports and imports:

$$t^r_{\text{TiVA,Net}} = t^r_{\text{TiVA},X} - t^r_{\text{TiVA},M}$$

Value added exports, imports and net trade can be derived for the other countries analogously.

Net trade in value added as defined here equals a country's total trade balance, i.e. GDP minus final consumption. This can be achieved by rewriting and manipulating the above equations in the following way:

$$\begin{aligned} t^r_{\text{TiVA,Net}} &= \begin{pmatrix}\mathbf{v}^r & \mathbf{0} & \mathbf{0}\end{pmatrix}\mathbf{L}(\mathbf{f}^{*s}+\mathbf{f}^{*t}) - \begin{pmatrix}\mathbf{0} & \mathbf{v}^s & \mathbf{v}^t\end{pmatrix}\mathbf{L}\mathbf{f}^{*r} \\ &= \begin{pmatrix}\mathbf{v}^r & \mathbf{0} & \mathbf{0}\end{pmatrix}\mathbf{L}(\mathbf{f}^{*s}+\mathbf{f}^{*t}) + \begin{pmatrix}\mathbf{v}^r & \mathbf{0} & \mathbf{0}\end{pmatrix}\mathbf{L}\mathbf{f}^{*r} - \begin{pmatrix}\mathbf{v}^r & \mathbf{0} & \mathbf{0}\end{pmatrix}\mathbf{L}\mathbf{f}^{*r} - \begin{pmatrix}\mathbf{0} & \mathbf{v}^s & \mathbf{v}^t\end{pmatrix}\mathbf{L}\mathbf{f}^{*r} \\ &= \begin{pmatrix}\mathbf{v}^r & \mathbf{0} & \mathbf{0}\end{pmatrix}\mathbf{L}(\mathbf{f}^{*r}+\mathbf{f}^{*s}+\mathbf{f}^{*t}) - \begin{pmatrix}\mathbf{v}^r & \mathbf{v}^s & \mathbf{v}^t\end{pmatrix}\mathbf{L}\mathbf{f}^{*r} \\ &= \begin{pmatrix}\mathbf{v}^r & \mathbf{0} & \mathbf{0}\end{pmatrix}\mathbf{L}\mathbf{f} - \mathbf{v}\mathbf{L}\mathbf{f}^{*r} \\ &= \begin{pmatrix}\mathbf{v}^r & \mathbf{0} & \mathbf{0}\end{pmatrix}\mathbf{x} - \boldsymbol{\iota}'(\mathbf{I}-\mathbf{A})(\mathbf{I}-\mathbf{A})^{-1}\mathbf{f}^{*r} \\ &= y^r - \boldsymbol{\iota}'\mathbf{f}^{*r}\end{aligned}$$

The first line rewrites the above definitions of value added exports and imports. In the second line we add and subtract the terms in the middle which are then collected in the third line and rewritten in more compact notation in the fourth line. In the fifth line we make use of the fact that $\mathbf{x} = \mathbf{L}\mathbf{f}$ and the value added coefficient vector can be written as $\mathbf{v} = \boldsymbol{\iota}'(\mathbf{I}-\mathbf{A})$ where $\boldsymbol{\iota}'$ denotes a $1 \times CG$ summation vector. The last line uses that the first term is country r's GDP, the value added coefficients vector times the gross output vector, and the second term is the level of country r's final demand (for both domestic and imported final products). For the general case of many countries this is derived as follows:

$$t^r_{\text{TiVA,Net}} = \mathbf{v}^r\mathbf{L}\mathbf{f}^{-r} - \mathbf{v}^{-r}\mathbf{L}\mathbf{f}^r = \mathbf{v}^r\mathbf{L}\mathbf{f} - \mathbf{v}\mathbf{L}\mathbf{f}^r = \mathbf{v}^r\mathbf{x} - \boldsymbol{\iota}'\mathbf{f}^r = y^r - \boldsymbol{\iota}'\mathbf{f}^r$$

Thus, a country's trade in value added is GDP minus final demand expenditures. If a country's GDP is larger (smaller) than its final consumption it is running a trade surplus (deficit) which is well known from national accounting. Next we show that this also equals a country's "value added in trade" in net terms and its trade balance in gross terms.

2.2. Measuring the "value added in trade"

The second measure is to calculate the content of value added as contained in a country's gross exports and imports and the subsequent net flows of value added embodied in gross trade flows. This therefore focuses on the domestic and foreign value added embodied in a country's gross exports and imports. This is the concept used in the literature on the factor content of trade (Trefler and Zhu, 2010).

Using the same notation as above we discuss the value added content of trade from the viewpoint of country r without any loss in generality. Following Trefler and Zhu (2010) we write the vector of gross trade as

$$\mathbf{t}^r = \begin{pmatrix} \mathbf{t}^{rs} + \mathbf{t}^{rt} \\ -\mathbf{t}^{sr} \\ -\mathbf{t}^{tr} \end{pmatrix}$$

$\mathbf{t}^{rc}$ denotes country c's imports from r or country r's exports to c. Country r's imports are included in negative terms. One should note that these trade vectors include both trade in final goods and trade in intermediates which sums up to a country's total gross exports or imports, i.e. $\mathbf{t}^{rs} = \mathbf{f}^{rs} + \mathbf{z}^{rs}$ where $\mathbf{z}^{rs}$ denotes country r's imports of intermediates from s and analogously for the other terms. As imports are included in negative terms this results in country r's net value added content in trade. It is again enlightening to write the equation in detail:

$$\begin{aligned}
t^r_{\text{VAiT,Net}} &= \begin{pmatrix} \mathbf{v}^r & \mathbf{v}^s & \mathbf{v}^t \end{pmatrix} \begin{pmatrix} \mathbf{L}^{rr} & \mathbf{L}^{rs} & \mathbf{L}^{rt} \\ \mathbf{L}^{sr} & \mathbf{L}^{ss} & \mathbf{L}^{st} \\ \mathbf{L}^{tr} & \mathbf{L}^{ts} & \mathbf{L}^{tt} \end{pmatrix} \begin{pmatrix} \mathbf{t}^{rs} + \mathbf{t}^{rt} \\ -\mathbf{t}^{sr} \\ -\mathbf{t}^{tr} \end{pmatrix} \\
&= (\mathbf{v}^r\mathbf{L}^{rr} + \mathbf{v}^s\mathbf{L}^{sr} + \mathbf{v}^t\mathbf{L}^{tr})(\mathbf{f}^{rs} + \mathbf{f}^{rt}) - (\mathbf{v}^r\mathbf{L}^{rs} + \mathbf{v}^s\mathbf{L}^{ss} + \mathbf{v}^t\mathbf{L}^{ts})\mathbf{f}^{sr} - (\mathbf{v}^r\mathbf{L}^{rt} + \mathbf{v}^s\mathbf{L}^{st} + \mathbf{v}^t\mathbf{L}^{tt})\mathbf{f}^{tr} \\
&= \mathbf{v}^r\Big(\mathbf{L}^{rr}(\mathbf{t}^{rs} + \mathbf{t}^{rt}) - \mathbf{L}^{rs}\mathbf{t}^{sr} - \mathbf{L}^{rt}\mathbf{t}^{tr}\Big) + \\
&\quad \mathbf{v}^s\Big(\mathbf{L}^{sr}(\mathbf{t}^{rs} + \mathbf{t}^{rt}) - \mathbf{L}^{ss}\mathbf{t}^{sr} - \mathbf{L}^{st}\mathbf{t}^{tr}\Big) + \\
&\quad \mathbf{v}^t\Big(\mathbf{L}^{tr}(\mathbf{t}^{rs} + \mathbf{t}^{rt}) - \mathbf{L}^{ts}\mathbf{t}^{sr} - \mathbf{L}^{tt}\mathbf{t}^{tr}\Big)
\end{aligned}$$

The first term in the second line captures the domestic and foreign value added embodied in country r's exports in gross terms. The second term captures the domestic and foreign value added embodied in country r's imports from s in gross terms, and analogously for the third term. This allows showing the relationship between a country's trade balance in gross and value added terms. Again using that $\mathbf{v} = \boldsymbol{\iota}'(\mathbf{I} - \mathbf{A})^{-1}$ shows

$$t^r_{\text{VAiT,Net}} = \mathbf{v}'(\mathbf{I} - \mathbf{A})^{-1}\mathbf{t} = \boldsymbol{\iota}'(\mathbf{I} - \mathbf{A})(\mathbf{I} - \mathbf{A})^{-1}\mathbf{t} = \boldsymbol{\iota}'\mathbf{t} = t^r_{\text{Gross,Net}}$$

i.e. the net content of value added in trade equals the net trade in gross terms. By appropriate definition of the matrices this can easily be generalized to many countries.

From this it follows that

$$t^r_{\text{TiVA,Net}} = y^r - \boldsymbol{\iota}'\mathbf{f}^{*r} = \boldsymbol{\iota}'\mathbf{t} = t^r_{\text{VAiT,Net}}$$

i.e. a country's trade balance does not change when measured in value added terms, as income minus consumption of (domestic and foreign) final goods, i.e. its savings, equals its net exports. To see this and the role of imported intermediates play more clearly we can rearrange this as

$$y^r = \boldsymbol{\iota}'\left[\begin{pmatrix} \mathbf{f}^{rr} \\ \mathbf{f}^{sr} \\ \mathbf{f}^{tr} \end{pmatrix} + \begin{pmatrix} \mathbf{t}^{rs} + \mathbf{t}^{rt} \\ -\mathbf{t}^{sr} \\ -\mathbf{t}^{tr} \end{pmatrix}\right] = \boldsymbol{\iota}'\begin{pmatrix} \mathbf{f}^{rr} + \mathbf{t}^{rs} + \mathbf{t}^{rt} \\ \mathbf{f}^{sr} - \mathbf{f}^{sr} - \mathbf{z}^{sr} \\ \mathbf{f}^{tr} - \mathbf{f}^{tr} - \mathbf{z}^{tr} \end{pmatrix} = \boldsymbol{\iota}'\left\{\begin{pmatrix} \mathbf{f}^{rr} + \mathbf{f}^{rs} + \mathbf{f}^{rt} \\ \mathbf{0} \\ \mathbf{0} \end{pmatrix} + \begin{pmatrix} \mathbf{z}^{rs} + \mathbf{z}^{rt} \\ -\mathbf{z}^{sr} \\ -\mathbf{z}^{tr} \end{pmatrix}\right\}$$

A country's GDP equals domestic and foreign demand for its products including exported intermediates from which imported intermediates have to be subtracted. Note, that this corresponds to national input-output tables where imported intermediates are included in the intermediates block and thus do not count for value added, i.e. GDP, whereas the column for exports includes both intermediates and final goods exports. It is interesting to consider two special cases. Without intermediates trade the equation would become $y^r = \boldsymbol{\iota}'(\mathbf{f}^{rr} + \mathbf{f}^{rs} + \mathbf{f}^{rt})$, i.e. GDP of country r equals expenditures on (or demand for) its final goods. As a second special case consider a country which does not produce final goods but only intermediates, e.g. oil, without any other imported intermediates. Exports would consist of intermediates only and GDP would become $y^r = \boldsymbol{\iota}'(\mathbf{z}^{rs} + \mathbf{z}^{rt})$. Finally, it is easy to see that when adding up over all countries the intermediates part cancels out resulting in the fact that world GDP equals world consumption.

2.3. Trade in value added and value added in trade in bilateral relations

Both approaches can be applied considering bilateral trade. We concentrate on trade between countries r and s in a setting with three countries without loss of generality. Though in a two-country case the measure for trade in value added and the value added in trade would not differ in net terms, it does so when considering bilateral relations in a multi-country world. We argue that the measure for bilateral relations should satisfy both an adding-up and a negative symmetry condition. The adding-up condition requires that when adding up bilateral flows one arrives at total flows in value added terms. The symmetry condition requires that in the bilateral relation a country's exports must equal the other country's imports and vice versa. This also implies that a country's net trade in value added terms or it's net value added in trade is the negative of the other country's balance.

For calculating "trade in value added" in a bilateral way we exclude country r's value added consumed in country t as we are only interested in its exports of value added to country s. With respect to imports we have to rule out country r's imports from t. Algebraically this suggests to set the value added coefficients of country t to zero. Note that this still would include country r's imports from t in gross terms as these partly embody value added from country s which has to be taken into account. Formally, value added exports (imports) of country r to (from) s would therefore be calculated as:

$$
\begin{aligned}
t^{rs}_{\text{TiVA,X}} &= \begin{bmatrix}\mathbf{v}^r & \mathbf{0} & \mathbf{0}\end{bmatrix}\begin{bmatrix}\mathbf{L}^{rr} & \mathbf{L}^{rs} & \mathbf{L}^{rt}\\ \mathbf{L}^{sr} & \mathbf{L}^{ss} & \mathbf{L}^{st}\\ \mathbf{L}^{tr} & \mathbf{L}^{ts} & \mathbf{L}^{tt}\end{bmatrix}\begin{pmatrix}\mathbf{0}+\mathbf{f}^{rs}+\mathbf{0}\\ \mathbf{0}+\mathbf{f}^{ss}+\mathbf{0}\\ \mathbf{0}+\mathbf{f}^{ts}+\mathbf{0}\end{pmatrix}\\
&= \mathbf{v}^r\mathbf{L}^{rr}\mathbf{f}^{rs} + \mathbf{v}^r\mathbf{L}^{rs}\mathbf{f}^{ss} + \mathbf{v}^r\mathbf{L}^{rt}\mathbf{f}^{ts}
\end{aligned}
$$

$$
\begin{aligned}
t^{rs}_{\text{TiVA,M}} &= \begin{bmatrix}\mathbf{0} & \mathbf{v}^s & \mathbf{0}\end{bmatrix}\begin{bmatrix}\mathbf{L}^{rr} & \mathbf{L}^{rs} & \mathbf{L}^{rt}\\ \mathbf{L}^{sr} & \mathbf{L}^{ss} & \mathbf{L}^{st}\\ \mathbf{L}^{tr} & \mathbf{L}^{ts} & \mathbf{L}^{tt}\end{bmatrix}\begin{pmatrix}\mathbf{f}^{rr}+\mathbf{0}+\mathbf{0}\\ \mathbf{f}^{sr}+\mathbf{0}+\mathbf{0}\\ \mathbf{f}^{tr}+\mathbf{0}+\mathbf{0}\end{pmatrix}\\
&= \mathbf{v}^s\mathbf{L}^{sr}\mathbf{f}^{rr} + \mathbf{v}^s\mathbf{L}^{ss}\mathbf{f}^{sr} + \mathbf{v}^s\mathbf{L}^{st}\mathbf{f}^{tr}
\end{aligned}
$$

First, note that when calculating bilateral value added exports, imports and bilateral net trade also with country t and add up over partner countries we would again arrive at country r's total net trade in value added which can be seen easily. Thus, in this sense the measure satisfies the adding-up requirement. Second, it is also easily seen that $t^{rs}_{\text{TiVA,Net}} = -t^{sr}_{\text{TiVA,Net}}$ as country r's value added exports to s equals country s's value added imports from r and vice versa. Thus this measure satisfies the negative symmetry condition.

When calculating the "value added in trade" in bilateral flows the two requirements suggest considering only the cells including bilateral trade flows in gross terms. Therefore we set $\mathbf{t}^{tr} = \mathbf{t}^{rt} = \mathbf{0}$ in the calculations:

$$\begin{aligned} t^{rs}_{\text{VAiT,Net}} &= \begin{pmatrix}\mathbf{v}^r & \mathbf{v}^s & \mathbf{v}^t\end{pmatrix}\begin{pmatrix}\mathbf{L}^{rr} & \mathbf{L}^{rs} & \mathbf{L}^{rt}\\ \mathbf{L}^{sr} & \mathbf{L}^{ss} & \mathbf{L}^{st}\\ \mathbf{L}^{tr} & \mathbf{L}^{ts} & \mathbf{L}^{tt}\end{pmatrix}\begin{pmatrix}\mathbf{t}^{rs}\\ -\mathbf{t}^{sr}\\ \mathbf{0}\end{pmatrix} \\ &= \mathbf{v}^r(\mathbf{L}^{rr}\mathbf{t}^{rs} - \mathbf{L}^{rs}\mathbf{t}^{sr}) + \mathbf{v}^s(\mathbf{L}^{sr}\mathbf{t}^{rs} - \mathbf{L}^{ss}\mathbf{t}^{sr}) + \mathbf{v}^t(\mathbf{L}^{tr}\mathbf{t}^{rs} - \mathbf{L}^{ts}\mathbf{t}^{sr}) \end{aligned}$$

Using the definition for the value added coefficients vector yields the result that bilateral net value added in trade equals bilateral net trade in gross terms analogously to above. (One should however notice that this also includes embodied value added from country t.) This measure also satisfies the adding-up and the negative symmetry property which can be seen easily. However, from these two expressions it also follows that $t^{rs}_{\text{TiVA,Net}} \neq t^{rs}_{\text{VAiT,Net}}$ with the sign of the difference not being determined (see the empirical results presented below).

2.4. Various primary factors of production

A country's value added is made up of rewards of various factors like labor and capital, or even more detailed breakdowns. In this case the same algebra applies and in particular the result of the equality of net trade in value added and net value added in trade still holds.[3] We show this for physical input units, i.e. we consider "trade in employment" and "employment in trade". Country r's employment embodied in total production of r for products demanded both domestically and from the foreign countries (which equals its endowments) minus (worldwide) employment contained in consumption of r, equals country r's net trade in employment.[4] This can be shown using a similar algebra as above where we replace the vector of value added coefficients with vectors of employment coefficients denoted by $\mathbf{e}^r$ which can be rearranged as follows:

$$\begin{aligned} t^r_{\text{TiE,Net}} &= t^r_{\text{EiT,Net}} \\ \mathbf{e}^r\mathbf{L}\mathbf{f}^{-r} - \mathbf{e}^{-r}\mathbf{L}\mathbf{f}^r &= \mathbf{e}\mathbf{L}\mathbf{t}^r \\ \mathbf{e}^r\mathbf{L}\mathbf{f} - \mathbf{e}\mathbf{L}\mathbf{f}^r &= \mathbf{e}\mathbf{L}\mathbf{t}^r \\ \mathbf{e}^r\mathbf{x} - \mathbf{e}\mathbf{L}\mathbf{f}^r &= \mathbf{e}\mathbf{L}\mathbf{t}^r \\ e^r &= \mathbf{e}\mathbf{L}(\mathbf{f}^r + \mathbf{t}^r) \end{aligned}$$

For interpretation we rewrite this for the case of three countries analogously to above:

$$e^r = \mathbf{e}\mathbf{L}\left\{\begin{pmatrix}\mathbf{f}^{rr}\\ \mathbf{f}^{sr}\\ \mathbf{f}^{tr}\end{pmatrix} + \begin{pmatrix}\mathbf{f}^{rs} + \mathbf{f}^{rt}\\ -\mathbf{f}^{sr}\\ -\mathbf{f}^{tr}\end{pmatrix} + \begin{pmatrix}\mathbf{z}^{rs} + \mathbf{z}^{rt}\\ -\mathbf{z}^{sr}\\ -\mathbf{z}^{tr}\end{pmatrix}\right\} = \mathbf{e}\mathbf{L}\left\{\begin{pmatrix}\mathbf{f}^{rr} + \mathbf{f}^{rs} + \mathbf{f}^{rt}\\ \mathbf{0}\\ \mathbf{0}\end{pmatrix} + \begin{pmatrix}\mathbf{z}^{rs} + \mathbf{z}^{rt}\\ -\mathbf{z}^{sr}\\ -\mathbf{z}^{tr}\end{pmatrix}\right\}$$

A similar interpretation as in the case of value added above holds. A country's employment equals its directly and indirectly embodied labor in production of final goods (for domestic and foreign consumption) and of exported intermediate products from which direct and indirect labor embodied in intermediate imports have to be subtracted. Without intermediates trade the vectors containing intermediates $\mathbf{z}^{rp}$ would

[3] Of course the equality with the trade balance in gross terms only applies for total value added.

[4] In the factor content of trade literature total employment used is then interpreted as factor endowments. Thus, this concept does not take macro-economic imbalances like unemployment into account.

vanish and the Leontief inverse would become block-diagonal. In this case a country's employment equals its direct and indirectly used labor for production of its final output (either domestically consumed or exported). Particularly, this links the literature on the factor content of trade to the literature on trade in value added.[5] Finally, one can again see easily that when summing up over all countries that the intermediates part cancels out resulting in world employment.

3. The World Input-Output Database (WIOD)

An empirical analysis requires data on output, inputs by factor and the domestic and foreign use of intermediate inputs by industry. We provide a short overview of the construction of such a database, the World Input-Output Database (WIOD); for details see Timmer et al. (2012).[6] The global input-output tables, on which the analysis is based, are derived from national supply and use tables which are combined with detailed trade data. The resulting set of international supply and use tables, i.e. a set of domestic and import use tables broken down by partner countries, are then transformed by standard procedures into a World Input-Output Table (WIOT). The data are collected on an annual basis from 1995 to 2009 for 59 products and 35 industries (ISIC Revision 3) and cover 40 countries (EU-27 countries, Turkey, Canada, USA and Mexico, Japan, Korea, Taiwan, Australia, Brazil, Russia, India, Indonesia and China) which account for about 85 percent of world GDP.

Thus, as building blocks for the WIOTs national supply and use tables (SUTs) which are the core statistical sources from which National Statistical Institutes (NSIs) derive national input-output tables are collected. SUTs are a natural starting point as they provide information on both products and industries. Supply tables provide information on products produced by each domestic industry and use tables indicate the use of each product by an industry or final user. By benchmarking the SUTs on consistent time series on gross output and value added from the National Accounting System, tables are linked over time in a consistent way. This is done by using an updating method (the "SUT-RAS method") which is akin to the well-known bi-proportional (RAS) updating method for input-output tables as described in Temurshoev and Timmer (2011).

The link of such tables with international trade data, which are product-based, can be naturally made in a SUT framework. For goods trade, products are allocated to three use categories based on the detailed product description at the HS 6-digit level: intermediates, final consumption, and investment in accordance with the information provided in the tables. The allocation follows from a revised correspondence between HS-6 digit and Broad Economic Categories (BEC). Services trade data from Balance of Payments statistics have been collected from various sources (including OECD, Eurostat, IMF and WTO), checked for consistency, and integrated into a bilateral service trade database. The international SUTs were then constructed using bilateral trade shares by use category which allows to split imports as provided in the national supply tables by use categories and countries of origin. This resulted in an import use table for each country, where each cell of the import use table is then split up by country of origin.

As a final step, these international SUTs are transformed into an industry-by-industry type World Input-Output Table (WIOT). Here, the so-called "fixed product-sales structure" assumption stating that each product has its own specific sales structure irrespective of the industry where it is produced (see Eurostat, 2008). Finally, a rest-of-world is constructed on basis of additional data with respect to output, value added and trade flows based on input coefficients derived from an average coefficients from Brazil, China, India, Indonesia, and Mexico. This results in a WIOT for 41 countries and 35 industries, i.e. the intermediates

[5] See also Johnson and Noguera (2012) for a similar discussion.

[6] See the World Input-Output Database project: www.wiod.org.

demand block is of dimension 1435 × 1435, plus the additional rows on value added and columns on final demand categories. It is important to note that the information on the level of trade flows is based on National Accounts statistics and the WIOT is derived in basic prices which requires some assumptions on domestic and international transport margins.

At the industry level the data are further combined with information obtained from Socio-Economic Accounts data (SEAs), including employment and labor compensation broken down by educational attainment categories and capital compensation. These Socio-Economic Accounts (SEAs) have largely been constructed on the basis of data from national statistical institutes and processed according to harmonized procedures. These procedures were developed to ensure international comparability of the basic data and to generate socio-economic accounts in a consistent and uniform way. Cross-country harmonization of the basic country data has focused on a number of areas including a common industrial classification, consistent definitions of various labor and capital types, and the use of similar price concepts for inputs and outputs. A novelty of the database is the detailed breakdown of labor service inputs which are based on series of employment and wages of various types of labor which are not part of the core set of National Accounts statistics published by NSIs (typically only total employment and wages by industry are available from the National Accounts). For these series additional material has been collected from employment and labor force statistics. Employment is cross-classified by educational attainment (high, medium and low educated according to ISCED classification). For each country, a choice was made concerning the best statistical source for consistent wage and employment data at the industry level. In most cases this was the labor force survey (LFS), which in a number of cases was combined with earnings surveys as wages are often not included in the LFS. In other instances, an establishment survey, or social-security database was used (for details see Timmer et al., 2010; Erumban et al., 2012). Most employment surveys are not designed to track developments over time and breaks in methodology or coverage frequently occur. Therefore, care has been taken to arrive at series which are consistent over time. Further, labor compensation of self-employed is not registered in the National Accounts, which, as emphasized by Krueger (1999), leads to an understatement of labor's share. In these cases an imputation by assuming that the compensation per hour of self-employed is equal to the compensation per hour of employees. This is especially important for industries which have a large share of self-employed workers, such as agriculture, trade, business and personal services. Also, we assume the same labor characteristics for self-employed as for employees when information on the former is missing. These assumptions are made at the industry level.[7] Finally, capital compensation is derived as gross value added minus labor compensation.

The resulting database is therefore rooted in statistics from the National Accounts and follows the concepts and conventions of the System of National Accounts (SNA) framework, and its European equivalent, the European System of National Accounts (ESA), in many respects. The basic statistics is closely related to the national accounts statistics published by NSIs, although with adjustments that vary by group of variables considered: output and intermediate inputs, labor input and capital input.

4. Empirical illustration

In this section we apply both concepts to show the magnitudes of "trade in value added" and "value added in trade" and highlight similarities and differences of both concepts. We start with an analysis at the aggregate level and then go on to discuss these two concepts in a bilateral setting. For simplicity, we aggregated the EU-27 countries to one category which therefore includes intra-EU trade.[8]

[7] Further, in this paper we use information from the EU LFS to split employment by educational groups at a more detailed sectoral level as available in the WIOD database.

[8] Aggregation was done after the calculations on the basis of the 41 countries.

4.1. Value added flows at aggregate level

Table 1 presents the results for both concepts together with export and import values when measured in gross terms. As argued in the theoretical section, country's trade surplus or deficit is equal when either measured in terms of "trade in value added" or "value added in trade". According to these figures, China shows the largest surplus with 170.9 bn US-$ followed by the EU-27 with 152.8 bn US-$ and Japan with 132.3 bn US-$. The by far largest deficit has the USA with 582.4 bn US-$. These figures should equal net trade in gross terms. The reason why the numbers presented are slightly different are due to the fact that in the calculations value added is not exactly equal to gross output minus intermediate inputs which emerges from taking net taxes on products and international transport margins into account as done in the WIOT data.[9] The last column shows net trade in percent of GDP. China (7.57 %) and Russia (12.98 %) have the highest shares of trade surpluses in terms of GDP, whereas the USA (-4.61 %), Turkey (-7.36 %) and the rest-of-world category show the largest deficits in terms of GDP. A second important result is that export and import values for "trade in value added" are in all cases lower as those compared to the figures for "value added in trade".[10] This results from the different concepts with the measure of "value added in trade" plagued by the problem of "double-counting" as it multiplies the coefficient matrix with exports and imports already including both intermediates and final goods for reasons outlined above. It is however important to note that this problem does not apply in the net trade figures where the "double-counting" cancels out.[11]

Table 1 Gross trade, trade in value added and value added in trade in bn US-$, 2005

	Gross trade			Value added in trade			Trade in value added			in %
Reporter	Exports	Imports	Net	Exports	Imports	Net	Exports	Imports	Net	of GDP
China	836.7	669.8	166.9	813.9	643.0	170.9	592.0	421.1	170.9	7.57
European Union	4619.9	4372.0	247.9	4266.8	4114.0	152.8	2988.5	2836.5	152.0	1.24
Japan	653.7	530.6	123.1	645.7	513.4	132.3	553.9	421.6	132.3	2.92
Russia	226.9	137.6	89.3	214.7	129.7	85.0	196.9	111.9	85.0	12.98
Canada	416.2	355.3	60.8	395.8	343.9	51.9	296.6	244.7	51.9	4.91
Korea	327.9	281.6	46.3	302.7	274.1	28.5	195.7	167.1	28.5	3.75
Brazil	134.0	96.8	37.2	118.4	93.0	25.3	105.5	79.4	26.1	3.33
Taiwan	226.7	200.8	25.9	215.5	194.7	20.7	117.8	97.1	20.7	6.01
Indonesia	93.9	78.2	15.7	92.5	75.8	16.7	76.4	59.7	16.7	6.03
Australia	149.3	151.4	-2.1	142.9	145.7	-2.9	123.1	126.0	-2.9	-0.43
Mexico	218.3	219.7	-1.4	207.3	211.7	-4.4	145.8	150.2	-4.4	-0.55
India	157.7	169.9	-12.1	147.0	165.3	-18.3	116.7	135.0	-18.3	-2.34
Turkey	83.9	112.7	-28.8	75.7	106.6	-30.8	55.8	86.6	-30.8	-7.36
Rest-of-world	1992.1	2113.5	-121.4	1966.2	2011.5	-45.3	1388.4	1433.8	-45.3	-4.77
USA	1187.0	1834.3	-647.3	1169.9	1752.3	-582.4	927.7	1510.1	-582.4	-4.61

Note: EU-27 exports and imports include intra-EU trade

Source: WIOD database; author's calculations

As shown in Section 2.4 both concepts can be applied for various factor income categories and physical input units. Table 2 therefore shows the resulting numbers when splitting value added into capital income

[9] When defining value added as gross output minus intermediates this would result in exactly the same numbers; results are available upon request.

[10] The latter would again be equal to gross trade figures when defining value added as gross output minus intermediates.

[11] Alternatively, one could apply the concept of "value added in trade" only to trade in final goods. This would result in the net trade balance of final goods in gross trade.

and labor income, and the latter into factor income by educational attainment categories. Further, the concept is applied to trade in factors in physical units in terms of capital and persons employed again broken down by educational attainment categories. Again, net trade by factor is equal for both concepts whereas export and import values would again be higher when measures as "value added in trade".[12] In this table countries are again ranked according to their trade balance. Strikingly, China's surplus is mainly driven by a positive balance in capital with labor (in value terms) contributing only less than 5%. However, its net exports contain a large surplus of employment (in physical terms) of more than 136 mn persons employed of which about two third are low educated. In terms of labor income broken down by educational attainment categories it turns out that China is running a deficit with respect to high and medium educated but a surplus with respect to low educated workers. Oppositely, the net balance with respect to the capital stock is negative. These figures therefore hint towards the low wages paid in China as compared to other countries with the factor rewards for capital seemingly being relatively larger - a fact which underpins the Heckscher-Ohlin framework, i.e. factor rewards of the abundant factor should be relatively smaller. For the next two countries, European Union and Japan, the opposite result holds. Net trade in capital income is lower, in case of the European Union even negative, as compared to labor. However, both countries show negative net content of employment in terms of persons employed with the numbers being much larger (in absolute terms) for medium and low educated workers and positive values with respect to the capital stock. A similar results also holds for the US with the deficit in capital income being much larger as compared to the deficit in labor income (-406.7 versus -175.7 bn US-$) and the content in terms of persons employed being again strongly negative. Two other interesting countries are Mexico showing a surplus in capital income but a deficit in labor income and India showing a much more balanced pattern. Generally, the net balance with respect to the capital stock is negative for countries like China, Russia, Indonesia, Mexico, Turkey and the rest-of-world.

4.2. Bilateral value added flows

Let us now turn to the bilateral relations focusing again on the US, Japan, the EU-27 and China as the reporter countries. We start again with discussing the trade flows with respect to value added and then proceed by the more detailed factors. Table 3 presents the figures for net trade in value added (TiVA) and net value added in trade (VAiT) for the four reporter countries together with the difference between these two measures. For each reporter we ranked the partner countries according to the trade balance according to value added in trade.

The EU as the reporter country has the largest trade deficit with China of 54.8 bn US-$ in terms of "value added in trade" whereas and in terms of "trade in value added" this reduces to 32.2 bn US-$, thus being about 40% lower. A similar reduction of about half is found with India where the deficit reduces from 16.6 to 8.2 bn US-$. For the other partner countries the deficits in both measures are relatively close together. With respect to partner countries where the EU has a surplus, this would be lowered in terms of "trade in value added" with the rest-of-world category but would increase in case of trade with the US, for example. Large reductions in relative terms can also be found for trade with Canada and to a much smaller extent with Australia.

The US runs bilateral trade deficits with all countries with the exception of Australia. Again, the largest trade deficit occurs with China which would be reduced by about 25% from 151.6 to 117.5 bn US-$. But, for example, it would increase against the EU from 112.9 to 141 bn US-$, i.e. by about 20%. With respect to other trading partners the trade deficit in terms of "trade in value added" is also sizeably reduced with

[12] Results are available upon request.

Table 2 Net trade by factor, 2005

	Value added and factor income						Physical inputs				
	Value	Factor income		Labor income			Factor input		Employment (in '000s)		
Reporter	added	Capital	Labor	High	Medium	Low	Capital	Empl.	High	Medium	Low
China	170.9	163.2	7.7	-56.9	-12.9	77.6	-47.7	136125.9	4598.3	40305.5	91222.1
European Union	152.8	-143.5	296.3	141.9	116.3	38.4	1294.9	-152226.1	-8503.0	-54622.2	-89101.0
Japan	132.3	29.4	102.9	44.1	89.6	-30.6	1131.7	-45560.2	-1525.1	-13110.8	-30924.3
Russia	85.0	47.7	37.3	2.1	46.6	-11.4	-158.9	-1420.5	402.5	6508.9	-8331.9
Canada	51.9	39.2	12.7	-14.5	43.9	-16.7	224.3	-11801.8	-580.7	-2788.6	-8432.5
Korea	28.5	-12.6	41.2	36.9	13.0	-8.6	182.0	-11388.5	814.8	-3616.3	-8587.0
Brazil	25.3	18.7	6.7	-0.3	-1.6	8.5	18.4	8381.2	424.3	1830.8	6126.1
Taiwan	20.7	10.7	10.1	1.4	-4.7	13.3	88.0	-3461.4	213.4	-1460.6	-2214.2
Indonesia	16.7	19.1	-2.4	-4.6	-6.5	8.7	-124.6	11703.1	193.0	1378.1	10132.0
Australia	-2.9	4.3	-7.2	-7.4	-8.0	8.2	122.2	-11116.3	-883.2	-4214.7	-6018.5
Mexico	-4.4	42.1	-46.5	-23.7	-16.9	-5.9	-163.1	-1259.3	-156.5	299.3	-1402.2
India	-18.3	-8.6	-9.7	0.1	-11.7	2.0	-0.2	42818.0	3776.1	12128.1	26913.8
Turkey	-30.8	-6.8	-24.0	-11.0	-16.9	4.0	-140.1	-3518.7	-377.5	-2002.9	-1138.3
Rest-of-world	-45.3	203.9	-249.2	-161.6	-132.1	43.4	-1359.4	187564.3	10854.6	72182.0	104527.6
USA	-582.4	-406.7	-175.7	53.6	-98.0	-131.0	-1067.4	-144839.6	-9251.1	-52816.7	-82771.8

Note: EU-27 exports and imports include intra-EU trade

Source: WIOD database; author's calculations

respect to Canada (92.3 to 74.3 bn US-$), Mexico (36.1 to 21.8 bn US-$), and India (23.3 to 17.4 bn US-$). Significant increases are found for Japan (50.7 to 67 bn US-$), and Russia (2.6 to 14.4 bn US-$).

Japan shows generally a much more balanced pattern of trade with respect to the two concepts with the trade deficit being reduced with Australia from 7.6 to 4.8 bn US-$ and with Indonesia from 6.5 to 4.5 bn US-$. Japan's surplus is sizeably reduced with Korea (from 14.2 to 7 bn US-$) and Taiwan (from 26.8 to 14.2 bn US-$), however much larger with the US where the surplus increases from 50.7 to 67 bn US-$.

For China one can see sizeable reductions of the trade deficit with Taiwan and Korea by about 70%. However, also China's surpluses are partly considerably reduced. In particular, the trade deficit with US shrinks from 151.6 to 117.5 bn US-$, with the EU from 54.8 to 32.2 bn US-$, with Mexico from 14.2 to 7 bn US-$ and for Canada from 12.5 to 8.8 bn US-$. An increase in its surpluses with respect to partner countries is seen for the rest-of-world category Finally, it is interesting to note the mirrored image of changes in surpluses and deficits when comparing the bilateral flows (e.g. US - China deficit and surplus, respectively). These results therefore partly confirm the cases studies in products like the iPod and other examples, that the US trade deficit would be lowered when measured in value added terms which is actually the case when considering bilateral relations for countries where production networks (or assembly trade) and linkages are strong. However, such results cannot be generalized when looking at a country's overall net trade - either as "value added in trade" or "trade in value added" - as one ends up with the overall trade deficit when summing up net trade over partner countries in the tables just discussed.

Figure 1 summarizes the differences for trade balances when either measured as "trade in value added" or as "value added in trade". A general picture is that for developing and emerging economies the trade surplus in terms of "trade in value added" is reduced as compared to "value added in trade" (see the chart for China and the position of US and EU, but also Mexico and Canada), but also the trade deficits being smaller (see e.g. position of Taiwan and Korea). As this is mirrored in trade balances of the more advanced economies, this also means that generally the trade deficits tend to be smaller (see the case of US and

Table 3 Bilateral net trade in value added and net value added trade in bn US-$, 2005

EU-27			USA			Japan			China		
Partner	VAiT	TiVA	Partner	VAiT	TiVA	Partner	VAiT	TiVA	Partner	VAiT	TiVA
China	-54.8	-32.2	China	-151.6	-117.5	Australia	-7.6	-4.8	Taiwan	-51.7	-16.3
Russia	-33.9	-36.9	European Union	-112.9	-141.0	Indonesia	-6.5	-4.5	Korea	-21.4	-6.8
Japan	-16.6	-20.9	Canada	-92.3	-74.3	India	-1.8	0.4	Japan	-4.9	-3.2
India	-16.6	-8.2	Rest-of-world	-79.8	-79.8	Brazil	1.4	1.2	Russia	-1.4	-2.5
Korea	-11.5	-10.2	Japan	-50.7	-67.0	Canada	1.7	1.6	Brazil	-1.4	-1.3
Brazil	-4.4	-5.8	Mexico	-36.1	-21.8	Turkey	1.9	2.5	Indonesia	-0.1	-0.7
Indonesia	-4.0	-3.9	India	-23.3	-17.4	China	4.9	3.2	Australia	0.6	1.4
Taiwan	1.8	-1.8	Taiwan	-14.7	-16.6	Russia	7.2	2.9	Turkey	5.1	3.9
Mexico	3.3	2.1	Brazil	-9.5	-11.3	Mexico	8.3	6.0	Rest-of-world	6.2	24.7
Turkey	5.6	7.8	Korea	-7.3	-14.4	Korea	14.2	7.0	India	6.8	6.2
Canada	9.0	4.5	Indonesia	-4.9	-6.5	Rest-of-world	14.5	14.5	Canada	12.5	8.8
Australia	15.7	12.6	Turkey	-3.1	-1.1	European Union	16.6	20.9	Mexico	14.2	7.0
USA	112.9	141.0	Russia	-2.6	-14.4	Taiwan	26.8	14.2	European Union	54.8	32.2
Rest-of-world	146.4	103.8	Australia	6.3	0.7	USA	50.7	67.0	USA	151.6	117.5

Note: VAiT ... value added in trade; TiVA ... trade in value added

Source: WIOD database; author's calculations

China), but also trade surpluses tend to be reduced for trade with developing and emerging economies (e.g. EU versus rest-of-world).

For completeness, we present the bilateral net trade figures broken down by factor income and physical inputs in Appendix Tables 4 to 7. It would go beyond the scope of this paper to outline the details of these results. However, let us mention a few important facts emerging from these figures: First, as already seen, for the aggregate net trade flows it seems that the more advanced countries tend to have larger deficits with respect to capital flows as compared to labor income flows (in value terms). For the three developed countries (US, EU and Japan) trade deficits in terms of capital tend to be larger for both concepts whereas these countries are large net importers of employment - and particularly so of low skilled employment - when measured in terms of persons employed. As a mirrored picture, emerging countries tend to have much larger surpluses in terms of capital as compared to labor - independently of the measurement concept applied - in trade with the developed economies whereas running a huge net surplus in physical employment terms. Basically, this hints towards a picture as expected from trade theory. Developing countries being abundant in labor tend to have low rewards to this factor as compared to capital together with relatively lower labor productivity as compared to capital productivity. A more detailed examination of this pattern will have to follow based on the measures of "trade in value added" and "value added in trade" focused on in this paper.

5. Conclusions

In this paper two concepts of measuring value added flows between countries have been introduced clarifying the empirical contributions in the recent literature on trade in value added and the factor content of trade. It is analytically shown that both concepts - "trade in value added" and "value added in trade" - result in the same level of net exports for a country's total trade which is also equal to a country's net trade in gross terms. However, this is not the case when looking at bilateral relations. where the difference of net trade between these two concepts can go in either direction. These concepts are also applied to value added

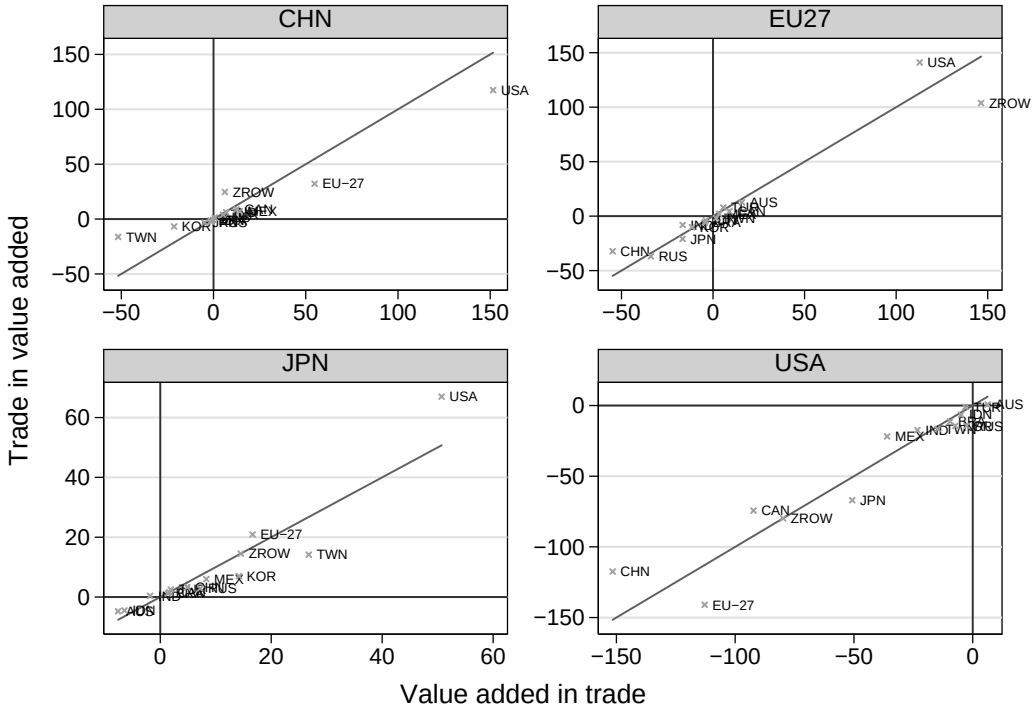

Figure 1. ”Trade in value added” and the ”Value added in trade”

broken down by income of various factors or to physical inputs like persons employed which are further differentiated by educational attainment categories.

The paper then presents selected empirical findings based on a recently compiled and unique database bringing together National Accounts data, supply and use and input-output tables and socio-economic accounts for a large range of countries in an integrated way, the world input-output database (WIOD). From these data a world-input-output table (WIOT) is derived which allows studying value added flows across countries in detail.

The empirical results tend to show that for developing and emerging economies the trade surplus in terms of ”trade in value added” is reduced as compared to ”value added in trade” in trade with more developed countries or trade deficits being somewhat smaller. This is mirrored in trade balances of the more advanced economies which is exemplified on figures for four countries. With respect to flows by factors the results tend to support the Heckscher-Ohlin framework when allowing for productivity differences as is studied in recent contributions to the factor content of trade. This paper aimed at clarifying the measurement concepts on which such factor content studies and other contributions focusing on vertical integration are based and highlight similarities and differences between ”trade in value added” and the ”value added in trade”.

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Appendix: Tables

Table 4 EU-27 flows by factor, 2005

	Value added and factor income						Physical inputs				
	Value	Factor income		Labor income			Factor input		Employment (in '000s)		
Reporter	added	Capital	Labor	High	Medium	Low	Capital	Empl.	High	Medium	Low
						Trade in value added					
Russia	-36.9	-26.4	-10.5	2.2	-17.4	4.7	91.4	-4203.9	-271.7	-3860.1	-72.1
China	-32.2	-44.2	12.0	18.6	7.5	-14.2	23.2	-37248.7	-1758.0	-12139.4	-23351.3
Japan	-20.9	-15.9	-5.0	-1.1	-9.4	5.5	-140.5	-21.3	-37.3	-191.9	207.9
Korea	-10.2	-3.8	-6.3	-5.9	-2.1	1.6	-36.0	-472.5	-281.2	-216.6	25.2
India	-8.2	-8.2	0.0	0.5	1.8	-2.3	0.7	-18282.6	-1404.1	-5701.7	-11176.8
Brazil	-5.8	-7.8	2.7	2.2	2.3	-1.8	8.9	-4343.7	-220.2	-1171.2	-2952.3
Indonesia	-3.9	-4.3	0.5	1.2	1.3	-2.0	32.6	-3868.3	-133.9	-771.8	-2962.6
Taiwan	-1.8	-3.2	1.4	1.2	1.6	-1.4	-9.4	-335.5	-69.7	-79.6	-186.2
Mexico	2.1	-8.8	10.9	4.8	3.8	2.3	39.9	-578.3	-16.0	-326.6	-235.8
Canada	4.5	-5.2	9.7	5.3	-0.8	5.2	-14.7	180.2	64.4	-52.1	168.0
Turkey	7.8	-4.8	12.6	6.8	8.5	-2.7	79.6	-967.0	55.7	33.2	-1055.9
Australia	12.6	0.9	11.7	5.7	5.7	0.3	9.2	263.9	92.7	161.5	9.7
Rest-of-world	103.8	-57.7	161.5	81.8	74.3	5.7	788.6	-85680.9	-5180.7	-31781.4	-48718.8
USA	141.0	45.9	95.1	18.4	39.2	37.5	421.4	3332.6	656.9	1475.6	1200.2
						Value added in trade					
China	-54.8	-54.9	0.1	14.1	1.6	-15.6	-31.3	-37923.1	-1943.9	-12594.4	-23384.8
Russia	-33.9	-25.0	-8.9	2.8	-16.8	5.0	96.1	-3652.2	-222.4	-3620.4	190.6
Japan	-16.6	-13.5	-3.2	-0.6	-7.3	4.7	-114.0	128.7	-16.4	-97.3	242.4
India	-16.6	-11.7	-4.9	-1.1	-0.5	-3.4	-14.5	-18458.8	-1431.8	-5848.8	-11178.2
Korea	-11.5	-5.5	-6.0	-5.0	-2.2	1.2	-37.4	-878.2	-268.8	-369.5	-239.8
Brazil	-4.4	-7.3	2.9	2.3	2.4	-1.8	9.6	-4335.2	-217.0	-1147.2	-2971.0
Indonesia	-4.0	-3.6	-0.3	0.8	0.8	-1.9	28.2	-3707.8	-137.9	-758.5	-2811.5
Taiwan	1.8	-2.0	3.8	2.1	2.2	-0.5	-1.5	-382.1	-48.1	-114.3	-219.6
Mexico	3.3	-7.8	11.2	4.6	4.0	2.5	39.6	-309.6	4.2	-208.2	-105.7
Turkey	5.6	-6.2	11.8	6.8	8.2	-3.2	79.2	-1132.4	57.2	-2.0	-1187.5
Canada	9.0	-2.7	11.7	5.6	0.5	5.6	-10.3	544.5	102.3	124.7	317.5
Australia	15.7	3.1	12.6	5.7	6.1	0.7	16.6	460.7	110.2	244.0	106.5
USA	112.9	38.5	74.3	10.6	30.3	33.3	335.3	4991.5	720.0	2142.4	2129.1
Rest-of-world	146.4	-44.9	191.3	93.2	86.8	11.6	899.4	-87572.2	-5210.6	-32372.7	-49988.9

Source: WIOD database; author's calculations

Table 5 US net flows by factor, 2005

	Value added and factor income						Physical inputs				
	Value	Factor income		Labor income			Factor input		Employment (in '000s)		
Reporter	added	Capital	Labor	High	Medium	Low	Capital	Empl.	High	Medium	Low
						Trade in value added					
European Union	-141.0	-45.9	-95.1	-18.4	-39.2	-37.5	-421.4	-3332.6	-656.9	-1475.6	-1200.2
China	-117.5	-82.0	-35.5	8.1	-12.1	-31.5	-127.4	-43737.6	-1606.9	-13140.4	-28990.3
Rest-of-world	-79.8	-113.5	33.7	50.5	21.8	-38.4	74.0	-66333.4	-4326.4	-25899.8	-36107.2
Canada	-74.3	-44.7	-29.6	8.0	-38.9	1.2	-190.1	-1384.3	-132.5	-1278.0	26.1
Japan	-67.0	-32.7	-34.2	-6.3	-24.4	-3.5	-305.8	-972.4	-213.9	-684.3	-74.2
Mexico	-21.8	-39.6	17.7	13.8	5.1	-1.2	49.6	-3667.0	-182.9	-1795.2	-1688.9
India	-17.4	-10.7	-6.7	-1.1	-1.3	-4.3	-31.8	-16616.6	-1300.9	-5374.0	-9941.8
Taiwan	-16.6	-8.8	-7.8	-1.1	-1.4	-5.3	-49.3	-842.3	-189.5	-250.6	-402.1
Korea	-14.4	-5.0	-9.5	-4.6	-3.7	-1.2	-50.0	-709.5	-295.9	-339.6	-74.0
Russia	-14.4	-7.8	-6.6	-0.4	-6.0	-0.2	6.3	-1271.4	-104.4	-1084.9	-82.1
Brazil	-11.3	-7.8	-3.5	0.2	-0.8	-3.0	-18.7	-2487.8	-170.4	-813.6	-1503.7
Indonesia	-6.5	-5.3	-1.2	0.8	0.3	-2.3	8.1	-3184.7	-90.6	-661.4	-2432.7
Turkey	-1.1	-1.7	0.6	1.0	0.8	-1.2	7.6	-271.8	-6.6	-41.2	-223.9
Australia	0.7	-1.3	2.0	3.1	1.6	-2.7	-18.5	-28.3	26.6	21.9	-76.9
						Value added in trade					
China	-151.6	-95.3	-56.2	-1.2	-22.2	-32.8	-202.6	-42131.2	-1735.2	-12887.6	-27508.4
European Union	-112.9	-38.5	-74.3	-10.6	-30.3	-33.3	-335.3	-4991.5	-720.0	-2142.4	-2129.1
Canada	-92.3	-53.6	-38.7	6.0	-44.2	-0.4	-222.6	-2479.2	-215.8	-1702.9	-560.4
Rest-of-world	-79.8	-109.5	29.6	49.7	20.6	-40.5	17.9	-65205.4	-4234.1	-25183.5	-35787.8
Japan	-50.7	-25.7	-25.0	-3.5	-18.2	-3.3	-232.8	-1070.4	-180.0	-664.0	-226.4
Mexico	-36.1	-47.1	11.1	11.8	1.9	-2.6	25.4	-4637.2	-284.6	-2239.2	-2113.4
India	-23.3	-13.0	-10.3	-2.3	-3.2	-4.8	-38.4	-16446.5	-1226.0	-5441.2	-9779.3
Taiwan	-14.7	-8.7	-6.0	0.0	-1.3	-4.7	-43.5	-1294.3	-194.8	-458.7	-640.9
Brazil	-9.5	-6.5	-3.1	0.2	-0.6	-2.6	-15.2	-2178.3	-147.2	-717.1	-1314.1
Korea	-7.3	-3.6	-3.7	-0.7	-1.5	-1.5	-31.9	-1096.8	-225.4	-464.2	-407.2
Indonesia	-4.9	-3.6	-1.3	0.5	0.0	-1.8	3.7	-2678.1	-78.0	-564.6	-2035.4
Turkey	-3.1	-2.2	-0.8	0.3	0.0	-1.1	2.9	-319.0	-16.7	-81.4	-220.8
Russia	-2.6	-1.7	-0.8	0.4	-1.3	0.0	5.8	-355.1	-26.4	-320.0	-8.7
Australia	6.3	2.5	3.8	3.1	2.3	-1.6	-1.0	43.3	33.1	50.1	-39.9

Source: WIOD database; author's calculations

Table 6 Japan flows by factor, 2005

	Value added and factor income						Physical inputs				
	Value	Factor income		Labor income			Factor input		Employment (in '000s)		
Reporter	added	Capital	Labor	High	Medium	Low	Capital	Empl.	High	Medium	Low
					Trade in value added						
Australia	-4.8	-4.7	-0.0	0.7	1.5	-2.2	-8.2	-9.6	15.2	40.4	-65.2
Indonesia	-4.5	-5.5	1.0	0.9	1.9	-1.8	28.2	-2026.2	-45.3	-371.3	-1609.6
India	0.4	-0.1	0.5	0.3	0.9	-0.6	8.7	-2440.5	-173.6	-772.9	-1494.0
Brazil	1.2	0.0	1.2	0.4	1.1	-0.4	9.1	-470.8	-12.9	-84.1	-373.8
Canada	1.6	-0.1	1.7	1.0	0.3	0.4	16.2	13.6	14.1	-7.4	7.0
Turkey	2.5	1.0	1.5	0.6	1.0	-0.1	10.5	-3.3	7.8	18.8	-29.9
Russia	2.9	1.1	1.8	1.0	0.5	0.3	28.5	-543.2	-26.4	-473.1	-43.7
China	3.2	-7.9	11.1	10.5	12.6	-12.0	141.9	-18819.5	-419.8	-4429.6	-13970.0
Mexico	6.0	1.6	4.4	1.6	2.6	0.3	28.3	-55.3	14.7	-4.2	-65.8
Korea	7.0	4.7	2.3	-1.3	3.4	0.1	34.1	-186.9	-126.5	-35.1	-25.4
Taiwan	14.2	5.4	8.7	3.0	6.8	-1.0	53.0	22.6	14.5	135.5	-127.4
Rest-of-world	14.5	-15.0	29.5	18.1	23.2	-11.7	335.1	-22034.8	-1038.0	-8004.1	-12992.8
European Union	20.9	15.9	5.0	1.1	9.4	-5.5	140.5	21.3	37.3	191.9	-207.9
USA	67.0	32.7	34.2	6.3	24.4	3.5	305.8	972.4	213.9	684.3	74.2
					Value added in trade						
Australia	-7.6	-6.3	-1.3	0.2	0.8	-2.3	-16.2	-95.6	4.1	2.3	-102.0
Indonesia	-6.5	-6.9	0.4	0.8	1.6	-2.0	26.4	-2176.5	-57.3	-432.9	-1686.3
India	-1.8	-1.0	-0.8	-0.1	0.0	-0.7	1.6	-2224.1	-152.2	-735.3	-1336.6
Brazil	1.4	0.2	1.1	0.4	1.0	-0.3	7.6	-348.3	-6.5	-50.0	-291.8
Canada	1.7	0.2	1.5	0.8	0.3	0.4	15.0	14.4	14.1	1.1	-0.8
Turkey	1.9	0.8	1.1	0.4	0.7	0.0	6.6	20.9	6.9	20.6	-6.6
China	4.9	-7.6	12.5	10.9	14.1	-12.6	162.1	-19425.2	-446.9	-4588.3	-14390.1
Russia	7.2	3.3	3.9	1.4	2.1	0.5	28.3	-215.7	2.1	-221.9	4.0
Mexico	8.3	3.0	5.3	1.8	3.1	0.4	32.0	88.2	28.1	59.3	0.9
Korea	14.2	7.8	6.4	0.1	6.2	0.2	63.6	-374.5	-121.4	-71.5	-181.6
Rest-of-world	14.5	-14.3	28.8	18.1	23.3	-12.4	362.5	-22018.6	-1045.4	-8110.1	-12863.1
European Union	16.6	13.5	3.2	0.6	7.3	-4.7	114.0	-128.7	16.4	97.3	-242.4
Taiwan	26.8	11.0	15.8	5.2	11.0	-0.4	95.2	253.2	53.0	254.6	-54.3
USA	50.7	25.7	25.0	3.5	18.2	3.3	232.8	1070.4	180.0	664.0	226.4

Source: WIOD database; author's calculations

Table 7 China flows by factor, 2005

	Value added and factor income						Physical inputs				
	Value	Factor income		Labor income			Factor input		Employment (in '000s)		
Reporter	added	Capital	Labor	High	Medium	Low	Capital	Empl.	High	Medium	Low
						Trade in value added					
Taiwan	-16.3	-7.2	-9.1	-3.0	-2.9	-3.1	-46.2	1084.0	-65.6	307.8	841.8
Korea	-6.8	2.0	-8.8	-8.6	-3.7	3.6	-42.8	6608.8	51.4	2002.2	4555.2
Japan	-3.2	7.9	-11.1	-10.5	-12.6	12.0	-141.9	18819.5	419.8	4429.6	13970.0
Russia	-2.5	-0.5	-2.0	-0.8	-2.8	1.7	7.4	1742.9	8.4	-37.5	1771.9
Brazil	-1.3	-0.6	-0.6	-0.5	-0.1	-0.1	-5.3	223.2	10.8	192.8	19.6
Indonesia	-0.7	-0.8	0.1	-0.1	0.3	-0.1	6.3	150.8	13.7	187.9	-50.8
Australia	1.4	1.3	0.1	-0.8	0.1	0.8	-17.3	4354.2	230.7	1456.1	2667.4
Turkey	3.9	2.4	1.5	0.1	0.7	0.8	5.8	1157.8	47.3	361.5	749.0
India	6.2	4.2	2.0	-0.3	0.9	1.5	5.7	1127.0	-34.7	353.6	808.2
Mexico	7.0	4.1	2.9	0.2	1.1	1.6	9.6	1946.8	83.7	619.8	1243.2
Canada	8.8	5.5	3.3	-0.4	0.0	3.7	1.1	5042.7	163.0	1420.1	3459.6
Rest-of-world	24.7	18.8	5.8	-5.3	1.4	9.7	65.5	12882.1	305.1	3731.9	8845.1
European Union	32.2	44.2	-12.0	-18.6	-7.5	14.2	-23.2	37248.7	1758.0	12139.4	23351.3
USA	117.5	82.0	35.5	-8.1	12.1	31.5	127.4	43737.6	1606.9	13140.4	28990.3
						Value added in trade					
Taiwan	-51.7	-24.2	-27.6	-9.5	-11.2	-6.9	-121.0	-96.1	-278.6	-240.3	422.8
Korea	-21.4	-4.0	-17.4	-13.2	-7.7	3.5	-76.6	7233.1	-35.3	2117.1	5151.3
Japan	-4.9	7.6	-12.5	-10.9	-14.1	12.6	-162.1	19425.2	446.9	4588.3	14390.1
Russia	-1.4	-0.1	-1.3	-0.6	-2.3	1.5	8.2	1501.5	4.4	-92.7	1589.8
Brazil	-1.4	-0.9	-0.5	-0.3	0.0	-0.2	-6.0	49.7	7.4	153.0	-110.7
Indonesia	-0.1	-0.5	0.4	-0.0	0.4	0.0	7.3	86.9	13.5	183.7	-110.2
Australia	0.6	0.3	0.4	-0.5	0.3	0.6	-20.0	4354.1	239.9	1462.1	2652.1
Turkey	5.1	2.9	2.2	0.4	1.0	0.9	7.8	1180.4	47.9	350.4	782.1
Rest-of-world	6.2	12.5	-6.3	-10.8	-4.8	9.4	43.2	13443.3	177.1	3616.6	9649.6
India	6.8	4.2	2.6	0.0	1.2	1.4	8.2	1005.8	-27.5	286.0	747.3
Canada	12.5	7.1	5.3	0.2	1.0	4.1	8.4	5350.6	186.9	1525.8	3637.9
Mexico	14.2	8.1	6.1	1.1	2.7	2.3	20.8	2537.1	136.6	873.6	1526.8
European Union	54.8	54.9	-0.1	-14.1	-1.6	15.6	31.3	37923.1	1943.9	12594.4	23384.8
USA	151.6	95.3	56.2	1.2	22.2	32.8	202.6	42131.2	1735.2	12887.6	27508.4

Source: WIOD database; author's calculations

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Trade in Value Added and the Value Added in Trade☆

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Abstract

This paper discussed two measures of value added flows between countries: "Trade in value added" accounts for value added of one country directly and indirectly embodied in final consumption of another country. "Value added in trade" measures the value added embodied in gross trade flows. The paper shows that both measures result in the same overall net trade of a country which equals its trade balance in gross terms which however does not hold for bilateral relations. These value added flows can further be broken down by various production factors including capital and labor income by educational attainment categories. Using the recently compiled World Input-Output Database (WIOD) selected results comparing EU-27, US, Japan and China based on both concepts regarding value added flows across countries are presented. For example, the US trade deficit with China is reduced by about 25% but would increase with respect to EU-27 by about 20%. These imbalances are further broken down by factor incomes.

JEL: F1, F15, F19

Keywords: value added trade, factor content of trade, trade integration, vertical specialization, production networks

1. Introduction

It is sometimes at least implicitly argued that a countrys trade deficit might be lower when measured in value added terms rather than in gross terms. This is often motivated by case studies for high-tech products such as the iPod (Varian, 2007; Linden et al., 2009) or iPhone (Xing and Detert, 2010). Such case study approaches however face some limitations as the particular components of a product under consideration are themselves made of other - maybe imported - components which makes it difficult to trace back a product to the ultimate producer. Therefore, for example, Varian (2007) concludes: "Ultimately, there is no simple answer to who makes the iPod or where it is made. The iPod, like many other products, is made in several countries by dozens of companies, with each stage of production contributing a different amount to the final value.". Another strand of literature examines value added trade based on input-output techniques which are variants or generalizations and further developments of the vertical specialization measures as suggested by Hummels et al. (2001) and many other papers following this approach. In most cases this literature is focused on the US trade deficit in general and with China in particular arguing that the US deficit with China is reduced by about 15-20 when measured in value added terms. Recent contributions in measuring value added trade based on input-output techniques include Hummels et al. (2001), Daudin et al. (2011), Johnson

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and Noguera (2012), and Koopman et al. (2010) and, with a focus on the factor content of trade and testing the Heckscher-Ohlin-Vanek predictions, Trefler and Zhu (2010). In both cases the literature both includes a focus on a country's total trade and its bilateral relations.[1]

In this paper we build on the above mentioned contributions and distinguish carefully between two concepts of value added flows across countries: The first - "trade in value added" - accounts for the value added of one country directly and indirectly contained in final consumption of another country. The typical question would be: 'How much value added of other countries is contained in the consumption of the country under examination?' The second concept - "value added in trade" - calculates the value added contained in gross trade flows between two countries. The typical question would be: 'How much of value added from other countries is contained in the gross imports of one country?' or 'How much of foreign value added does the gross exports of a country embody?'

Though these two concepts measure different flows of value added across countries we show that a country's trade surplus or deficit is the same in both cases and, furthermore, equals this country's net trade when measured in gross terms. After succinctly defining both concepts this can be shown analytically. However, this result at the macro level does not carry over when considering bilateral relations. In this case the concept of "trade in value added" results in different levels of bilateral surpluses or deficits as measured in gross terms. Defining bilateral "value added in trade" is less straightforward. We therefore require that such a measure should satisfy two properties: First, adding up a country's bilateral trade surpluses or deficits over all partner countries should result in this country's overall trade surplus or deficit. Second, a country's bilateral trade surplus (deficit) with another country must this other country's bilateral deficit (surplus), i.e. it's mirrored. Under these two requirements it turns out that the bilateral "value added in trade" surplus or deficit equals a country's bilateral net trade in gross terms.

In Section 2 we define these two concepts and show analytically that these result in the same net trade figures of a country's overall trade in gross terms. We also discuss the differences when looking at bilateral trade relations. Furthermore, we extend both approaches to be applied for value added components (e.g. capital and labor income and the latter broken down by educational attainment categories) and physical factor inputs (e.g. employment). Section 3 gives a short overview of the data used for the empirical part which relies on a recently compiled and unique world input-output database (WIOD). Section 4 then provides selected empirical results to highlight similarities and differences of these two concepts and important patterns of trade across countries. These results point towards the underlying questions concerning trade patterns, factor rewards and the factor content of trade. However, it is not the intention of this paper and would go beyond the scope of it provide detailed explanations. The focus of this paper is on the measurement issue and the differences and similarities of the two concepts mixed up in the literature. Section 5 concludes.

2. Trade in value added and value added in trade

In this section we propose measures for "trade in value added" and "value added in trade" and discuss how these relate to each other. We start discussion with a country's overall trade and then go on to consider these approaches in bilateral relations. For clarity we discuss these concepts in a three country setting without loss of generality. An empirical application can then be found in Section 4.

2.1. Measuring "trade in value added"

We start with the proper measure of "trade in value added". The basic question asked here is how much of value added of a particular country r is contained in consumption of another country s. Based on an

[1] In the "factor content of trade" literature the important contributions include Choi and Krishna (2004) and Lai and Zhu (2007). With respect to trade in intermediates these papers accept the result by Staiger (1986). All of them build upon Helpman (1984).

input-output approach the basic relationship to start with is

$$\mathbf{x} = \mathbf{A}\mathbf{x} + \mathbf{f} = \mathbf{L}\mathbf{f}$$

$\mathbf{x}$ denotes a $CG \times 1$ vector of gross output (with C being the number of countries and G the number of products considered). $\mathbf{A}$ is a $CG \times CG$ matrix of technical input-output coefficients with each element denoting the input used in a particular industry in one country per unit of gross output. $\mathbf{f}$ denotes the $CG \times 1$ vector of final demand. The second part rearranges this equation such that gross output is written as a function of the Leontief inverse, $\mathbf{L} = (\mathbf{I} - \mathbf{A})^{-1}$, and the final demand vector. For three countries and using partitioned matrices this equation can be written as follows:

$$\begin{bmatrix}\mathbf{x}^r\\ \mathbf{x}^s\\ \mathbf{x}^t\end{bmatrix} = \begin{bmatrix}\mathbf{A}^{rr} & \mathbf{A}^{rs} & \mathbf{A}^{rt}\\ \mathbf{A}^{sr} & \mathbf{A}^{ss} & \mathbf{A}^{st}\\ \mathbf{A}^{tr} & \mathbf{A}^{ts} & \mathbf{A}^{tt}\end{bmatrix}\begin{bmatrix}\mathbf{x}^r\\ \mathbf{x}^s\\ \mathbf{x}^t\end{bmatrix} + \begin{bmatrix}\mathbf{f}^r\\ \mathbf{f}^s\\ \mathbf{f}^t\end{bmatrix} = \begin{bmatrix}\mathbf{L}^{rr} & \mathbf{L}^{rs} & \mathbf{L}^{rt}\\ \mathbf{L}^{sr} & \mathbf{L}^{ss} & \mathbf{L}^{st}\\ \mathbf{L}^{tr} & \mathbf{L}^{ts} & \mathbf{L}^{tt}\end{bmatrix}\begin{pmatrix}\mathbf{f}^{rr} + \mathbf{f}^{rs} + \mathbf{f}^{rt}\\ \mathbf{f}^{sr} + \mathbf{f}^{ss} + \mathbf{f}^{st}\\ \mathbf{f}^{tr} + \mathbf{f}^{ts} + \mathbf{f}^{tt}\end{pmatrix}$$

$\mathbf{x}^c$ ($c = r, s, t$) denotes the $G \times 1$ vector of gross output in country c, $\mathbf{L}^{cd}$ the respective $G \times G$ submatrix of the Leontief inverse and $\mathbf{f}^{cd}$ the $G \times 1$ vector of final demand of country d in country c. It is important to distinguish between demand for final products which are produced in country c and thus includes exports, i.e. the $G \times 1$ vector $\mathbf{f}^c = \mathbf{f}^{cr} + \mathbf{f}^{cs} + \mathbf{f}^{ct}$, and the $CG \times 1$ vector denoting country c's final demand (domestically and imported), i.e. $\mathbf{f}^{*c} = \left((\mathbf{f}^{rc})', (\mathbf{f}^{sc})', (\mathbf{f}^{tc})'\right)'$. Pre-multiplying this equation with a $1 \times CG$ vector of value added coefficients, i.e. value added per unit of gross output $\mathbf{v}$, results in value added and will be used to calculate trade in value added terms. (Note, for notational reasons, vectors $\mathbf{v}$ and its subvectors $\mathbf{v}^c$ denote row vectors.)

Value added exports of country r to all other countries include value added created in country r to satisfy final demand in countries s and t.[2] Selecting the appropriate terms in the above equation gives:

$$\begin{aligned} t^r_{\text{TiVA},X} &= \begin{bmatrix}\mathbf{v}^r & \mathbf{0} & \mathbf{0}\end{bmatrix}\begin{bmatrix}\mathbf{L}^{rr} & \mathbf{L}^{rs} & \mathbf{L}^{rt}\\ \mathbf{L}^{sr} & \mathbf{L}^{ss} & \mathbf{L}^{st}\\ \mathbf{L}^{tr} & \mathbf{L}^{ts} & \mathbf{L}^{tt}\end{bmatrix}\begin{pmatrix}\mathbf{0} + \mathbf{f}^{rs} + \mathbf{f}^{rt}\\ \mathbf{0} + \mathbf{f}^{ss} + \mathbf{f}^{st}\\ \mathbf{0} + \mathbf{f}^{ts} + \mathbf{f}^{tt}\end{pmatrix}\\ &= \mathbf{v}^r\mathbf{L}^{rr}(\mathbf{f}^{rs} + \mathbf{f}^{rt}) + \mathbf{v}^r\mathbf{L}^{rs}(\mathbf{f}^{ss} + \mathbf{f}^{st}) + \mathbf{v}^r\mathbf{L}^{rt}(\mathbf{f}^{ts} + \mathbf{f}^{tt}) \end{aligned}$$

As we are only interested in value added created in country r we set the value added coefficients for the other countries to zero. Further, as we are not interested in how much value added is created in r to satisfy country r's final demand itself, we set the entries of country r's final demand vector, $\mathbf{f}^{*r}$, to zero. In particular this excludes subvector $\mathbf{f}^{sr}$ which would appear in the second term (in the second line of the equation above) as $\mathbf{v}^r\mathbf{L}^{rs}\mathbf{f}^{sr}$. This would include value added created in r needed to satisfy final demand imports of r from s thus capturing re-imports of country r value added which we do not count as value added exports. The first term in the second line therefore is value added created in country r to satisfy final demand imports (in gross terms) of countries s and t from country r. The second terms captures value added created in country r to satisfy country s domestic demand and demand via imports in gross terms from country t. As production of these final demand goods also uses intermediate inputs from r these embody value added created in r and therefore count as country r's value added exports. An analogous interpretation holds for the third term. In the general case for many countries we can write this expression as $t^r_{\text{TiVA,X}} = \mathbf{v}^r\mathbf{L}\mathbf{f}^{-r}$, where $\mathbf{v}^r$ denotes the value added coefficients vector with non-negative entries for country r and zeros for the other countries, and $\mathbf{f}^{-r}$ the consumption vector of all countries except r.

[2] This is the definition used in Johnson and Noguera (2012).

Value added imports of country r from all other countries should account for value added created in countries s and t to satisfy final demand of country r. Again selecting the appropriate terms the equation has to be written as:

$$\begin{aligned} t^r_{\text{TiVA},M} &= \begin{bmatrix}\mathbf{0} & \mathbf{v}^s & \mathbf{v}^t\end{bmatrix}\begin{bmatrix}\mathbf{L}^{rr} & \mathbf{L}^{rs} & \mathbf{L}^{rt}\\ \mathbf{L}^{sr} & \mathbf{L}^{ss} & \mathbf{L}^{st}\\ \mathbf{L}^{tr} & \mathbf{L}^{ts} & \mathbf{L}^{tt}\end{bmatrix}\begin{pmatrix}\mathbf{f}^{rr}+\mathbf{0}+\mathbf{0}\\ \mathbf{f}^{sr}+\mathbf{0}+\mathbf{0}\\ \mathbf{f}^{tr}+\mathbf{0}+\mathbf{0}\end{pmatrix} \\ &= (\mathbf{v}^s\mathbf{L}^{sr}+\mathbf{v}^t\mathbf{L}^{tr})\mathbf{f}^{rr}+(\mathbf{v}^s\mathbf{L}^{ss}+\mathbf{v}^t\mathbf{L}^{ts})\mathbf{f}^{sr}+(\mathbf{v}^s\mathbf{L}^{st}+\mathbf{v}^t\mathbf{L}^{tt})\mathbf{f}^{tr}\end{aligned}$$

The first term (in the second line) accounts for value added created in country s and t to satisfy country r's domestic demand, the second term denotes value added created in both countries to satisfy country r's demand for final products imported from country s, and analogously for the third term. In general notation this can be written as $t^r_{\text{TiVA,M}} = \mathbf{v}^{-r}\mathbf{L}\mathbf{f}^r$ with an analogous definition of the vectors as above.

Net trade in value added is defined as the difference between value added exports and imports:

$$t^r_{\text{TiVA,Net}} = t^r_{\text{TiVA},X} - t^r_{\text{TiVA},M}$$

Value added exports, imports and net trade can be derived for the other countries analogously.

Net trade in value added as defined here equals a country's total trade balance, i.e. GDP minus final consumption. This can be achieved by rewriting and manipulating the above equations in the following way:

$$\begin{aligned} t^r_{\text{TiVA,Net}} &= \begin{pmatrix}\mathbf{v}^r & \mathbf{0} & \mathbf{0}\end{pmatrix}\mathbf{L}(\mathbf{f}^{*s}+\mathbf{f}^{*t}) - \begin{pmatrix}\mathbf{0} & \mathbf{v}^s & \mathbf{v}^t\end{pmatrix}\mathbf{L}\mathbf{f}^{*r} \\ &= \begin{pmatrix}\mathbf{v}^r & \mathbf{0} & \mathbf{0}\end{pmatrix}\mathbf{L}(\mathbf{f}^{*s}+\mathbf{f}^{*t}) + \begin{pmatrix}\mathbf{v}^r & \mathbf{0} & \mathbf{0}\end{pmatrix}\mathbf{L}\mathbf{f}^{*r} - \begin{pmatrix}\mathbf{v}^r & \mathbf{0} & \mathbf{0}\end{pmatrix}\mathbf{L}\mathbf{f}^{*r} - \begin{pmatrix}\mathbf{0} & \mathbf{v}^s & \mathbf{v}^t\end{pmatrix}\mathbf{L}\mathbf{f}^{*r} \\ &= \begin{pmatrix}\mathbf{v}^r & \mathbf{0} & \mathbf{0}\end{pmatrix}\mathbf{L}(\mathbf{f}^{*r}+\mathbf{f}^{*s}+\mathbf{f}^{*t}) - \begin{pmatrix}\mathbf{v}^r & \mathbf{v}^s & \mathbf{v}^t\end{pmatrix}\mathbf{L}\mathbf{f}^{*r} \\ &= \begin{pmatrix}\mathbf{v}^r & \mathbf{0} & \mathbf{0}\end{pmatrix}\mathbf{L}\mathbf{f} - \mathbf{v}\mathbf{L}\mathbf{f}^{*r} \\ &= \begin{pmatrix}\mathbf{v}^r & \mathbf{0} & \mathbf{0}\end{pmatrix}\mathbf{x} - \boldsymbol{\iota}'(\mathbf{I}-\mathbf{A})(\mathbf{I}-\mathbf{A})^{-1}\mathbf{f}^{*r} \\ &= y^r - \boldsymbol{\iota}'\mathbf{f}^{*r}\end{aligned}$$

The first line rewrites the above definitions of value added exports and imports. In the second line we add and subtract the terms in the middle which are then collected in the third line and rewritten in more compact notation in the fourth line. In the fifth line we make use of the fact that $\mathbf{x} = \mathbf{L}\mathbf{f}$ and the value added coefficient vector can be written as $\mathbf{v} = \boldsymbol{\iota}'(\mathbf{I}-\mathbf{A})$ where $\boldsymbol{\iota}'$ denotes a $1 \times CG$ summation vector. The last line uses that the first term is country r's GDP, the value added coefficients vector times the gross output vector, and the second term is the level of country r's final demand (for both domestic and imported final products). For the general case of many countries this is derived as follows:

$$t^r_{\text{TiVA,Net}} = \mathbf{v}^r\mathbf{L}\mathbf{f}^{-r} - \mathbf{v}^{-r}\mathbf{L}\mathbf{f}^r = \mathbf{v}^r\mathbf{L}\mathbf{f} - \mathbf{v}\mathbf{L}\mathbf{f}^r = \mathbf{v}^r\mathbf{x} - \boldsymbol{\iota}'\mathbf{f}^r = y^r - \boldsymbol{\iota}'\mathbf{f}^r$$

Thus, a country's trade in value added is GDP minus final demand expenditures. If a country's GDP is larger (smaller) than its final consumption it is running a trade surplus (deficit) which is well known from national accounting. Next we show that this also equals a country's "value added in trade" in net terms and its trade balance in gross terms.

2.2. Measuring the "value added in trade"

The second measure is to calculate the content of value added as contained in a country's gross exports and imports and the subsequent net flows of value added embodied in gross trade flows. This therefore focuses on the domestic and foreign value added embodied in a country's gross exports and imports. This is the concept used in the literature on the factor content of trade (Trefler and Zhu, 2010).

Using the same notation as above we discuss the value added content of trade from the viewpoint of country r without any loss in generality. Following Trefler and Zhu (2010) we write the vector of gross trade as

$$\mathbf{t}^r = \begin{pmatrix} \mathbf{t}^{rs} + \mathbf{t}^{rt} \\ -\mathbf{t}^{sr} \\ -\mathbf{t}^{tr} \end{pmatrix}$$

$\mathbf{t}^{rc}$ denotes country c's imports from r or country r's exports to c. Country r's imports are included in negative terms. One should note that these trade vectors include both trade in final goods and trade in intermediates which sums up to a country's total gross exports or imports, i.e. $\mathbf{t}^{rs} = \mathbf{f}^{rs} + \mathbf{z}^{rs}$ where $\mathbf{z}^{rs}$ denotes country r's imports of intermediates from s and analogously for the other terms. As imports are included in negative terms this results in country r's net value added content in trade. It is again enlightening to write the equation in detail:

$$\begin{aligned}
t^r_{\text{VAiT,Net}} &= \begin{pmatrix} \mathbf{v}^r & \mathbf{v}^s & \mathbf{v}^t \end{pmatrix} \begin{pmatrix} \mathbf{L}^{rr} & \mathbf{L}^{rs} & \mathbf{L}^{rt} \\ \mathbf{L}^{sr} & \mathbf{L}^{ss} & \mathbf{L}^{st} \\ \mathbf{L}^{tr} & \mathbf{L}^{ts} & \mathbf{L}^{tt} \end{pmatrix} \begin{pmatrix} \mathbf{t}^{rs} + \mathbf{t}^{rt} \\ -\mathbf{t}^{sr} \\ -\mathbf{t}^{tr} \end{pmatrix} \\
&= (\mathbf{v}^r\mathbf{L}^{rr} + \mathbf{v}^s\mathbf{L}^{sr} + \mathbf{v}^t\mathbf{L}^{tr})(\mathbf{f}^{rs} + \mathbf{f}^{rt}) - (\mathbf{v}^r\mathbf{L}^{rs} + \mathbf{v}^s\mathbf{L}^{ss} + \mathbf{v}^t\mathbf{L}^{ts})\mathbf{f}^{sr} - (\mathbf{v}^r\mathbf{L}^{rt} + \mathbf{v}^s\mathbf{L}^{st} + \mathbf{v}^t\mathbf{L}^{tt})\mathbf{f}^{tr} \\
&= \mathbf{v}^r\Big(\mathbf{L}^{rr}(\mathbf{t}^{rs} + \mathbf{t}^{rt}) - \mathbf{L}^{rs}\mathbf{t}^{sr} - \mathbf{L}^{rt}\mathbf{t}^{tr}\Big) + \\
&\quad \mathbf{v}^s\Big(\mathbf{L}^{sr}(\mathbf{t}^{rs} + \mathbf{t}^{rt}) - \mathbf{L}^{ss}\mathbf{t}^{sr} - \mathbf{L}^{st}\mathbf{t}^{tr}\Big) + \\
&\quad \mathbf{v}^t\Big(\mathbf{L}^{tr}(\mathbf{t}^{rs} + \mathbf{t}^{rt}) - \mathbf{L}^{ts}\mathbf{t}^{sr} - \mathbf{L}^{tt}\mathbf{t}^{tr}\Big)
\end{aligned}$$

The first term in the second line captures the domestic and foreign value added embodied in country r's exports in gross terms. The second term captures the domestic and foreign value added embodied in country r's imports from s in gross terms, and analogously for the third term. This allows showing the relationship between a country's trade balance in gross and value added terms. Again using that $\mathbf{v} = \boldsymbol{\iota}'(\mathbf{I} - \mathbf{A})^{-1}$ shows

$$t^r_{\text{VAiT,Net}} = \mathbf{v}'(\mathbf{I} - \mathbf{A})^{-1}\mathbf{t} = \boldsymbol{\iota}'(\mathbf{I} - \mathbf{A})(\mathbf{I} - \mathbf{A})^{-1}\mathbf{t} = \boldsymbol{\iota}'\mathbf{t} = t^r_{\text{Gross,Net}}$$

i.e. the net content of value added in trade equals the net trade in gross terms. By appropriate definition of the matrices this can easily be generalized to many countries.

From this it follows that

$$t^r_{\text{TiVA,Net}} = y^r - \boldsymbol{\iota}'\mathbf{f}^{*r} = \boldsymbol{\iota}'\mathbf{t} = t^r_{\text{VAiT,Net}}$$

i.e. a country's trade balance does not change when measured in value added terms, as income minus consumption of (domestic and foreign) final goods, i.e. its savings, equals its net exports. To see this and the role of imported intermediates play more clearly we can rearrange this as

$$y^r = \boldsymbol{\iota}'\left[\begin{pmatrix} \mathbf{f}^{rr} \\ \mathbf{f}^{sr} \\ \mathbf{f}^{tr} \end{pmatrix} + \begin{pmatrix} \mathbf{t}^{rs} + \mathbf{t}^{rt} \\ -\mathbf{t}^{sr} \\ -\mathbf{t}^{tr} \end{pmatrix}\right] = \boldsymbol{\iota}'\begin{pmatrix} \mathbf{f}^{rr} + \mathbf{t}^{rs} + \mathbf{t}^{rt} \\ \mathbf{f}^{sr} - \mathbf{f}^{sr} - \mathbf{z}^{sr} \\ \mathbf{f}^{tr} - \mathbf{f}^{tr} - \mathbf{z}^{tr} \end{pmatrix} = \boldsymbol{\iota}'\left\{\begin{pmatrix} \mathbf{f}^{rr} + \mathbf{f}^{rs} + \mathbf{f}^{rt} \\ \mathbf{0} \\ \mathbf{0} \end{pmatrix} + \begin{pmatrix} \mathbf{z}^{rs} + \mathbf{z}^{rt} \\ -\mathbf{z}^{sr} \\ -\mathbf{z}^{tr} \end{pmatrix}\right\}$$

A country's GDP equals domestic and foreign demand for its products including exported intermediates from which imported intermediates have to be subtracted. Note, that this corresponds to national input-output tables where imported intermediates are included in the intermediates block and thus do not count for value added, i.e. GDP, whereas the column for exports includes both intermediates and final goods exports. It is interesting to consider two special cases. Without intermediates trade the equation would become $y^r = \boldsymbol{\iota}'(\mathbf{f}^{rr} + \mathbf{f}^{rs} + \mathbf{f}^{rt})$, i.e. GDP of country r equals expenditures on (or demand for) its final goods. As a second special case consider a country which does not produce final goods but only intermediates, e.g. oil, without any other imported intermediates. Exports would consist of intermediates only and GDP would become $y^r = \boldsymbol{\iota}'(\mathbf{z}^{rs} + \mathbf{z}^{rt})$. Finally, it is easy to see that when adding up over all countries the intermediates part cancels out resulting in the fact that world GDP equals world consumption.

2.3. Trade in value added and value added in trade in bilateral relations

Both approaches can be applied considering bilateral trade. We concentrate on trade between countries r and s in a setting with three countries without loss of generality. Though in a two-country case the measure for trade in value added and the value added in trade would not differ in net terms, it does so when considering bilateral relations in a multi-country world. We argue that the measure for bilateral relations should satisfy both an adding-up and a negative symmetry condition. The adding-up condition requires that when adding up bilateral flows one arrives at total flows in value added terms. The symmetry condition requires that in the bilateral relation a country's exports must equal the other country's imports and vice versa. This also implies that a country's net trade in value added terms or it's net value added in trade is the negative of the other country's balance.

For calculating "trade in value added" in a bilateral way we exclude country r's value added consumed in country t as we are only interested in its exports of value added to country s. With respect to imports we have to rule out country r's imports from t. Algebraically this suggests to set the value added coefficients of country t to zero. Note that this still would include country r's imports from t in gross terms as these partly embody value added from country s which has to be taken into account. Formally, value added exports (imports) of country r to (from) s would therefore be calculated as:

$$
\begin{aligned}
t^{rs}_{\text{TiVA,X}} &= \begin{bmatrix}\mathbf{v}^r & \mathbf{0} & \mathbf{0}\end{bmatrix}\begin{bmatrix}\mathbf{L}^{rr} & \mathbf{L}^{rs} & \mathbf{L}^{rt}\\ \mathbf{L}^{sr} & \mathbf{L}^{ss} & \mathbf{L}^{st}\\ \mathbf{L}^{tr} & \mathbf{L}^{ts} & \mathbf{L}^{tt}\end{bmatrix}\begin{pmatrix}\mathbf{0}+\mathbf{f}^{rs}+\mathbf{0}\\ \mathbf{0}+\mathbf{f}^{ss}+\mathbf{0}\\ \mathbf{0}+\mathbf{f}^{ts}+\mathbf{0}\end{pmatrix}\\
&= \mathbf{v}^r\mathbf{L}^{rr}\mathbf{f}^{rs} + \mathbf{v}^r\mathbf{L}^{rs}\mathbf{f}^{ss} + \mathbf{v}^r\mathbf{L}^{rt}\mathbf{f}^{ts}
\end{aligned}
$$

$$
\begin{aligned}
t^{rs}_{\text{TiVA,M}} &= \begin{bmatrix}\mathbf{0} & \mathbf{v}^s & \mathbf{0}\end{bmatrix}\begin{bmatrix}\mathbf{L}^{rr} & \mathbf{L}^{rs} & \mathbf{L}^{rt}\\ \mathbf{L}^{sr} & \mathbf{L}^{ss} & \mathbf{L}^{st}\\ \mathbf{L}^{tr} & \mathbf{L}^{ts} & \mathbf{L}^{tt}\end{bmatrix}\begin{pmatrix}\mathbf{f}^{rr}+\mathbf{0}+\mathbf{0}\\ \mathbf{f}^{sr}+\mathbf{0}+\mathbf{0}\\ \mathbf{f}^{tr}+\mathbf{0}+\mathbf{0}\end{pmatrix}\\
&= \mathbf{v}^s\mathbf{L}^{sr}\mathbf{f}^{rr} + \mathbf{v}^s\mathbf{L}^{ss}\mathbf{f}^{sr} + \mathbf{v}^s\mathbf{L}^{st}\mathbf{f}^{tr}
\end{aligned}
$$

First, note that when calculating bilateral value added exports, imports and bilateral net trade also with country t and add up over partner countries we would again arrive at country r's total net trade in value added which can be seen easily. Thus, in this sense the measure satisfies the adding-up requirement. Second, it is also easily seen that $t^{rs}_{\text{TiVA,Net}} = -t^{sr}_{\text{TiVA,Net}}$ as country r's value added exports to s equals country s's value added imports from r and vice versa. Thus this measure satisfies the negative symmetry condition.

When calculating the "value added in trade" in bilateral flows the two requirements suggest considering only the cells including bilateral trade flows in gross terms. Therefore we set $\mathbf{t}^{tr} = \mathbf{t}^{rt} = \mathbf{0}$ in the calculations:

$$\begin{aligned} t^{rs}_{\text{VAiT,Net}} &= \begin{pmatrix}\mathbf{v}^r & \mathbf{v}^s & \mathbf{v}^t\end{pmatrix}\begin{pmatrix}\mathbf{L}^{rr} & \mathbf{L}^{rs} & \mathbf{L}^{rt}\\ \mathbf{L}^{sr} & \mathbf{L}^{ss} & \mathbf{L}^{st}\\ \mathbf{L}^{tr} & \mathbf{L}^{ts} & \mathbf{L}^{tt}\end{pmatrix}\begin{pmatrix}\mathbf{t}^{rs}\\ -\mathbf{t}^{sr}\\ \mathbf{0}\end{pmatrix} \\ &= \mathbf{v}^r(\mathbf{L}^{rr}\mathbf{t}^{rs} - \mathbf{L}^{rs}\mathbf{t}^{sr}) + \mathbf{v}^s(\mathbf{L}^{sr}\mathbf{t}^{rs} - \mathbf{L}^{ss}\mathbf{t}^{sr}) + \mathbf{v}^t(\mathbf{L}^{tr}\mathbf{t}^{rs} - \mathbf{L}^{ts}\mathbf{t}^{sr}) \end{aligned}$$

Using the definition for the value added coefficients vector yields the result that bilateral net value added in trade equals bilateral net trade in gross terms analogously to above. (One should however notice that this also includes embodied value added from country t.) This measure also satisfies the adding-up and the negative symmetry property which can be seen easily. However, from these two expressions it also follows that $t^{rs}_{\text{TiVA,Net}} \neq t^{rs}_{\text{VAiT,Net}}$ with the sign of the difference not being determined (see the empirical results presented below).

2.4. Various primary factors of production

A country's value added is made up of rewards of various factors like labor and capital, or even more detailed breakdowns. In this case the same algebra applies and in particular the result of the equality of net trade in value added and net value added in trade still holds.[3] We show this for physical input units, i.e. we consider "trade in employment" and "employment in trade". Country r's employment embodied in total production of r for products demanded both domestically and from the foreign countries (which equals its endowments) minus (worldwide) employment contained in consumption of r, equals country r's net trade in employment.[4] This can be shown using a similar algebra as above where we replace the vector of value added coefficients with vectors of employment coefficients denoted by $\mathbf{e}^r$ which can be rearranged as follows:

$$\begin{aligned} t^r_{\text{TiE,Net}} &= t^r_{\text{EiT,Net}} \\ \mathbf{e}^r\mathbf{L}\mathbf{f}^{-r} - \mathbf{e}^{-r}\mathbf{L}\mathbf{f}^r &= \mathbf{e}\mathbf{L}\mathbf{t}^r \\ \mathbf{e}^r\mathbf{L}\mathbf{f} - \mathbf{e}\mathbf{L}\mathbf{f}^r &= \mathbf{e}\mathbf{L}\mathbf{t}^r \\ \mathbf{e}^r\mathbf{x} - \mathbf{e}\mathbf{L}\mathbf{f}^r &= \mathbf{e}\mathbf{L}\mathbf{t}^r \\ e^r &= \mathbf{e}\mathbf{L}(\mathbf{f}^r + \mathbf{t}^r) \end{aligned}$$

For interpretation we rewrite this for the case of three countries analogously to above:

$$e^r = \mathbf{e}\mathbf{L}\left\{\begin{pmatrix}\mathbf{f}^{rr}\\ \mathbf{f}^{sr}\\ \mathbf{f}^{tr}\end{pmatrix} + \begin{pmatrix}\mathbf{f}^{rs} + \mathbf{f}^{rt}\\ -\mathbf{f}^{sr}\\ -\mathbf{f}^{tr}\end{pmatrix} + \begin{pmatrix}\mathbf{z}^{rs} + \mathbf{z}^{rt}\\ -\mathbf{z}^{sr}\\ -\mathbf{z}^{tr}\end{pmatrix}\right\} = \mathbf{e}\mathbf{L}\left\{\begin{pmatrix}\mathbf{f}^{rr} + \mathbf{f}^{rs} + \mathbf{f}^{rt}\\ \mathbf{0}\\ \mathbf{0}\end{pmatrix} + \begin{pmatrix}\mathbf{z}^{rs} + \mathbf{z}^{rt}\\ -\mathbf{z}^{sr}\\ -\mathbf{z}^{tr}\end{pmatrix}\right\}$$

A similar interpretation as in the case of value added above holds. A country's employment equals its directly and indirectly embodied labor in production of final goods (for domestic and foreign consumption) and of exported intermediate products from which direct and indirect labor embodied in intermediate imports have to be subtracted. Without intermediates trade the vectors containing intermediates $\mathbf{z}^{rp}$ would

[3] Of course the equality with the trade balance in gross terms only applies for total value added.

[4] In the factor content of trade literature total employment used is then interpreted as factor endowments. Thus, this concept does not take macro-economic imbalances like unemployment into account.

vanish and the Leontief inverse would become block-diagonal. In this case a country's employment equals its direct and indirectly used labor for production of its final output (either domestically consumed or exported). Particularly, this links the literature on the factor content of trade to the literature on trade in value added.[5] Finally, one can again see easily that when summing up over all countries that the intermediates part cancels out resulting in world employment.

3. The World Input-Output Database (WIOD)

An empirical analysis requires data on output, inputs by factor and the domestic and foreign use of intermediate inputs by industry. We provide a short overview of the construction of such a database, the World Input-Output Database (WIOD); for details see Timmer et al. (2012).[6] The global input-output tables, on which the analysis is based, are derived from national supply and use tables which are combined with detailed trade data. The resulting set of international supply and use tables, i.e. a set of domestic and import use tables broken down by partner countries, are then transformed by standard procedures into a World Input-Output Table (WIOT). The data are collected on an annual basis from 1995 to 2009 for 59 products and 35 industries (ISIC Revision 3) and cover 40 countries (EU-27 countries, Turkey, Canada, USA and Mexico, Japan, Korea, Taiwan, Australia, Brazil, Russia, India, Indonesia and China) which account for about 85 percent of world GDP.

Thus, as building blocks for the WIOTs national supply and use tables (SUTs) which are the core statistical sources from which National Statistical Institutes (NSIs) derive national input-output tables are collected. SUTs are a natural starting point as they provide information on both products and industries. Supply tables provide information on products produced by each domestic industry and use tables indicate the use of each product by an industry or final user. By benchmarking the SUTs on consistent time series on gross output and value added from the National Accounting System, tables are linked over time in a consistent way. This is done by using an updating method (the "SUT-RAS method") which is akin to the well-known bi-proportional (RAS) updating method for input-output tables as described in Temurshoev and Timmer (2011).

The link of such tables with international trade data, which are product-based, can be naturally made in a SUT framework. For goods trade, products are allocated to three use categories based on the detailed product description at the HS 6-digit level: intermediates, final consumption, and investment in accordance with the information provided in the tables. The allocation follows from a revised correspondence between HS-6 digit and Broad Economic Categories (BEC). Services trade data from Balance of Payments statistics have been collected from various sources (including OECD, Eurostat, IMF and WTO), checked for consistency, and integrated into a bilateral service trade database. The international SUTs were then constructed using bilateral trade shares by use category which allows to split imports as provided in the national supply tables by use categories and countries of origin. This resulted in an import use table for each country, where each cell of the import use table is then split up by country of origin.

As a final step, these international SUTs are transformed into an industry-by-industry type World Input-Output Table (WIOT). Here, the so-called "fixed product-sales structure" assumption stating that each product has its own specific sales structure irrespective of the industry where it is produced (see Eurostat, 2008). Finally, a rest-of-world is constructed on basis of additional data with respect to output, value added and trade flows based on input coefficients derived from an average coefficients from Brazil, China, India, Indonesia, and Mexico. This results in a WIOT for 41 countries and 35 industries, i.e. the intermediates

[5] See also Johnson and Noguera (2012) for a similar discussion.

[6] See the World Input-Output Database project: www.wiod.org.

demand block is of dimension 1435 × 1435, plus the additional rows on value added and columns on final demand categories. It is important to note that the information on the level of trade flows is based on National Accounts statistics and the WIOT is derived in basic prices which requires some assumptions on domestic and international transport margins.

At the industry level the data are further combined with information obtained from Socio-Economic Accounts data (SEAs), including employment and labor compensation broken down by educational attainment categories and capital compensation. These Socio-Economic Accounts (SEAs) have largely been constructed on the basis of data from national statistical institutes and processed according to harmonized procedures. These procedures were developed to ensure international comparability of the basic data and to generate socio-economic accounts in a consistent and uniform way. Cross-country harmonization of the basic country data has focused on a number of areas including a common industrial classification, consistent definitions of various labor and capital types, and the use of similar price concepts for inputs and outputs. A novelty of the database is the detailed breakdown of labor service inputs which are based on series of employment and wages of various types of labor which are not part of the core set of National Accounts statistics published by NSIs (typically only total employment and wages by industry are available from the National Accounts). For these series additional material has been collected from employment and labor force statistics. Employment is cross-classified by educational attainment (high, medium and low educated according to ISCED classification). For each country, a choice was made concerning the best statistical source for consistent wage and employment data at the industry level. In most cases this was the labor force survey (LFS), which in a number of cases was combined with earnings surveys as wages are often not included in the LFS. In other instances, an establishment survey, or social-security database was used (for details see Timmer et al., 2010; Erumban et al., 2012). Most employment surveys are not designed to track developments over time and breaks in methodology or coverage frequently occur. Therefore, care has been taken to arrive at series which are consistent over time. Further, labor compensation of self-employed is not registered in the National Accounts, which, as emphasized by Krueger (1999), leads to an understatement of labor's share. In these cases an imputation by assuming that the compensation per hour of self-employed is equal to the compensation per hour of employees. This is especially important for industries which have a large share of self-employed workers, such as agriculture, trade, business and personal services. Also, we assume the same labor characteristics for self-employed as for employees when information on the former is missing. These assumptions are made at the industry level.[7] Finally, capital compensation is derived as gross value added minus labor compensation.

The resulting database is therefore rooted in statistics from the National Accounts and follows the concepts and conventions of the System of National Accounts (SNA) framework, and its European equivalent, the European System of National Accounts (ESA), in many respects. The basic statistics is closely related to the national accounts statistics published by NSIs, although with adjustments that vary by group of variables considered: output and intermediate inputs, labor input and capital input.

4. Empirical illustration

In this section we apply both concepts to show the magnitudes of "trade in value added" and "value added in trade" and highlight similarities and differences of both concepts. We start with an analysis at the aggregate level and then go on to discuss these two concepts in a bilateral setting. For simplicity, we aggregated the EU-27 countries to one category which therefore includes intra-EU trade.[8]

[7] Further, in this paper we use information from the EU LFS to split employment by educational groups at a more detailed sectoral level as available in the WIOD database.

[8] Aggregation was done after the calculations on the basis of the 41 countries.

4.1. Value added flows at aggregate level

Table 1 presents the results for both concepts together with export and import values when measured in gross terms. As argued in the theoretical section, country's trade surplus or deficit is equal when either measured in terms of "trade in value added" or "value added in trade". According to these figures, China shows the largest surplus with 170.9 bn US-$ followed by the EU-27 with 152.8 bn US-$ and Japan with 132.3 bn US-$. The by far largest deficit has the USA with 582.4 bn US-$. These figures should equal net trade in gross terms. The reason why the numbers presented are slightly different are due to the fact that in the calculations value added is not exactly equal to gross output minus intermediate inputs which emerges from taking net taxes on products and international transport margins into account as done in the WIOT data.[9] The last column shows net trade in percent of GDP. China (7.57 %) and Russia (12.98 %) have the highest shares of trade surpluses in terms of GDP, whereas the USA (-4.61 %), Turkey (-7.36 %) and the rest-of-world category show the largest deficits in terms of GDP. A second important result is that export and import values for "trade in value added" are in all cases lower as those compared to the figures for "value added in trade".[10] This results from the different concepts with the measure of "value added in trade" plagued by the problem of "double-counting" as it multiplies the coefficient matrix with exports and imports already including both intermediates and final goods for reasons outlined above. It is however important to note that this problem does not apply in the net trade figures where the "double-counting" cancels out.[11]

Table 1 Gross trade, trade in value added and value added in trade in bn US-$, 2005

	Gross trade			Value added in trade			Trade in value added			in %
Reporter	Exports	Imports	Net	Exports	Imports	Net	Exports	Imports	Net	of GDP
China	836.7	669.8	166.9	813.9	643.0	170.9	592.0	421.1	170.9	7.57
European Union	4619.9	4372.0	247.9	4266.8	4114.0	152.8	2988.5	2836.5	152.0	1.24
Japan	653.7	530.6	123.1	645.7	513.4	132.3	553.9	421.6	132.3	2.92
Russia	226.9	137.6	89.3	214.7	129.7	85.0	196.9	111.9	85.0	12.98
Canada	416.2	355.3	60.8	395.8	343.9	51.9	296.6	244.7	51.9	4.91
Korea	327.9	281.6	46.3	302.7	274.1	28.5	195.7	167.1	28.5	3.75
Brazil	134.0	96.8	37.2	118.4	93.0	25.3	105.5	79.4	26.1	3.33
Taiwan	226.7	200.8	25.9	215.5	194.7	20.7	117.8	97.1	20.7	6.01
Indonesia	93.9	78.2	15.7	92.5	75.8	16.7	76.4	59.7	16.7	6.03
Australia	149.3	151.4	-2.1	142.9	145.7	-2.9	123.1	126.0	-2.9	-0.43
Mexico	218.3	219.7	-1.4	207.3	211.7	-4.4	145.8	150.2	-4.4	-0.55
India	157.7	169.9	-12.1	147.0	165.3	-18.3	116.7	135.0	-18.3	-2.34
Turkey	83.9	112.7	-28.8	75.7	106.6	-30.8	55.8	86.6	-30.8	-7.36
Rest-of-world	1992.1	2113.5	-121.4	1966.2	2011.5	-45.3	1388.4	1433.8	-45.3	-4.77
USA	1187.0	1834.3	-647.3	1169.9	1752.3	-582.4	927.7	1510.1	-582.4	-4.61

Note: EU-27 exports and imports include intra-EU trade

Source: WIOD database; author's calculations

As shown in Section 2.4 both concepts can be applied for various factor income categories and physical input units. Table 2 therefore shows the resulting numbers when splitting value added into capital income

[9] When defining value added as gross output minus intermediates this would result in exactly the same numbers; results are available upon request.

[10] The latter would again be equal to gross trade figures when defining value added as gross output minus intermediates.

[11] Alternatively, one could apply the concept of "value added in trade" only to trade in final goods. This would result in the net trade balance of final goods in gross trade.

and labor income, and the latter into factor income by educational attainment categories. Further, the concept is applied to trade in factors in physical units in terms of capital and persons employed again broken down by educational attainment categories. Again, net trade by factor is equal for both concepts whereas export and import values would again be higher when measures as "value added in trade".[12] In this table countries are again ranked according to their trade balance. Strikingly, China's surplus is mainly driven by a positive balance in capital with labor (in value terms) contributing only less than 5%. However, its net exports contain a large surplus of employment (in physical terms) of more than 136 mn persons employed of which about two third are low educated. In terms of labor income broken down by educational attainment categories it turns out that China is running a deficit with respect to high and medium educated but a surplus with respect to low educated workers. Oppositely, the net balance with respect to the capital stock is negative. These figures therefore hint towards the low wages paid in China as compared to other countries with the factor rewards for capital seemingly being relatively larger - a fact which underpins the Heckscher-Ohlin framework, i.e. factor rewards of the abundant factor should be relatively smaller. For the next two countries, European Union and Japan, the opposite result holds. Net trade in capital income is lower, in case of the European Union even negative, as compared to labor. However, both countries show negative net content of employment in terms of persons employed with the numbers being much larger (in absolute terms) for medium and low educated workers and positive values with respect to the capital stock. A similar results also holds for the US with the deficit in capital income being much larger as compared to the deficit in labor income (-406.7 versus -175.7 bn US-$) and the content in terms of persons employed being again strongly negative. Two other interesting countries are Mexico showing a surplus in capital income but a deficit in labor income and India showing a much more balanced pattern. Generally, the net balance with respect to the capital stock is negative for countries like China, Russia, Indonesia, Mexico, Turkey and the rest-of-world.

4.2. Bilateral value added flows

Let us now turn to the bilateral relations focusing again on the US, Japan, the EU-27 and China as the reporter countries. We start again with discussing the trade flows with respect to value added and then proceed by the more detailed factors. Table 3 presents the figures for net trade in value added (TiVA) and net value added in trade (VAiT) for the four reporter countries together with the difference between these two measures. For each reporter we ranked the partner countries according to the trade balance according to value added in trade.

The EU as the reporter country has the largest trade deficit with China of 54.8 bn US-$ in terms of "value added in trade" whereas and in terms of "trade in value added" this reduces to 32.2 bn US-$, thus being about 40% lower. A similar reduction of about half is found with India where the deficit reduces from 16.6 to 8.2 bn US-$. For the other partner countries the deficits in both measures are relatively close together. With respect to partner countries where the EU has a surplus, this would be lowered in terms of "trade in value added" with the rest-of-world category but would increase in case of trade with the US, for example. Large reductions in relative terms can also be found for trade with Canada and to a much smaller extent with Australia.

The US runs bilateral trade deficits with all countries with the exception of Australia. Again, the largest trade deficit occurs with China which would be reduced by about 25% from 151.6 to 117.5 bn US-$. But, for example, it would increase against the EU from 112.9 to 141 bn US-$, i.e. by about 20%. With respect to other trading partners the trade deficit in terms of "trade in value added" is also sizeably reduced with

[12] Results are available upon request.

Table 2 Net trade by factor, 2005

	Value added and factor income						Physical inputs				
	Value	Factor income		Labor income			Factor input		Employment (in '000s)		
Reporter	added	Capital	Labor	High	Medium	Low	Capital	Empl.	High	Medium	Low
China	170.9	163.2	7.7	-56.9	-12.9	77.6	-47.7	136125.9	4598.3	40305.5	91222.1
European Union	152.8	-143.5	296.3	141.9	116.3	38.4	1294.9	-152226.1	-8503.0	-54622.2	-89101.0
Japan	132.3	29.4	102.9	44.1	89.6	-30.6	1131.7	-45560.2	-1525.1	-13110.8	-30924.3
Russia	85.0	47.7	37.3	2.1	46.6	-11.4	-158.9	-1420.5	402.5	6508.9	-8331.9
Canada	51.9	39.2	12.7	-14.5	43.9	-16.7	224.3	-11801.8	-580.7	-2788.6	-8432.5
Korea	28.5	-12.6	41.2	36.9	13.0	-8.6	182.0	-11388.5	814.8	-3616.3	-8587.0
Brazil	25.3	18.7	6.7	-0.3	-1.6	8.5	18.4	8381.2	424.3	1830.8	6126.1
Taiwan	20.7	10.7	10.1	1.4	-4.7	13.3	88.0	-3461.4	213.4	-1460.6	-2214.2
Indonesia	16.7	19.1	-2.4	-4.6	-6.5	8.7	-124.6	11703.1	193.0	1378.1	10132.0
Australia	-2.9	4.3	-7.2	-7.4	-8.0	8.2	122.2	-11116.3	-883.2	-4214.7	-6018.5
Mexico	-4.4	42.1	-46.5	-23.7	-16.9	-5.9	-163.1	-1259.3	-156.5	299.3	-1402.2
India	-18.3	-8.6	-9.7	0.1	-11.7	2.0	-0.2	42818.0	3776.1	12128.1	26913.8
Turkey	-30.8	-6.8	-24.0	-11.0	-16.9	4.0	-140.1	-3518.7	-377.5	-2002.9	-1138.3
Rest-of-world	-45.3	203.9	-249.2	-161.6	-132.1	43.4	-1359.4	187564.3	10854.6	72182.0	104527.6
USA	-582.4	-406.7	-175.7	53.6	-98.0	-131.0	-1067.4	-144839.6	-9251.1	-52816.7	-82771.8

Note: EU-27 exports and imports include intra-EU trade

Source: WIOD database; author's calculations

respect to Canada (92.3 to 74.3 bn US-$), Mexico (36.1 to 21.8 bn US-$), and India (23.3 to 17.4 bn US-$). Significant increases are found for Japan (50.7 to 67 bn US-$), and Russia (2.6 to 14.4 bn US-$).

Japan shows generally a much more balanced pattern of trade with respect to the two concepts with the trade deficit being reduced with Australia from 7.6 to 4.8 bn US-$ and with Indonesia from 6.5 to 4.5 bn US-$. Japan's surplus is sizeably reduced with Korea (from 14.2 to 7 bn US-$) and Taiwan (from 26.8 to 14.2 bn US-$), however much larger with the US where the surplus increases from 50.7 to 67 bn US-$.

For China one can see sizeable reductions of the trade deficit with Taiwan and Korea by about 70%. However, also China's surpluses are partly considerably reduced. In particular, the trade deficit with US shrinks from 151.6 to 117.5 bn US-$, with the EU from 54.8 to 32.2 bn US-$, with Mexico from 14.2 to 7 bn US-$ and for Canada from 12.5 to 8.8 bn US-$. An increase in its surpluses with respect to partner countries is seen for the rest-of-world category Finally, it is interesting to note the mirrored image of changes in surpluses and deficits when comparing the bilateral flows (e.g. US - China deficit and surplus, respectively). These results therefore partly confirm the cases studies in products like the iPod and other examples, that the US trade deficit would be lowered when measured in value added terms which is actually the case when considering bilateral relations for countries where production networks (or assembly trade) and linkages are strong. However, such results cannot be generalized when looking at a country's overall net trade - either as "value added in trade" or "trade in value added" - as one ends up with the overall trade deficit when summing up net trade over partner countries in the tables just discussed.

Figure 1 summarizes the differences for trade balances when either measured as "trade in value added" or as "value added in trade". A general picture is that for developing and emerging economies the trade surplus in terms of "trade in value added" is reduced as compared to "value added in trade" (see the chart for China and the position of US and EU, but also Mexico and Canada), but also the trade deficits being smaller (see e.g. position of Taiwan and Korea). As this is mirrored in trade balances of the more advanced economies, this also means that generally the trade deficits tend to be smaller (see the case of US and

Table 3 Bilateral net trade in value added and net value added trade in bn US-$, 2005

EU-27			USA			Japan			China		
Partner	VAiT	TiVA	Partner	VAiT	TiVA	Partner	VAiT	TiVA	Partner	VAiT	TiVA
China	-54.8	-32.2	China	-151.6	-117.5	Australia	-7.6	-4.8	Taiwan	-51.7	-16.3
Russia	-33.9	-36.9	European Union	-112.9	-141.0	Indonesia	-6.5	-4.5	Korea	-21.4	-6.8
Japan	-16.6	-20.9	Canada	-92.3	-74.3	India	-1.8	0.4	Japan	-4.9	-3.2
India	-16.6	-8.2	Rest-of-world	-79.8	-79.8	Brazil	1.4	1.2	Russia	-1.4	-2.5
Korea	-11.5	-10.2	Japan	-50.7	-67.0	Canada	1.7	1.6	Brazil	-1.4	-1.3
Brazil	-4.4	-5.8	Mexico	-36.1	-21.8	Turkey	1.9	2.5	Indonesia	-0.1	-0.7
Indonesia	-4.0	-3.9	India	-23.3	-17.4	China	4.9	3.2	Australia	0.6	1.4
Taiwan	1.8	-1.8	Taiwan	-14.7	-16.6	Russia	7.2	2.9	Turkey	5.1	3.9
Mexico	3.3	2.1	Brazil	-9.5	-11.3	Mexico	8.3	6.0	Rest-of-world	6.2	24.7
Turkey	5.6	7.8	Korea	-7.3	-14.4	Korea	14.2	7.0	India	6.8	6.2
Canada	9.0	4.5	Indonesia	-4.9	-6.5	Rest-of-world	14.5	14.5	Canada	12.5	8.8
Australia	15.7	12.6	Turkey	-3.1	-1.1	European Union	16.6	20.9	Mexico	14.2	7.0
USA	112.9	141.0	Russia	-2.6	-14.4	Taiwan	26.8	14.2	European Union	54.8	32.2
Rest-of-world	146.4	103.8	Australia	6.3	0.7	USA	50.7	67.0	USA	151.6	117.5

Note: VAiT ... value added in trade; TiVA ... trade in value added

Source: WIOD database; author's calculations

China), but also trade surpluses tend to be reduced for trade with developing and emerging economies (e.g. EU versus rest-of-world).

For completeness, we present the bilateral net trade figures broken down by factor income and physical inputs in Appendix Tables 4 to 7. It would go beyond the scope of this paper to outline the details of these results. However, let us mention a few important facts emerging from these figures: First, as already seen, for the aggregate net trade flows it seems that the more advanced countries tend to have larger deficits with respect to capital flows as compared to labor income flows (in value terms). For the three developed countries (US, EU and Japan) trade deficits in terms of capital tend to be larger for both concepts whereas these countries are large net importers of employment - and particularly so of low skilled employment - when measured in terms of persons employed. As a mirrored picture, emerging countries tend to have much larger surpluses in terms of capital as compared to labor - independently of the measurement concept applied - in trade with the developed economies whereas running a huge net surplus in physical employment terms. Basically, this hints towards a picture as expected from trade theory. Developing countries being abundant in labor tend to have low rewards to this factor as compared to capital together with relatively lower labor productivity as compared to capital productivity. A more detailed examination of this pattern will have to follow based on the measures of "trade in value added" and "value added in trade" focused on in this paper.

5. Conclusions

In this paper two concepts of measuring value added flows between countries have been introduced clarifying the empirical contributions in the recent literature on trade in value added and the factor content of trade. It is analytically shown that both concepts - "trade in value added" and "value added in trade" - result in the same level of net exports for a country's total trade which is also equal to a country's net trade in gross terms. However, this is not the case when looking at bilateral relations. where the difference of net trade between these two concepts can go in either direction. These concepts are also applied to value added

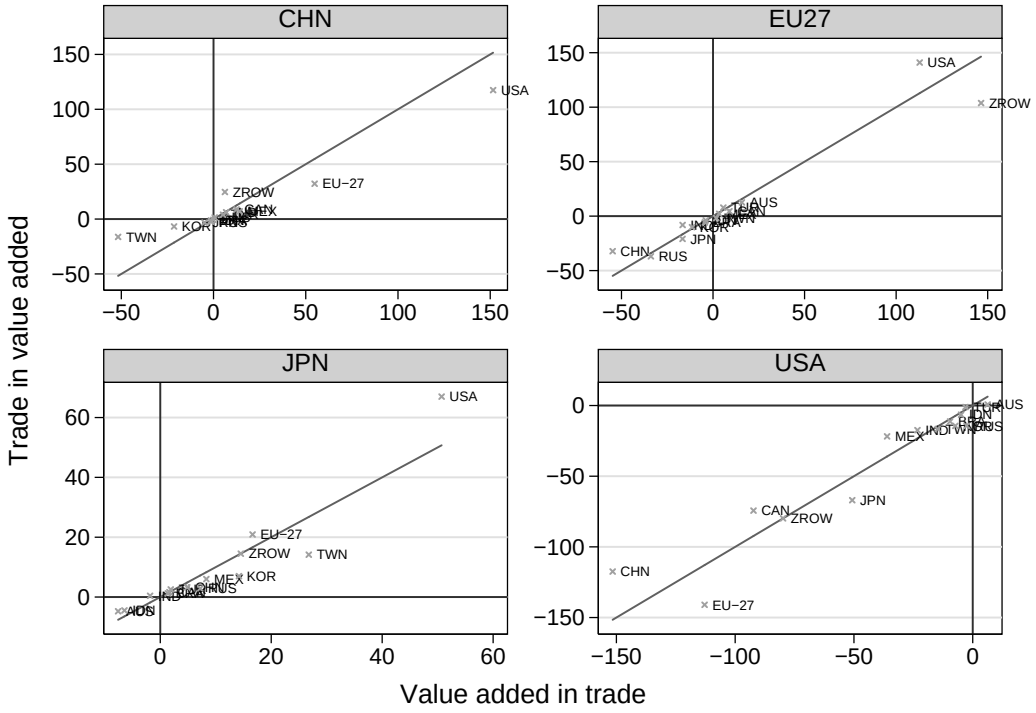

Figure 1. ”Trade in value added” and the ”Value added in trade”

broken down by income of various factors or to physical inputs like persons employed which are further differentiated by educational attainment categories.

The paper then presents selected empirical findings based on a recently compiled and unique database bringing together National Accounts data, supply and use and input-output tables and socio-economic accounts for a large range of countries in an integrated way, the world input-output database (WIOD). From these data a world-input-output table (WIOT) is derived which allows studying value added flows across countries in detail.

The empirical results tend to show that for developing and emerging economies the trade surplus in terms of ”trade in value added” is reduced as compared to ”value added in trade” in trade with more developed countries or trade deficits being somewhat smaller. This is mirrored in trade balances of the more advanced economies which is exemplified on figures for four countries. With respect to flows by factors the results tend to support the Heckscher-Ohlin framework when allowing for productivity differences as is studied in recent contributions to the factor content of trade. This paper aimed at clarifying the measurement concepts on which such factor content studies and other contributions focusing on vertical integration are based and highlight similarities and differences between ”trade in value added” and the ”value added in trade”.

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Appendix: Tables

Table 4 EU-27 flows by factor, 2005

	Value added and factor income						Physical inputs				
	Value	Factor income		Labor income			Factor input		Employment (in '000s)		
Reporter	added	Capital	Labor	High	Medium	Low	Capital	Empl.	High	Medium	Low
						Trade in value added					
Russia	-36.9	-26.4	-10.5	2.2	-17.4	4.7	91.4	-4203.9	-271.7	-3860.1	-72.1
China	-32.2	-44.2	12.0	18.6	7.5	-14.2	23.2	-37248.7	-1758.0	-12139.4	-23351.3
Japan	-20.9	-15.9	-5.0	-1.1	-9.4	5.5	-140.5	-21.3	-37.3	-191.9	207.9
Korea	-10.2	-3.8	-6.3	-5.9	-2.1	1.6	-36.0	-472.5	-281.2	-216.6	25.2
India	-8.2	-8.2	0.0	0.5	1.8	-2.3	0.7	-18282.6	-1404.1	-5701.7	-11176.8
Brazil	-5.8	-7.8	2.7	2.2	2.3	-1.8	8.9	-4343.7	-220.2	-1171.2	-2952.3
Indonesia	-3.9	-4.3	0.5	1.2	1.3	-2.0	32.6	-3868.3	-133.9	-771.8	-2962.6
Taiwan	-1.8	-3.2	1.4	1.2	1.6	-1.4	-9.4	-335.5	-69.7	-79.6	-186.2
Mexico	2.1	-8.8	10.9	4.8	3.8	2.3	39.9	-578.3	-16.0	-326.6	-235.8
Canada	4.5	-5.2	9.7	5.3	-0.8	5.2	-14.7	180.2	64.4	-52.1	168.0
Turkey	7.8	-4.8	12.6	6.8	8.5	-2.7	79.6	-967.0	55.7	33.2	-1055.9
Australia	12.6	0.9	11.7	5.7	5.7	0.3	9.2	263.9	92.7	161.5	9.7
Rest-of-world	103.8	-57.7	161.5	81.8	74.3	5.7	788.6	-85680.9	-5180.7	-31781.4	-48718.8
USA	141.0	45.9	95.1	18.4	39.2	37.5	421.4	3332.6	656.9	1475.6	1200.2
						Value added in trade					
China	-54.8	-54.9	0.1	14.1	1.6	-15.6	-31.3	-37923.1	-1943.9	-12594.4	-23384.8
Russia	-33.9	-25.0	-8.9	2.8	-16.8	5.0	96.1	-3652.2	-222.4	-3620.4	190.6
Japan	-16.6	-13.5	-3.2	-0.6	-7.3	4.7	-114.0	128.7	-16.4	-97.3	242.4
India	-16.6	-11.7	-4.9	-1.1	-0.5	-3.4	-14.5	-18458.8	-1431.8	-5848.8	-11178.2
Korea	-11.5	-5.5	-6.0	-5.0	-2.2	1.2	-37.4	-878.2	-268.8	-369.5	-239.8
Brazil	-4.4	-7.3	2.9	2.3	2.4	-1.8	9.6	-4335.2	-217.0	-1147.2	-2971.0
Indonesia	-4.0	-3.6	-0.3	0.8	0.8	-1.9	28.2	-3707.8	-137.9	-758.5	-2811.5
Taiwan	1.8	-2.0	3.8	2.1	2.2	-0.5	-1.5	-382.1	-48.1	-114.3	-219.6
Mexico	3.3	-7.8	11.2	4.6	4.0	2.5	39.6	-309.6	4.2	-208.2	-105.7
Turkey	5.6	-6.2	11.8	6.8	8.2	-3.2	79.2	-1132.4	57.2	-2.0	-1187.5
Canada	9.0	-2.7	11.7	5.6	0.5	5.6	-10.3	544.5	102.3	124.7	317.5
Australia	15.7	3.1	12.6	5.7	6.1	0.7	16.6	460.7	110.2	244.0	106.5
USA	112.9	38.5	74.3	10.6	30.3	33.3	335.3	4991.5	720.0	2142.4	2129.1
Rest-of-world	146.4	-44.9	191.3	93.2	86.8	11.6	899.4	-87572.2	-5210.6	-32372.7	-49988.9

Source: WIOD database; author's calculations

Table 5 US net flows by factor, 2005

	Value added and factor income						Physical inputs				
	Value	Factor income		Labor income			Factor input		Employment (in '000s)		
Reporter	added	Capital	Labor	High	Medium	Low	Capital	Empl.	High	Medium	Low
						Trade in value added					
European Union	-141.0	-45.9	-95.1	-18.4	-39.2	-37.5	-421.4	-3332.6	-656.9	-1475.6	-1200.2
China	-117.5	-82.0	-35.5	8.1	-12.1	-31.5	-127.4	-43737.6	-1606.9	-13140.4	-28990.3
Rest-of-world	-79.8	-113.5	33.7	50.5	21.8	-38.4	74.0	-66333.4	-4326.4	-25899.8	-36107.2
Canada	-74.3	-44.7	-29.6	8.0	-38.9	1.2	-190.1	-1384.3	-132.5	-1278.0	26.1
Japan	-67.0	-32.7	-34.2	-6.3	-24.4	-3.5	-305.8	-972.4	-213.9	-684.3	-74.2
Mexico	-21.8	-39.6	17.7	13.8	5.1	-1.2	49.6	-3667.0	-182.9	-1795.2	-1688.9
India	-17.4	-10.7	-6.7	-1.1	-1.3	-4.3	-31.8	-16616.6	-1300.9	-5374.0	-9941.8
Taiwan	-16.6	-8.8	-7.8	-1.1	-1.4	-5.3	-49.3	-842.3	-189.5	-250.6	-402.1
Korea	-14.4	-5.0	-9.5	-4.6	-3.7	-1.2	-50.0	-709.5	-295.9	-339.6	-74.0
Russia	-14.4	-7.8	-6.6	-0.4	-6.0	-0.2	6.3	-1271.4	-104.4	-1084.9	-82.1
Brazil	-11.3	-7.8	-3.5	0.2	-0.8	-3.0	-18.7	-2487.8	-170.4	-813.6	-1503.7
Indonesia	-6.5	-5.3	-1.2	0.8	0.3	-2.3	8.1	-3184.7	-90.6	-661.4	-2432.7
Turkey	-1.1	-1.7	0.6	1.0	0.8	-1.2	7.6	-271.8	-6.6	-41.2	-223.9
Australia	0.7	-1.3	2.0	3.1	1.6	-2.7	-18.5	-28.3	26.6	21.9	-76.9
						Value added in trade					
China	-151.6	-95.3	-56.2	-1.2	-22.2	-32.8	-202.6	-42131.2	-1735.2	-12887.6	-27508.4
European Union	-112.9	-38.5	-74.3	-10.6	-30.3	-33.3	-335.3	-4991.5	-720.0	-2142.4	-2129.1
Canada	-92.3	-53.6	-38.7	6.0	-44.2	-0.4	-222.6	-2479.2	-215.8	-1702.9	-560.4
Rest-of-world	-79.8	-109.5	29.6	49.7	20.6	-40.5	17.9	-65205.4	-4234.1	-25183.5	-35787.8
Japan	-50.7	-25.7	-25.0	-3.5	-18.2	-3.3	-232.8	-1070.4	-180.0	-664.0	-226.4
Mexico	-36.1	-47.1	11.1	11.8	1.9	-2.6	25.4	-4637.2	-284.6	-2239.2	-2113.4
India	-23.3	-13.0	-10.3	-2.3	-3.2	-4.8	-38.4	-16446.5	-1226.0	-5441.2	-9779.3
Taiwan	-14.7	-8.7	-6.0	0.0	-1.3	-4.7	-43.5	-1294.3	-194.8	-458.7	-640.9
Brazil	-9.5	-6.5	-3.1	0.2	-0.6	-2.6	-15.2	-2178.3	-147.2	-717.1	-1314.1
Korea	-7.3	-3.6	-3.7	-0.7	-1.5	-1.5	-31.9	-1096.8	-225.4	-464.2	-407.2
Indonesia	-4.9	-3.6	-1.3	0.5	0.0	-1.8	3.7	-2678.1	-78.0	-564.6	-2035.4
Turkey	-3.1	-2.2	-0.8	0.3	0.0	-1.1	2.9	-319.0	-16.7	-81.4	-220.8
Russia	-2.6	-1.7	-0.8	0.4	-1.3	0.0	5.8	-355.1	-26.4	-320.0	-8.7
Australia	6.3	2.5	3.8	3.1	2.3	-1.6	-1.0	43.3	33.1	50.1	-39.9

Source: WIOD database; author's calculations

Table 6 Japan flows by factor, 2005

	Value added and factor income						Physical inputs				
	Value	Factor income		Labor income			Factor input		Employment (in '000s)		
Reporter	added	Capital	Labor	High	Medium	Low	Capital	Empl.	High	Medium	Low
					Trade in value added						
Australia	-4.8	-4.7	-0.0	0.7	1.5	-2.2	-8.2	-9.6	15.2	40.4	-65.2
Indonesia	-4.5	-5.5	1.0	0.9	1.9	-1.8	28.2	-2026.2	-45.3	-371.3	-1609.6
India	0.4	-0.1	0.5	0.3	0.9	-0.6	8.7	-2440.5	-173.6	-772.9	-1494.0
Brazil	1.2	0.0	1.2	0.4	1.1	-0.4	9.1	-470.8	-12.9	-84.1	-373.8
Canada	1.6	-0.1	1.7	1.0	0.3	0.4	16.2	13.6	14.1	-7.4	7.0
Turkey	2.5	1.0	1.5	0.6	1.0	-0.1	10.5	-3.3	7.8	18.8	-29.9
Russia	2.9	1.1	1.8	1.0	0.5	0.3	28.5	-543.2	-26.4	-473.1	-43.7
China	3.2	-7.9	11.1	10.5	12.6	-12.0	141.9	-18819.5	-419.8	-4429.6	-13970.0
Mexico	6.0	1.6	4.4	1.6	2.6	0.3	28.3	-55.3	14.7	-4.2	-65.8
Korea	7.0	4.7	2.3	-1.3	3.4	0.1	34.1	-186.9	-126.5	-35.1	-25.4
Taiwan	14.2	5.4	8.7	3.0	6.8	-1.0	53.0	22.6	14.5	135.5	-127.4
Rest-of-world	14.5	-15.0	29.5	18.1	23.2	-11.7	335.1	-22034.8	-1038.0	-8004.1	-12992.8
European Union	20.9	15.9	5.0	1.1	9.4	-5.5	140.5	21.3	37.3	191.9	-207.9
USA	67.0	32.7	34.2	6.3	24.4	3.5	305.8	972.4	213.9	684.3	74.2
					Value added in trade						
Australia	-7.6	-6.3	-1.3	0.2	0.8	-2.3	-16.2	-95.6	4.1	2.3	-102.0
Indonesia	-6.5	-6.9	0.4	0.8	1.6	-2.0	26.4	-2176.5	-57.3	-432.9	-1686.3
India	-1.8	-1.0	-0.8	-0.1	0.0	-0.7	1.6	-2224.1	-152.2	-735.3	-1336.6
Brazil	1.4	0.2	1.1	0.4	1.0	-0.3	7.6	-348.3	-6.5	-50.0	-291.8
Canada	1.7	0.2	1.5	0.8	0.3	0.4	15.0	14.4	14.1	1.1	-0.8
Turkey	1.9	0.8	1.1	0.4	0.7	0.0	6.6	20.9	6.9	20.6	-6.6
China	4.9	-7.6	12.5	10.9	14.1	-12.6	162.1	-19425.2	-446.9	-4588.3	-14390.1
Russia	7.2	3.3	3.9	1.4	2.1	0.5	28.3	-215.7	2.1	-221.9	4.0
Mexico	8.3	3.0	5.3	1.8	3.1	0.4	32.0	88.2	28.1	59.3	0.9
Korea	14.2	7.8	6.4	0.1	6.2	0.2	63.6	-374.5	-121.4	-71.5	-181.6
Rest-of-world	14.5	-14.3	28.8	18.1	23.3	-12.4	362.5	-22018.6	-1045.4	-8110.1	-12863.1
European Union	16.6	13.5	3.2	0.6	7.3	-4.7	114.0	-128.7	16.4	97.3	-242.4
Taiwan	26.8	11.0	15.8	5.2	11.0	-0.4	95.2	253.2	53.0	254.6	-54.3
USA	50.7	25.7	25.0	3.5	18.2	3.3	232.8	1070.4	180.0	664.0	226.4

Source: WIOD database; author's calculations

Table 7 China flows by factor, 2005

	Value added and factor income						Physical inputs				
	Value	Factor income		Labor income			Factor input		Employment (in '000s)		
Reporter	added	Capital	Labor	High	Medium	Low	Capital	Empl.	High	Medium	Low
						Trade in value added					
Taiwan	-16.3	-7.2	-9.1	-3.0	-2.9	-3.1	-46.2	1084.0	-65.6	307.8	841.8
Korea	-6.8	2.0	-8.8	-8.6	-3.7	3.6	-42.8	6608.8	51.4	2002.2	4555.2
Japan	-3.2	7.9	-11.1	-10.5	-12.6	12.0	-141.9	18819.5	419.8	4429.6	13970.0
Russia	-2.5	-0.5	-2.0	-0.8	-2.8	1.7	7.4	1742.9	8.4	-37.5	1771.9
Brazil	-1.3	-0.6	-0.6	-0.5	-0.1	-0.1	-5.3	223.2	10.8	192.8	19.6
Indonesia	-0.7	-0.8	0.1	-0.1	0.3	-0.1	6.3	150.8	13.7	187.9	-50.8
Australia	1.4	1.3	0.1	-0.8	0.1	0.8	-17.3	4354.2	230.7	1456.1	2667.4
Turkey	3.9	2.4	1.5	0.1	0.7	0.8	5.8	1157.8	47.3	361.5	749.0
India	6.2	4.2	2.0	-0.3	0.9	1.5	5.7	1127.0	-34.7	353.6	808.2
Mexico	7.0	4.1	2.9	0.2	1.1	1.6	9.6	1946.8	83.7	619.8	1243.2
Canada	8.8	5.5	3.3	-0.4	0.0	3.7	1.1	5042.7	163.0	1420.1	3459.6
Rest-of-world	24.7	18.8	5.8	-5.3	1.4	9.7	65.5	12882.1	305.1	3731.9	8845.1
European Union	32.2	44.2	-12.0	-18.6	-7.5	14.2	-23.2	37248.7	1758.0	12139.4	23351.3
USA	117.5	82.0	35.5	-8.1	12.1	31.5	127.4	43737.6	1606.9	13140.4	28990.3
						Value added in trade					
Taiwan	-51.7	-24.2	-27.6	-9.5	-11.2	-6.9	-121.0	-96.1	-278.6	-240.3	422.8
Korea	-21.4	-4.0	-17.4	-13.2	-7.7	3.5	-76.6	7233.1	-35.3	2117.1	5151.3
Japan	-4.9	7.6	-12.5	-10.9	-14.1	12.6	-162.1	19425.2	446.9	4588.3	14390.1
Russia	-1.4	-0.1	-1.3	-0.6	-2.3	1.5	8.2	1501.5	4.4	-92.7	1589.8
Brazil	-1.4	-0.9	-0.5	-0.3	0.0	-0.2	-6.0	49.7	7.4	153.0	-110.7
Indonesia	-0.1	-0.5	0.4	-0.0	0.4	0.0	7.3	86.9	13.5	183.7	-110.2
Australia	0.6	0.3	0.4	-0.5	0.3	0.6	-20.0	4354.1	239.9	1462.1	2652.1
Turkey	5.1	2.9	2.2	0.4	1.0	0.9	7.8	1180.4	47.9	350.4	782.1
Rest-of-world	6.2	12.5	-6.3	-10.8	-4.8	9.4	43.2	13443.3	177.1	3616.6	9649.6
India	6.8	4.2	2.6	0.0	1.2	1.4	8.2	1005.8	-27.5	286.0	747.3
Canada	12.5	7.1	5.3	0.2	1.0	4.1	8.4	5350.6	186.9	1525.8	3637.9
Mexico	14.2	8.1	6.1	1.1	2.7	2.3	20.8	2537.1	136.6	873.6	1526.8
European Union	54.8	54.9	-0.1	-14.1	-1.6	15.6	31.3	37923.1	1943.9	12594.4	23384.8
USA	151.6	95.3	56.2	1.2	22.2	32.8	202.6	42131.2	1735.2	12887.6	27508.4

Source: WIOD database; author's calculations