Measuring the Level of Participation and Position of Chinese Regions in Global Value Chains?*

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Abstract

Global value chains are supported not only directly by domestic regions that export goods and services to the world market, but also indirectly by other domestic regions that provide parts, components, and intermediate services to final exporting regions. Understanding the domestic components of global value chains is especially important for large developing countries like China and India, where there may be large variations in economic scale and development between domestic regions. This paper proposes a new framework for measuring value chains by embedding China's 2007 domestic interregional input-output (IO) table into the World IO Table (WIOT). Using this framework, our empirical results show that 1) the measuring bias of China's bilateral trade balance coming from both traditional gross exports and the WIOT can be further corrected since the heterogeneity in production functions across Chinese regions has been fully considered in our new framework; 2) Unlike the participation pattern of China's coastal regions, the inland regions join GVCs indirectly by providing intermediate products to the coastal region. As a result, China's inland regions show a relatively high degree of participation in GVCs; 3) China's coastal regions has relatively high presence in GVCs through value added export which is mainly achieved through the domestic segment of GVCs. While, the value added export of China's inland regions are mainly through the international segment of GVCs. Our new measuring framework can clearly describe how global production is fragmented and extended through linkages across China's domestic regions.

Keywords: Value chain; Input-output; Trade in value added

*The views expressed in the paper are solely those of the authors and do not necessarily reflect the views of the U.S. International Trade Commission or any of its individual commissioners.

1 Introduction

The rise of global value chains (GVCs)[1] has been considered one of the most important features of the rapid economic globalization in recent decades. The economic and popular literature has described phenomena relating to GVCs as “vertical specialization,” “production fragmentation,” “outsourcing,” “offshoring,” “global supply chains,” and so on. Despite the use of these different terms, they all point to the same fact: higher volumes of intermediate products such as parts, components, and intermediate services are being produced in stages or processes across different countries and then exported to other countries for further production. This phenomenon has been explained as the so-called second unbundling (Baldwin, 2011).

Until now, most GVCs related researches focus on the country-by-country relationship, rather than investigating how GVCs are fragmented and extended inside a country’s territory as well as the relationship between domestic value chains (DVCs) and GVCs even if these two chains act each other very closely under the deepening globalization. The fact observed in the real world is that GVCs are supported not only directly by domestic regions that export goods and services to the world market, but also indirectly by other domestic regions that provide parts, components, and intermediate services to final exporting regions. Understanding the domestic components of global value chains is especially important for large developing countries like China and India, where there may be large variations in economic scale and development between domestic regions. Our work is aimed at estimating how the final exporting regions have sourced value from other domestic regions into goods that are exported.

With the aim of understanding the evolution of GVCs, as well as the position and degree of participation of individual countries in GVCs, many economic measurements have been developed. Why do we need better measurements of GVCs? There are at least two important reasons: First, current international trade statistics fall short in terms of the research requirements needed to understand GVCs. This is perhaps the reason why WTO statistical officers have stated “what you see is not what you get.”[2] Second, better measurement can help to provide more relevant and reliable information to policy-makers, particularly since “you can’t manage what you can’t measure.”

[1] For sociological approaches on GVCs, see, for example, Gereffi et al. (2006) and Gereffi and Lee (2012).

[2] Source: Maurer and Degain (2010).

Three main approaches are currently used to measure GVCs. The first approach is based on survey data obtained for a specific firm and product. For example, case studies examining China's role in Apple's global supply chain (e.g., Linden et al., 2009; Dedrick et al., 2010) have received a great deal of attention. Xing and Detert (2010) examined the case of the iPhone and found that China just contributed only 3.6% of $2.0 billion export to the US, the rest of value added was simply from Germany, Japan, Korea, the US, and other countries. These studies rely on "tear down" analyses that assign the value of individual components to source companies and their countries. These firm- and product-based case studies can provide intuitive images of GVCs in terms of the activities of multinational enterprises. However, when we examine the Chinese economy's role in global production networks as a whole, its share of total value added through the export of final products to the United States was actually about 75% in 2005 (Meng et al., 2011). This indicates that the "tear down" case studies focus on only the supply chain of a specific firm and particular products, and are clearly not representative of the broader role of China's domestic production networks and inter-industrial linkages in the whole value creation process. Other work on this topic shows that domestic value added can vary substantially between different economic sectors (see Koopman et al. (KWW 2014), Erumban et al. (2011), Stehrer (2012), and OECD-WTO (2013).

The second approach is based on a country's national input-output (IO) table. Using the IO table, we can avoid the shortcomings of firm- and product-based case studies since the domestic inter-industry relationships are explicitly considered. As shown in Hummels et al. (2001) trade data (import/export) alone cannot be used to reliably measure the import content of exports or the degree of vertical specialization (VS) since domestic inputs of intermediate products may also incorporate imported parts and components. Thus, Hummels et al. (2001) proposed using IO tables as a tool for measuring VS since they can capture both direct and indirect impacts in a balanced demand and supply system. However, it should be noted that in a national IO table, imports and exports are treated as exogenous variables. This means that spill-over and feedback effects from the rest of the world (ROW) or can't be fully considered in the measurements proposed by Hummels et al. (2001).

As a response to the limitations of the approaches discussed above, international IO tables have been used to measure GVCs. In this third approach an international IO table can be compiled by combining countries' national IO tables and trade statistics.[3] An international IO table

[3] International IO tables can also be compiled by using supply-use tables (Dietzenbachera et al., 2013). In addition,

therefore consists of detailed information on both inter-country (trade data) and inter-industry (IO table) linkages. Many new measures of GVCs have been developed using international IO databases, including Kuroiwa, (2006), Escaith (2008), Uchida and Inoamata (2009), Yang et al. (2009), Degain and Maurer (2010), Erumban et al. (2010), Fukasaku et al. (2011), Johnson and Noguera (2012), Meng et al. (2011), Abdul et al. (2011), Los et al. (2012), Stehrer (2012), Timmer et al. (2013) and Koopman et al. (KWW 2014). Most of these papers discuss in broad terms the connections between their approaches and the approach of Hummels et al. (2001), except Koopman et al. (KWW 2014), which we refer to as KWW below. KWW provides a unified and transparent mathematical framework for completely decomposing gross exports into its various components, including exports of value added, domestic value added that returns home, foreign value added, and other additional double-counted terms. This framework establishes a precise relationship between value added measures of trade and official trade statistics, thus providing an observable benchmark for value added trade estimates. The KWW approach will be integral to the approach proposed below.

However, most of the research efforts discussed above have treated China as a single entity, though KWW separates China's exports into two parts, normal and processing, they fail to examine how globalization and fragmentation might have contributed to the resulting expansion of GVCs inside China at the regional level. There are several reasons why the measurement of regional developments within a country such as China is of interest:

1) Within large developing economies such as China, there is a great deal of variation in economic size, industrial structure, and overseas dependency across regions. GVCs are supported not only by domestic regions which export goods and services to the world market directly, but also by other domestic regions that participate in the global economy indirectly through domestic supply chains when they provide parts, components, and intermediate services to leading export-oriented regions. In order to better understand how GVCs are fragmented and extended inside China, or how GVCs impact domestic regions at different stages of development, a domestic-regional perspective on GVCs is necessary.
2) Local governments and policy-makers have great interest in understanding how and where their regions participate in GVCs and how they might enhance their local

some supplementary information is also necessary during the construction of international IO table, such as balance of payments, information related to international trade and transport margins, and survey data on the use of import goods (Meng et al., 2013).

industry and firms in ways that deliver more local value added, employment, and income. A better understanding of how GVCs impact domestic regions can help local government to develop more effective responses to the challenges of rapid globalization.

3) Given the rapid reductions in tariff, non-tariff, transportation, and communication costs, transnational and inter-regional interactions are likely to play an increasing role in forming GVCs. For example, the economic interdependence between China's Liaoning province and Korea may be stronger than Liaoning's economic interdependence with other inland Chinese provinces.

Meng et al. (2012) apply the concept of trade in value added (TiVA) to China's domestic interregional IO table. They find that China's inland regions tend to produce more value added by joining the domestic portion of coastal regions' global supply chains instead of relying on increasing direct exports to the world market. However, their results are tentative; in their model the linkages between domestic value chains (DVCs) and GVCs are not measured in a closed IO model because there is no information about the country of destination for regional exports and also no information about the country of origin for imports.

In order to overcome the above limitation, this paper embeds China's 2007 domestic interregional IO table into the WIOT to get a kind of embedded international IO (EMIIO) table. When applying the KWW method into this EMIIO table, very interesting findings appears which can't be obtained by using an individual China's interregional IO table or WIOT. The main conclusions of our empirical analysis can be summarized as follows:

1) The EMIIO-based TiVA measurement can reduce the overestimation of bilateral trade balance compared to the WIOT-based TiVA measurement. This illustrates the impact of the heterogeneity of economic structure across Chinese regions.
2) Without using the EMIIO table, it's difficult to know how much a domestic region exactly contributes to China's national bilateral trade balance. This is mainly because that the conventional gross-export based measurement can't capture the value added flow across regions and countries correctly.
3) The analytical results of the structure of regional value added export/outflow by country/region of destination can provide important information which had previously been obscured by the traditional trade statistics or WIOT-based methods. In particular, China's inland regions also show a relatively high degree of participation in GVCs. Unlike

the participation pattern of the coastal region, the inland regions join GVCs indirectly by providing intermediate products to the coastal region.

4) Domestic regions take part in DVCs and GVCs by different routes. China Coast has relatively high presence in GVCs through value added export, but this value added export is mainly achieved through the domestic segment of GVCs. China's inland regions, however, export value added mainly through the international segment of GVCs. This finding indicates that although separate domestic regions may be at different development stages, they can still join GVCs by employing their comparative advantages and specializing in different fragmented production processes.

The remainder of this paper is organized as follows. In Section 2 we construct an EMIIO table by taking a well-known international IO table, the WIOT (Dietzenbacher et al., 2013), and embed a country's (in this case China's) domestic-interregional IO table inside while ensuring consistency through the use of a linear programming model. Section 3 then discusses some new ideas about how to use the KWW framework to measure the position and degree of participation of a specific country's domestic regions in GVCs. We also provide an extended decomposition based on the KWW method to distinguish the domestic and international segments of GVCs in detail. In Section 4, we apply the extended KWW decomposition method to China's EMIIO table (four domestic regions and four country or country-groups, with eight sectors) to illustrate how China's domestic regions participate in GVCs. Section 5 presents our concluding remarks.

2 Embedding a specific country's domestic-interregional IO table into an existing international IO table

2.1 Framework of the EMIIO table and data configuration

For ease of explanation, we consider a two-country case where the target country has two domestic regions and two sectors for each region. The existing data that can be used to construct an EMIIO table for the target country include the following:

1) The target country's domestic-interregional IO table with separate import row and export column vectors (Table 1).

2) A closed international IO table (Table 2)[4].

3) Domestic-regional export data by sector and by country of destination and domestic-regional import data by sector and by country of origin from customs statistics.

For simplicity, just three final demand items (household consumption, government consumption, and capital formation including change of inventory) and one value added item are considered in this paper. The format of the EMIIO table is shown in Table 3. We can see that the domestic-interregional IO table of the target country (country 1), has been embedded in an international IO framework.

Table 1 Layout of a domestic interregional IO table

CMRIO		Intermediate demand				Final demand						Export outside target cuntry	Total output
		Region 1		Region 2		Region 1			Region 2				
		sector 1	sector 2	sector 1	sector 2	Household consumption	Government consumption	Capital formatino	Household consumption	Government consumption	Capital formatino		
Region 1	sector 1												
	sector 2												
Region 2	sector 1												
	sector 2												
Import outside target cuntry													
Value added													
Total input													

Table 2 Layout of an international IO table

4 "A closed international IO table" used here means that the transaction of intermediate products across all countries including the rest of the world is available".

<table>
<tr><td colspan="2" rowspan="3">WIOT</td><td colspan="4">Intermediate demand</td><td colspan="6">Final demand</td><td rowspan="3">Total output</td></tr>
<tr><td colspan="2">Country 1</td><td colspan="2">Country 2</td><td colspan="3">Country 1</td><td colspan="3">Country 2</td></tr>
<tr><td>sector 1</td><td>sector 2</td><td>sector 1</td><td>sector 2</td><td>Household consumption</td><td>Government consumption</td><td>Capital formatino</td><td>Household consumption</td><td>Government consumption</td><td>Capital formatino</td></tr>
<tr><td rowspan="2">Country 1</td><td>sector 1</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>sector 2</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td rowspan="2">Country 2</td><td>sector 1</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>sector 2</td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Value added</td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Total input</td><td></td><td></td><td></td><td></td></tr>
</table>

Table 3 layout of an EMIIO table

<table>
<tr><td colspan="2" rowspan="3">Embedded WIOT with CMRIO</td><td colspan="6">Intermediate demand</td><td colspan="9">Final demand</td><td rowspan="3">Total output</td></tr>
<tr><td colspan="2">Country 1's Region 1</td><td colspan="2">Country 1's Region 2</td><td colspan="2">Country 2</td><td colspan="3">Country 1's Region 1</td><td colspan="3">Country 1's Region 2</td><td colspan="3">Country 2</td></tr>
<tr><td>sector 1</td><td>sector 2</td><td>sector 1</td><td>sector 2</td><td>sector 1</td><td>sector 2</td><td>Household consumption</td><td>Government consumption</td><td>Capital formatino</td><td>Household consumption</td><td>Government consumption</td><td>Capital formatino</td><td>Household consumption</td><td>Government consumption</td><td>Capital formatino</td></tr>
<tr><td rowspan="2">Country 1's Region 1</td><td>sector 1</td><td colspan="4" rowspan="4">Block A1</td><td colspan="2" rowspan="4">Block C1</td><td colspan="6" rowspan="4">Block A2</td><td colspan="3" rowspan="4">Block C2</td><td></td></tr>
<tr><td>sector 2</td><td></td></tr>
<tr><td rowspan="2">Country 1's Region 2</td><td>sector 1</td><td></td></tr>
<tr><td>sector 2</td><td></td></tr>
<tr><td rowspan="2">Country 2</td><td>sector 1</td><td colspan="4" rowspan="2">Block B1</td><td></td><td></td><td colspan="6" rowspan="2">Block B2</td><td></td><td></td><td></td><td></td></tr>
<tr><td>sector 2</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Value added</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td colspan="2">Total input</td><td></td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Table 4 Variable and parameter definitions

	International IO table (known)	Domestic-interregional IO table (known)	EMIIO table ($R, S \neq Ct$) (unknown variable to be estimated)
Transaction of intermediate products	$\bar{x}_{ij}^{RS}$	xd_{ij}^{rs}	$x_{ij}^{RS} = \bar{x}_{ij}^{RS}, x_{ij}^{rS}, x_{ij}^{Rs}, x_{ij}^{rs}$
Transaction of final demand products	$\bar{y}_{ik}^{RS}$	yd_{ik}^{rs}	$y_{ik}^{RS} = \bar{y}_{ik}^{RS}, y_{ik}^{rS}, y_{ik}^{Rs}, y_{ik}^{rs}$
Import row-vector and export column-vector		MX_j^s, MY_k^s EX_i^r	
Output	$\bar{X}_i^R$	XD_i^r	$X_i^R = \bar{X}_i^R, X_i^r$
Value added	$\bar{V}_j^S$	VD_j^s	$V_j^S = \bar{V}_j^S, V_j^s$
Column-sum of final demand	$\bar{Y}_k^S$	YD_k^s	$Y_k^S = \bar{Y}_k^S, Y_k^s$

The notations used to specify IO-related variables in the paper are given in Table 4. In addition, the regional export and import data taken from customs statistics are further separated into three main categories (intermediate goods, household consumption goods, capital goods) using the Broad Economic Categories (BEC) defined by the United Nations Statistics Division. The notation used to express regional export and import data is shown below.

mx_p^{Rs}: Region s's imports in the target country from country R for intermediate good p.
$my_{p,k}^{Rs}$: Region s's imports in the target country from country R for final good p.
ex_p^{rS}: Region r's exports from the target country to country S for intermediate good p.
$ey_{p,k}^{rS}$: Region r's exports from the target country to country S for final good p.

Here, p and q represent the kind of good; k represents the two end-use categories (household consumption goods and capital goods) for final goods.

The country, region, and sector dimension configuration used in this paper is shown below.
Sector: $i, j \in \{1,2, \dots, ns\}$, where i and j represent the sector located row-wise and column-wise in an IO table respectively; ns represents the number of sectors.
Country: $R, S \in \{1, 2, \dots, Ct, \dots, G\}$, where Ct represents the number of the target country to be embedded in the international IO table; R and S represent the countries of origin and destination, respectively; and G represents the number of countries.
Domestic region: $r, s \in Ct\{1, 2, \dots, g\}$, where r and s represent the target country Ct's

domestic regions of origin and destination, respectively; and g represents the number of regions.

Final demand item: $k \in \{1,2,\dots,nf\}$, where nf represents the number of final demand items.

For simplicity, we just consider one value added item.

2.2 Determination of initial values for endogenous variables

In our example, the target country is Ct. One important principle in embedding an IO table is the use of the existing international IO table as the control total[5]. Constants in the embedded table should include x_{ij}^{RS}, y_{ik}^{RS}, X_i^R, V_j^S, and Y_k^S. For the other parts, we conduct an estimation based on both the structure of the existing IO tables and the regional import-export data from customs statistics.

The initial values for the domestic regions of the target country in an EMIIO table can be estimated using the following equations:

$$\hat{x}_{ij}^{rs} = \sum_i \sum_j \bar{x}_{ij}^{CtCt} \cdot \frac{xd_{ij}^{rs}}{\sum_r \sum_s \sum_i \sum_j xd_{ij}^{rs}}, \tag{1}$$

$$\hat{y}_{ik}^{rs} = \sum_i \sum_k \bar{y}_{ik}^{CtCt} \cdot \frac{|yd_{ik}^{rs}|}{\sum_r \sum_s \sum_i \sum_k |yd_{ik}^{rs}|}, \tag{2}$$

$$\hat{X}_i^r = \sum_i \bar{X}_i^{Ct} \cdot \frac{XD_i^r}{\sum_r \sum_i XD_i^r}, \tag{3}$$

$$\hat{V}_j^r = \sum_j \bar{V}_j^{Ct} \cdot \frac{VD_j^r}{\sum_r \sum_j VD_j^r}, \tag{4}$$

$$\hat{Y}_k^s = \sum_k \bar{Y}_k^{Ct} \cdot \frac{YD_k^r}{\sum_r \sum_k YD_k^r}. \tag{5}$$

These equations give initial values for the target country's domestic interregional trade in intermediate products (Eq. (1)'s left side: region r's product i used to produce region s's

[5] The "control total" is a widely used terminology in the IO field, especially when we need to balance a matrix in which the value for all elements in the matrix is tentatively given, but their row-sum and column-sum are not consistent to the expected (fixed) values. These fixed values for row-sum and column-sum are usually called as "control total". During the balancing procedure, these values always need to be kept constant.

product j), trade in final products (Eq. (2)'s left side: region r's product i used to fulfill region s's final demand item k), regional output (Eq. (3)), regional value added (Eq. (4)), and regional final demand (Eq. (5)) in the EMIIO table by using the structure of the existing domestic interregional IO table to distribute the target country's corresponding total value as obtained from the international IO table.

The initial values for regional imports of the target country by country of origin in the embedded IO table can be tentatively given as follows:

$$\hat{x}_{pj}^{Rs} = \left(\sum_j \bar{x}_{pj}^{RCt} \cdot \frac{mx_p^{Rs}}{\sum_s mx_p^{Rs}}\right) \cdot \frac{\sum_r xd_{pj}^{rs}}{\sum_r \sum_j xd_{pj}^{rs}}, \ (R \neq Ct, p = good) \tag{6}$$

$$\hat{x}_{qj}^{Rs} = \left(\sum_j \bar{x}_{qj}^{RCt} \cdot \frac{\sum_p mx_p^{Rs}}{\sum_s \sum_p mx_p^{Rs}}\right) \cdot \frac{\sum_r xd_{qj}^{rs}}{\sum_r \sum_j xd_{qj}^{rs}}, \ (R \neq Ct, \ q = service) \tag{6a}$$

$$\hat{y}_{pk}^{Rs} = \left(\sum_k \bar{y}_{pk}^{RCt} \cdot \frac{my_p^{Rs}}{\sum_s my_p^{Rs}}\right) \cdot \frac{\sum_r \left|yd_{pk}^{rs}\right|}{\sum_r \sum_k \left|yd_{pk}^{rs}\right|}, \ (R \neq Ct, p = good) \tag{7}$$

$$\hat{y}_{q,k}^{Rs} = \left(\sum_k \bar{y}_{qk}^{RCt} \cdot \frac{\sum_p my_p^{Rs}}{\sum_s \sum_p my_p^{Rs}}\right) \cdot \frac{\sum_r \left|yd_{qk}^{rs}\right|}{\sum_r \sum_k \left|yd_{i,}^{rs}\right|}, \ (R \neq Ct, \ q = service) \tag{7a}$$

These equations give initial values for the target country's regional imports of intermediate goods (Eq. 6) and services (Eq. 6a) and regional imports of final goods (Eq. 7) and services (Eq. 7a) by country of origin in the EMIIO table by using the structure of the existing customs regional import data and domestic interregional IO table to distribute the target country's corresponding total import value as obtained from the international IO table. It should be noted, that due to the lack of regional import statistics on services by country of origin, we use the structure of regional import statistics on goods as a proxy to estimate the initial value for services (Eqs. 6a and 7a). This means we assume that more goods are shipped from country R to region s, more services may also imported by region s from country R.

The initial values for regional exports of the target country by country of destination in the EMIIO table are first estimated using the following equations:

$$\hat{x}_{pj}^{rS} = \bar{x}_{pj}^{CtS} \cdot \frac{ex_p^{rS}}{\sum_r ex_p^{rS}}, \ (S \neq Ct, p = good), \tag{8}$$

$$\hat{x}_{qj}^{rS} = \bar{x}_{qj}^{CtS} \cdot \frac{\sum_r ex_p^{rS}}{\sum_r \sum_p ex_p^{rS}}, \ (S \neq Ct, q = service), \tag{8a}$$

$$\hat{y}^{rS}_{pk} = \bar{y}^{CtS}_{pk} \cdot \frac{ey^{rS}_{p}}{\sum_r ey^{rS}_{p}},\ \ (\mathrm{S\ s =, i = good}), \tag{9}$$

$$\hat{y}^{rS}_{qk} = \bar{y}^{CtS}_{qk} \cdot \frac{\sum_r ey^{rS}_{p}}{\sum_r \sum_p ey^{rS}_{p}},\ \ (\mathrm{S \neq Ct, q = service}). \tag{9a}$$

These equations give initial values for the target country's regional exports of intermediate goods (Eq. (8) or (8a)) and services (Eq. (8b)) and regional exports of final goods (Eq. (9) or (9a)) and services (Eq. (9b)) by country of destination in the EMIIO table by using the structure of the existing customs regional export data to distribute the target country's corresponding total export value as obtained from the international IO table. The lack of regional export statistics on services by country of destination, we again use the structure of regional export statistics on goods as a proxy to estimate the initial value for services (Eq. (8a)). This means we assume that if a region exports more goods to a foreign country, it may export more services to that same country. Another option for this estimation is to use the regional total export of services as taken from the existing domestic interregional IO table as a proxy.

2.3 Estimation methodology and reconciliation procedure

For ease of estimation, we separate the whole EMIIO table into several blocks (see Table 3). The blocks (A1 and A2) concerning the domestic-interregional transaction of the target country are estimated and balanced by using the following linear programming model. The objective function (F1) in the model is given as

$$\text{Minimize F1} = \frac{1}{2}\begin{cases} \sum_r \sum_s \sum_i \sum_j \frac{(x^{rs}_{ij} - \hat{x}^{rs}_{ij})^2}{\hat{x}^{rs}_{ij}} + \sum_r \sum_s \sum_i \sum_k \frac{(y^{rs}_{ik} - \hat{y}^{rs}_{ik})^2}{\hat{y}^{rs}_{ik}} \\ + \sum_r \sum_i \frac{(X^r_i - \hat{X}^r_i)^2}{\hat{X}^r_i} + \sum_r \sum_j \frac{\left(V^r_j - \hat{V}^r_j\right)^2}{\hat{V}^r_j} + \sum_r \sum_k \frac{(Y^r_k - \hat{Y}^r_k)^2}{\hat{Y}^r_k} \end{cases}, \tag{10}$$

subject to

$$\sum_s \sum_j x^{rs}_{ij} = \sum_j \bar{x}^{CtCt}_{ij} \cdot \frac{\sum_s \sum_j xd^{rs}_{ij}}{\sum_r \sum_s \sum_j xd^{rs}_{ij}}, \tag{11}$$

$$\sum_r \sum_i x^{rs}_{ij} = \sum_i \bar{x}^{CtCt}_{ij} \cdot \frac{\sum_r \sum_i xd^{rs}_{ij}}{\sum_s \sum_r \sum_i xd^{rs}_{ij}}, \tag{12}$$

$$\sum_r \sum_s x^{rs}_{ij} = \bar{x}^{CtCt}_{ij}, \tag{13}$$

$$\sum_i \sum_j x_{ij}^{rs} = \sum_i \sum_j \bar{x}_{ij}^{CtCt} \cdot \frac{\sum_i \sum_j xd_{ij}^{rs}}{\sum_r \sum_s \sum_i \sum_j xd_{ij}^{rs}}, \tag{14}$$

$$\sum_s \sum_k y_{ik}^{rs} = \sum_k \bar{y}_{ik}^{CtCt} \cdot \frac{\sum_s \sum_k |yd_{ik}^{rs}|}{\sum_r \sum_s \sum_k |yd_{ik}^{rs}|}, \tag{15}$$

$$\sum_r \sum_i y_{ik}^{rs} = \sum_i \bar{y}_{ik}^{CtCt} \cdot \frac{\sum_r \sum_i |yd_{ik}^{rs}|}{\sum_s \sum_r \sum_i |yd_{ik}^{rs}|}, \tag{16}$$

$$\sum_r \sum_s y_{ik}^{rs} = \bar{y}_{ik}^{CtCt}, \tag{17}$$

$$\sum_i \sum_k y_{ik}^{rs} = \sum_i \sum_k \bar{y}_{ik}^{CtCt} \cdot \frac{\sum_i \sum_k |yd_{ik}^{rs}|}{\sum_r \sum_s \sum_i \sum_k |yd_{ik}^{rs}|}, \tag{18}$$

$$\sum_r X_i^r = \bar{X}_i^{Ct}, \tag{19}$$

$$\sum_r V_j^r = \bar{V}_j^{Ct}, \tag{20}$$

$$\sum_r YE_k^r = Y_k^{Ct}. \tag{21}$$

The balancing conditions row-wise (row control totals) are given by Eq. (11) for intermediate product transactions and by Eq. (15) for final product transactions. The balancing conditions column-wise (column control totals) are given by Eq. (12) for intermediate product transactions and by Eq. (16) for final product transactions. Eqs. (13) and (17) represent the control totals for inter-industrial intermediate and final product transactions, respectively. Eqs. (14) and (18) give the control for inter-regional intermediate and final product transactions, respectively. Eqs. (19), (20), and (21) give the control for sectoral output, value added, and final demand.

Based on this minimization process, the domestic-interregional transactions can be estimated with balanced row, column, inter-regional and inter-industry relationships. The estimation results can then help us to calculate control total figures for other blocks.

The regional imports of the target country by industry and by country of origin in the embedded IO table (Blocks B1 and B2) can be estimated as follows:

$$\text{Minimize F2} = \frac{1}{2}\left[\sum_R \sum_s \sum_i \sum_j \frac{(x_{ij}^{Rs} - \hat{x}_{ij}^{Rs})^2}{\hat{x}_{ij}^{Rs}} + \sum_R \sum_s \sum_i \sum_k \frac{(y_{ik}^{Rs} - \hat{y}_{ik}^{Rs})^2}{\hat{y}_{ik}^{Rs}}\right], \tag{22}$$

subject to

$$\sum_s \sum_j x_{ij}^{Rs} = \sum_j \bar{x}_{ij}^{RCt}, \tag{23}$$

$$\sum_R \sum_i x_{ij}^{Rs} = X_j^s - V_j^s - \sum_r \sum_i x_{ij}^{rs} \quad , \tag{24}$$

$$\sum_s \sum_k y_{ik}^{Rs} = \sum_k \bar{y}_{ik}^{RCt}, \tag{25}$$

$$\sum_R \sum_i y_{ik}^{Rs} = Y_k^s - \sum_r \sum_i y_{ik}^{rs}, \tag{26}$$
$$\sum_s x_{ij}^{Rs} = \bar{x}_{ij}^{RCt}, \tag{27}$$
$$\sum_s \sum_i x_{ij}^{Rs} = \sum_i \bar{x}_{ij}^{RCt}, \tag{27a}$$
$$\sum_s y_{ik}^{Rs} = \bar{y}_{ik}^{RCt}, \tag{28}$$
$$\sum_s \sum_i y_{ik}^{Rs} = \sum_i \bar{y}_{ik}^{RCt}. \tag{28a}$$

The balancing conditions row-wise (row control totals) in terms of the target country's regional imports are given by Eq. (23) for intermediate products, and by Eq. (25) for final products. Eqs. (24) and (26) represent the balancing conditions column-wise (column control total) for the same block. Eqs. (27) and (28) give the individual cell control inside the transaction blocks for intermediate and final products, respectively. Eqs. (27a) and (28a) are the relaxed balancing conditions from Eq. (27) and (28). Note, for Eqs. (22)–(28a), $R \neq Ct$.

Using a method similar to the one above, the regional exports of the target country by sector and by country of destination in the embedded IO table can be estimated as follows:

$$\text{Minimize F3} = \frac{1}{2}\left[\sum_r \sum_S \sum_i \sum_j \frac{(x_{ij}^{rS} - \hat{x}_{ij}^{rS})^2}{\hat{x}_{ij}^{rS}} + \sum_r \sum_S \sum_i \sum_k \frac{(y_{ik}^{rS} - \hat{y}_{ik}^{rS})^2}{\hat{y}_{ik}^{rS}}\right], \tag{29}$$

subject to

$$\sum_S \sum_j x_{ij}^{rS} = \sum_S \sum_j \bar{x}_{ij}^{CtS} \cdot \frac{\sum_S ex_p^{rS}}{\sum_r \sum_S ex_p^{rS}}, \tag{30}$$
$$\sum_r \sum_i x_{ij}^{rS} = \sum_i \bar{x}_{ij}^{CtS}, \tag{31}$$
$$\sum_S \sum_k y_{ik}^{rS} = \sum_S \sum_k \bar{y}_{ik}^{CtS} \cdot \frac{\sum_S ey_p^{rS}}{\sum_r \sum_S ey_p^{rS}}, \tag{32}$$
$$\sum_r \sum_i y_{ik}^{rS} = \sum_i \bar{y}_{ik}^{CtS}, \tag{33}$$
$$\sum_r x_{ij}^{rS} = \bar{x}_{ij}^{CtS}, \tag{34}$$
$$\sum_j \sum_r x_{ij}^{rS} = \sum_j \bar{x}_{ij}^{CtS}, \tag{34a}$$
$$\sum_r y_{ik}^{rS} = \bar{y}_{ik}^{CtS}, \tag{35}$$
$$\sum_r \sum_k y_{ik}^{rS} = \sum_k \bar{y}_{ik}^{CtS}, \tag{35a}$$
$$\sum_S \sum_j x_{ij}^{rS} + \sum_S \sum_k y_{ik}^{rS} + \sum_s \sum_j x_{ij}^{rs} + \sum_s \sum_k y_{ik}^{rs} = X_i^r. \tag{36}$$

The balancing conditions row-wise (row control totals) in terms of the target country's regional exports are given by Eq. (30) for intermediate products, and by Eq. (32) for final products. Eqs. (31) and (33) represent the balancing conditions column-wise (column control total) for the same block. Eqs. (34) and (35) give the individual cell control inside the transaction blocks for intermediate and final products, respectively. Eqs. (34a) and (35a) are the relaxed balancing conditions from Eqs. (34) and (35). There is no need to give a column-balancing condition for the whole EMIIO table in terms of the target country, since according to Eqs. (12), (24), and (31), the column balance has been guaranteed (self-evidenced). However, there is no guarantee of a row balance across the whole table in terms of the target country. For this reason, we use Eq. (36) to provide the row-balancing condition. Note that for Eqs. (30)–(36), $\mathrm{S} \neq \mathrm{Ct}$.

Up to this point, we have shown how a country's domestic interregional IO table can be consistently embedded into an international IO framework by using linear programming models for different blocks, one by one. With sufficient calculation capacity for more systematic work, we can aggregate all blocks together and solve the linear programming problems at the same time. To maintain the consistency of bilateral trade balance, we must add the following constraints to the entire linear programming problem.

$$\sum_r \sum_j x_{ij}^{rS} - \sum_r \sum_j x_{ij}^{Sr} = \sum_j \bar{x}_{ij}^{CtS} - \sum_j \bar{x}_{ij}^{SCt}, \qquad (\mathrm{S} \neq \mathrm{Ct}), \tag{37}$$
$$\sum_r \sum_k y_{ik}^{rS} - \sum_r \sum_k y_{ik}^{Sr} = \sum_k \bar{y}_{ik}^{CtS} - \sum_k \bar{y}_{ik}^{SCt}, \qquad (\mathrm{S} \neq \mathrm{Ct}). \tag{38}$$

Thus, we have the following linear programming problem for estimating the EMIIO table:

$$\text{Minimize } \mathrm{F1} + \mathrm{F2} + \mathrm{F3},$$
subject to Eqs. (11)-(21), (23)-(28), (30-36), (37), (38).

3 Measuring a region's position and degree of participation in both DVCs and GVCs

3.1 Measuring bilateral Trade in Value-Added

In a closed international IO framework (for simplicity, number of countries = G, number of sector =N, number of final demand items = 1, number of value added items = 1), the world's total GDP can be given as follows:

$$GDP = diag(V) \cdot (I - A)^{-1} \cdot Y$$
$$= \mathrm{diag}(\mathrm{V}) \cdot \mathrm{B} \cdot \mathrm{Y}, \tag{39}$$

where, $GDP = (GDP^1, GDP^2, \ldots, GDP^G)^t$, $V = (V^1, V^2, \ldots, V^G)$, $A = \begin{pmatrix} A^{11} & \cdots & A^{1G} \\ \vdots & \ddots & \vdots \\ A^{G1} & \cdots & A^{GG} \end{pmatrix}$, $B = \begin{pmatrix} B^{11} & \cdots & B^{1G} \\ \vdots & \ddots & \vdots \\ B^{G1} & \cdots & B^{GG} \end{pmatrix}$, $Y = \begin{pmatrix} Y^{11} \\ \vdots \\ Y^{G1} \end{pmatrix} + \cdots + \begin{pmatrix} Y^{1G} \\ \vdots \\ Y^{GG} \end{pmatrix}$. GDP^R is a N*1 column vector representing country R's GDP by sector; V^R is a 1*N row vector representing country R's value added ratio (the share of value added in total input) by sector; A^{RS} is a N*N matrix showing intermediate input coefficients (the share of intermediate imports coming from country R in country S's total input); B^{RS} is a N*N sub-matrix of the international Leontief inverse; Y^{RS} is a N*1 column vector representing country S's final demand on products produced in country R. Following the concept proposed by Johnson and Noguera (2012), country R's value added export to country S (TiVA^{RS}) is defined as the value added induced in country R by country S's final demand:

$$(0, \ldots, \mathrm{TiVA}^{RS}, \ldots 0)^t = diag(0, \ldots, V^R, \ldots 0) \begin{pmatrix} B^{11} & \cdots & B^{1G} \\ \vdots & \ddots & \vdots \\ B^{G1} & \cdots & B^{GG} \end{pmatrix} \begin{pmatrix} Y^{1S} \\ \vdots \\ Y^{GS} \end{pmatrix}$$

$$\mathrm{TiVA}^{RS} = diag(V^R)(B^{R1}Y^{1S} + B^{R2}Y^{2S} + \cdots + B^{RG}Y^{GS}). \tag{40}$$

When applying the above TiVA concept to our EMIIO table, the region-by-region, region-by-country, country-by-region value added exports can be easily measured. This can help us understand how value added is created across both region and country's border.

In addition, given the TiVA measuring results by EMIIO, we can re-estimate the regional RCA (Revealed Comparative Advantage) indictor. The concept of RCA is mainly based on the theory of Ricardian comparative advantage. The most widely used indicator of RCA is given as follows (Béla Balassa, 1965):

$$\mathrm{RCA}_\mathrm{i}^\mathrm{R} = \frac{\mathrm{EX}_\mathrm{i}^\mathrm{R} / \sum_\mathrm{i} \mathrm{EX}_\mathrm{i}^\mathrm{R}}{\sum_\mathrm{R} \mathrm{EX}_\mathrm{i}^\mathrm{R} / \sum_\mathrm{R} \sum_\mathrm{i} \mathrm{EX}_\mathrm{i}^\mathrm{R}}, \tag{41}$$

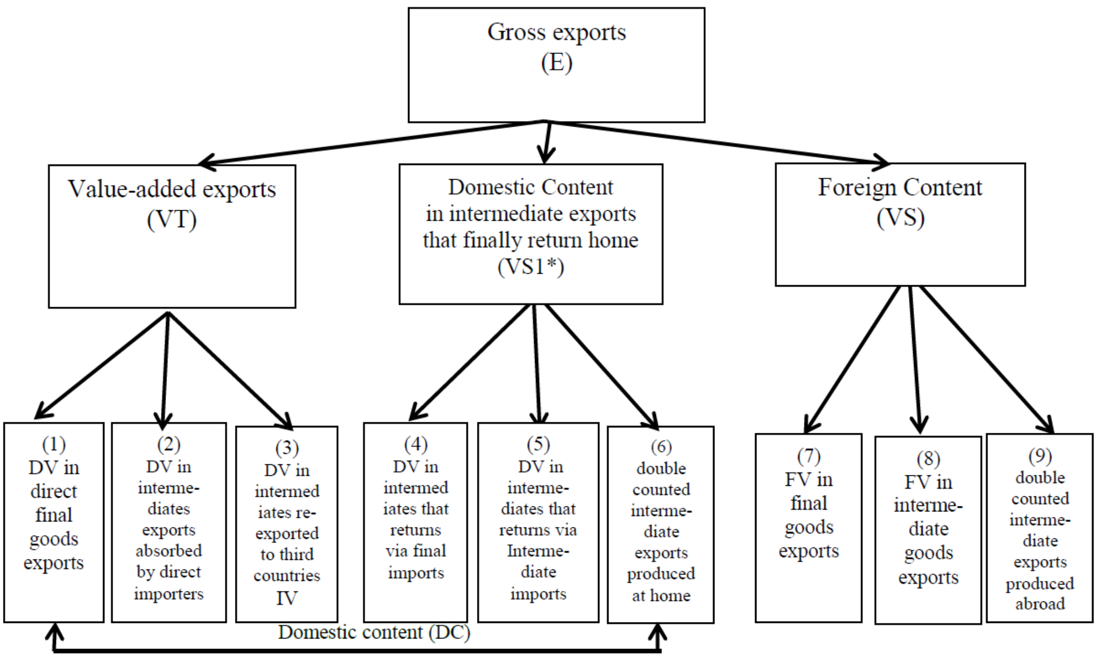
where $\mathrm{EX}_\mathrm{i}^\mathrm{R}$ represents country r's exports of product i. This indicator represents the relative advantage or disadvantage of a country in international trade for a certain class of goods or services. However, when intermediate imports are used in the production of exports, this indicator may lose its original meaning. Since a region's (i.e. region r) value added in a specific sector i as exported to other country (i.e. country S) in our EMIIO framework can be measured by $\mathrm{TiVA}_\mathrm{i}^\mathrm{rS}$, we can follow Meng et al (2012)'s idea of bilateral RCA to measure a region's comparative advantage referring to a specific country at value creation in the following way:

$$\mathrm{RCA}_{.j}^{rS} = \frac{\mathrm{TiVA}_i^{rS} / \sum_i \mathrm{TiVA}_i^{rS}}{\sum_r \mathrm{TiVA}_i^{rS} / \sum_r \sum_j \mathrm{TiVA}_i^{rS}} \tag{42}$$

3.2 Tracing value added in gross exports for both DVCs and GVCs

To illustrate the performance of a country's domestic regions in GVCs, we apply the KWW gross export decomposition method to our EMIIO system. Using this method, we can see how GVCs are fragmented and extended inside a specific country.

Figure 1 KWW gross export accounting system



Source: Koopman et al. (KWW 2014)

The KWW decomposition method is shown in Figure 1. A country's total exports in gross terms can be decomposed into three parts: value added exports (VT), domestic content in intermediate exports that ultimately return home (VS1*) and foreign content (VS). Every part at this stage can be further decomposed into three more parts. VT yields (1) domestic value added (DV) in direct final goods exports, (2) DV in intermediate exports absorbed by direct importers, and (3) DV in intermediates re-exported to third countries. VS1* is separated into

(4) DV in intermediates that return via final imports, (5) DV in intermediates that return via intermediate imports, and (6) double-counted intermediate exports produced at home. VS is further decomposed into (7) foreign value added (FV) in final goods exports, (8) FV in intermediate goods exports and (9) double-counted intermediate exports produced abroad.

When using the notation in terms of IO techniques, the KWW decomposition method in an international IO system with n sectors and G countries can be given as follows:

$$
\begin{aligned}
&uE_{S*} = VT_{S*} + VS1_{S*} + VS_{S*} \\
&= \{V_S \sum_{R\neq S}^{G} B_{SS} Y_{SR} + V_S \sum_{R\neq S}^{G} B_{SR} Y_{RR} + V_S \sum_{R\neq S}^{G} \sum_{T\neq S,R}^{G} B_{SR} Y_{RT}\} \\
&+ \{V_S \sum_{R\neq S}^{G} B_{SR} Y_{RS} + V_S \sum_{R\neq S}^{G} B_{SR} A_{RS} (I - A_{SS})^{-1} Y_{SS}\} + V_S \sum_{R\neq S}^{G} B_{SR} A_{RS} (I - A_{SS})^{-1} E_{S*} \\
&+ \{\sum_{T\neq S}^{G} \sum_{R\neq S}^{G} V_T B_{TS} Y_{TS} + \sum_{T\neq S}^{G} \sum_{R\neq S}^{G} V_T B_{TS} A_{SR} (I - A_{RR})^{-1} Y_{RR}\} + \sum_{T\neq S}^{G} V_T B_{TS} A_{SR} \sum_{R\neq S}^{G} (I - A_{RR})^{-1} E_{R*}
\end{aligned}
\tag{43}
$$

Here, u is a row vector of 1's, E_s represents country S's export by sector, and V_s is the diagonal matrix as constructed by country S's sectoral value added rate (non-diagonal elements are given by 0). B_{SR} is the submatrix of the international Leontief inverse representing the induced output by way of international production networks in country S when there is a one unit increase in final demand in country R. Y_{SR} represents country R's final demand for goods and services produced in country S. A_{RS} is the international intermediate input coefficient representing the amount, by sector, of intermediate inputs (imports) coming from country R when Country S produces one unit of output.

Since the EMIIO table includes both domestic regions and foreign countries, we must distinguish between these dimensions in our notation. For simplicity we use R, S, and T to represent countries and r, s, and t to represent domestic regions. In the EMIIO system the number of countries is given by G and the number of regions by g. When focusing on the decomposition of VT as shown above and using the notation shown for country and region, the extended decomposition incorporating a country's domestic regions into an international IO system can be given as follows:

$$VT_{s*}=\left[V_s\sum_{r\neq s}^{g}B_{ss}Y_{sr}+V_s\sum_{r\neq s}^{g}B_{sr}Y_{rr}+V_s\sum_{r\neq s}^{g}\sum_{t\neq s,r}^{g}B_{sr}Y_{rt}\right]+\left[V_s\sum_{R}^{G}\sum_{t\neq s}^{g}B_{sR}Y_{Rt}\right]$$
$$+\left[V_s\sum_{R}^{G}B_{sR}Y_{RR}+V_s\sum_{R}^{G}\sum_{T\neq R}^{G}B_{sR}Y_{RT}\right]+\left[V_s\sum_{R}^{G}B_{ss}Y_{sR}+V_s\sum_{r\neq s}^{g}\sum_{T}^{G}B_{sr}Y_{rT}\right]. \quad (44)$$

Here, VT_{s*} represents region s's value added exports and outflows. In particular, outflows mean domestic trade flows across regions. The first term on the right side of Eq. (44) represents region s's value added outflow in GVCs by domestic segment (VOD). This term includes three parts. The first represents region s's value added in direct final goods outflow (VOD1); the second shows region s's value added in intermediate outflows absorbed by direct domestic demander (VOD2), and the third is region s's value added in intermediates re-shipped to third domestic regions (VOD3). The second term on the right side of Eq. (44) represents region s's value added in intermediates re-shipped to third domestic regions by way of international segments of GVCs (VOI). The third term represents region s's value added exports by way of international segments of GVCs (VEI). This term can be further separated into two parts. The first is region s's value added in intermediates exports absorbed by direct international importers (VEI1), and the second is region s's value added in intermediates re-exported to third countries (VEI2). The final term on the right side of Eq. (44) shows region s's value added exports by way of domestic segments of GVCs (VED). The first part in this term represents region s's value added in direct final goods exports (VED1), and the second represents region s's value added in intermediates re-exported to third countries (VED2). Based on the above discussion, the decomposition of a region's value added outflow and export can be illustrated by Figure 2.

Using the extended KWW decomposition technique in an EMIIO framework, the measurement of GVCs can be divided into international and domestic segments. This framework can help us understand how, and by what routes, a country's domestic regions engage in GVCs. The method used to distinguish the domestic and international segments in the above decomposition method is based on block matrixes in the Leontief inverse used. If the notation in the block matrix involves only domestic regions, we consider the value added induced by this block matrix to be achieved by the domestic segment of GVCs. For the other block matrices in which a country notation such as R, S, or T are involved, we consider the value added induced by these block matrices to come through the international segment of GVCs.

Figure 2 Decomposition of regional value added outflow and export by GVC routes (a)

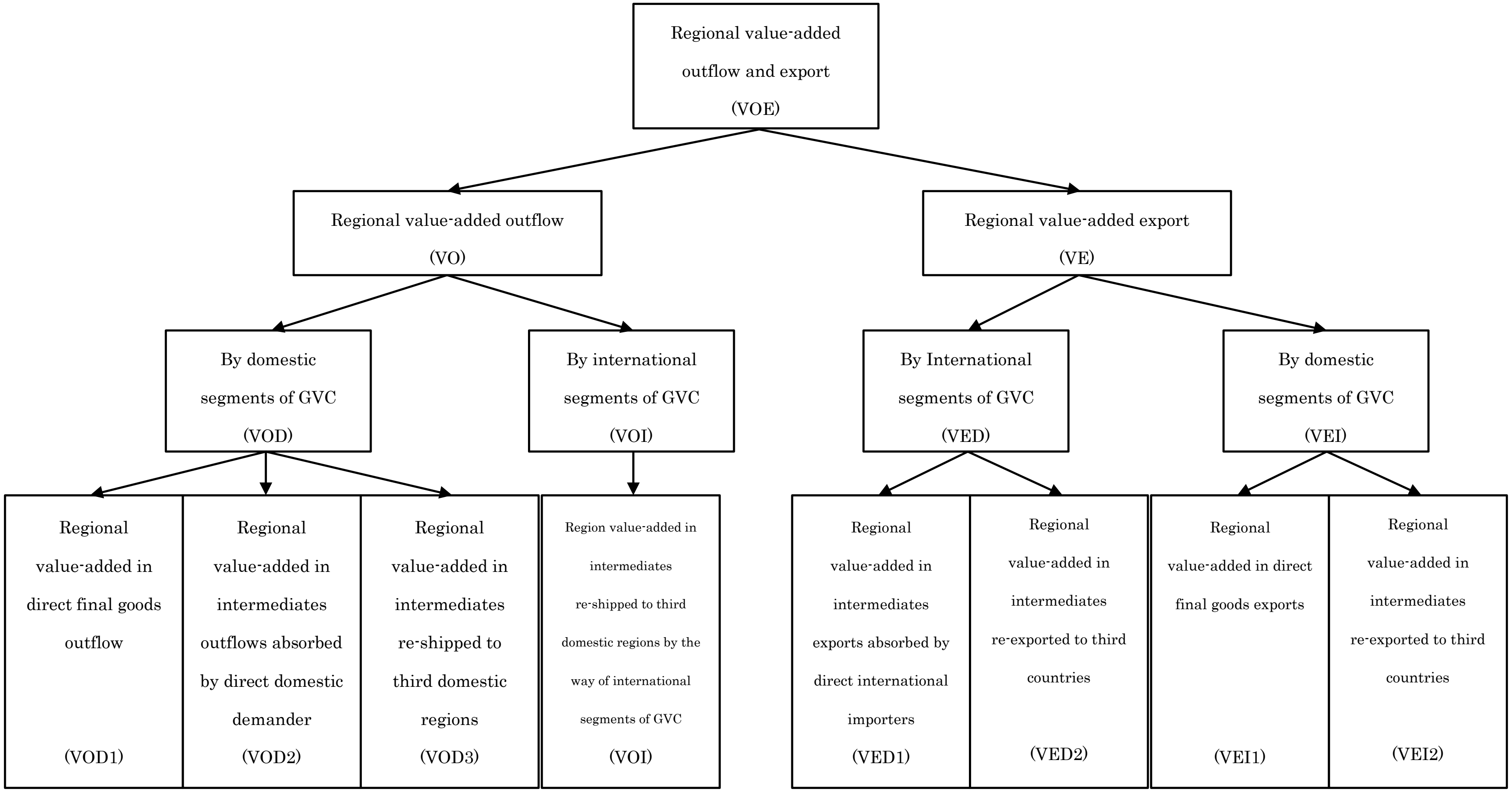
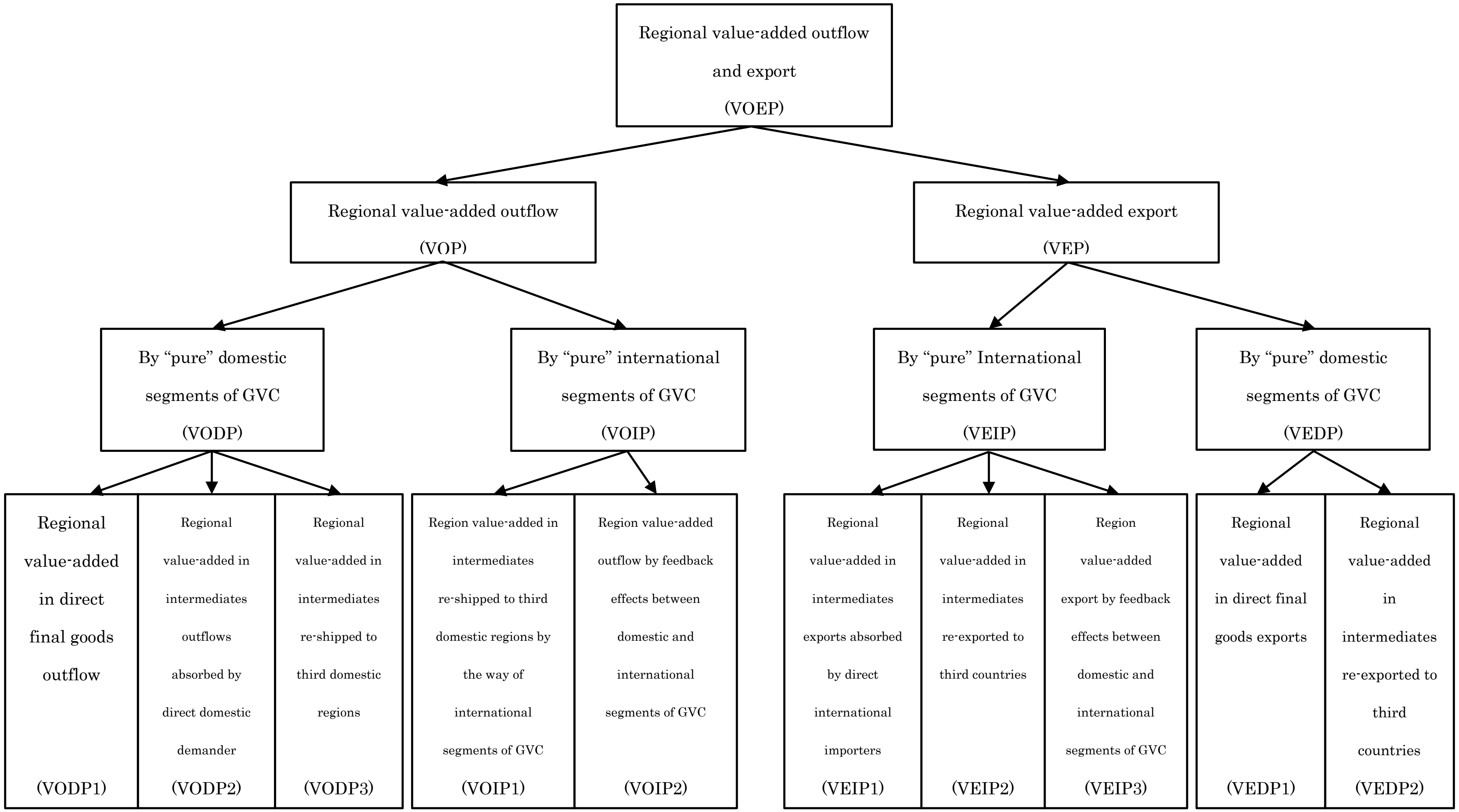


Figure 3 Decomposition of regional value added outflow and export by GVC routes (b)



However, B_{sr} may not exactly represent a pure domestic segment of GVCs, since this inter-regional block matrix (B_{sr}) is obtained from the large matrix of the Leontief inverse based on the EMIIO table. If there are no international segments in the EMIIO, we can't have B_{sr}. To more clearly define the pure domestic and pure international segments, we introduce a block matrix of B_{sr}^{d} to the above extended KWW decomposition form. This block matrix is from the large matrix of the Leontief inverse based on the domestic interregional IO table. The difference between B_{sr} and B_{sr}^{d} is the international feedback effect (see Miller and Blair, 1985) between the domestic and international segments in GVCs. Using this definition, we can rewrite Eq. (44) in the following form:

$$
\begin{aligned}
VT_{s*} = & \left[V_s \sum_{r \neq s}^{g} B_{ss}^{d} Y_{sr} + V_s \sum_{r \neq s}^{g} B_{sr}^{d} Y_{rr} + V_s \sum_{r \neq s}^{g} \sum_{t \neq s,r}^{g} B_{sr}^{d} Y_{rt} \right] \\
& + \left[V_s \sum_{r \neq s}^{g} (B_{ss} - B_{ss}^{d}) Y_{sr} + V_s \sum_{r \neq s}^{g} (B_{sr} - B_{sr}^{d}) Y_{rr} + V_s \sum_{r \neq s}^{g} \sum_{t \neq s,r}^{g} (B_{sr} - B_{sr}^{d}) Y_{rt} \right] + \left[V_s \sum_{R}^{G} \sum_{t \neq s}^{g} B_{sR} Y_{Rt} \right] \\
& + \left[V_s \sum_{R}^{G} B_{sR} Y_{RR} + V_s \sum_{R}^{G} \sum_{T \neq R}^{G} B_{sR} Y_{RT} \right] + \left[V_s \sum_{R}^{G} (B_{ss} - B_{ss}^{d}) Y_{sR} + V_s \sum_{r \neq s}^{g} \sum_{T}^{G} (B_{sr} - B_{sr}^{d}) Y_{rT} \right] \\
& + \left[V_s \sum_{R}^{G} B_{ss}^{d} Y_{sR} + V_s \sum_{r \neq s}^{g} \sum_{T}^{G} B_{sr}^{d} Y_{rT} \right]
\end{aligned}
$$

(45)

The first row of the equation shows the value added outflow achieved by the pure domestic segment of GVCs (VODP) in region s. The second row shows region s's value added outflow by way of the pure international segment of GVCs (VOIP). The third row represents region s's value added exports through the pure international segment of GVCs (VEDP), while the final row shows region s's value added exports by way of the pure domestic segment of GVCs (VEIP). Following Figure 2, the above decomposition can be illustrated in Figure 3.

4 Empirical analysis

4.1 Data

We use the following data to embed China's domestic interregional IO data into an international IO framework:

1) China's domestic multi-regional IO (CMRIO) table for 2007.
2) The World Input-Output Table (WIOT) for 2007.
3) China's customs import and export statistics at the provincial level.

The CMRIO tables are compiled by China's State Information Center. The most detailed table shows 8 domestic regions and 29 sectors. To simplify our exercise and ensure consistency between the CMRIO and other data sources, we aggregate the data from an 8-region, 29-sector table to a 4-region, 8-sector table. The CMRIO table is a non-competitive IO table with information on total imported goods and services by sector and final demand.

The WIOT is part of an international IO database developed and funded by the European Commission. This database consists of a time series of international IO data for 40 countries, 35 industries, and 59 products. In our exercise, we use the 2007 industry-by-industry[6] table as our control total. Again, for ease and simplicity in this exercise, we aggregate the WIOT from a 40-country, 35-industry table to a table with 5 country groups and 8 industries.

The country/country-group, region, and sector classifications used in the paper are as follows:

Country/country-group, region   Sector

[6] The WIOT data used in the paper is an industry-by-industry type, but the trade data used to link China's domestic interregional input-output table into WIOT is at the product level. This may cause biases to some extent, when the industry or product classification is very detailed. It's no doubt, the ideal way is to use product-by-product data for both WIOT and China' regional input-output tables, but at present this kind of data is not officially published and immediately available for us (for compiling this kind of data, we need additional and massive efforts, which has been beyond our research capacity). However, as shown in the paper, we aggregated the WIOT's 40 industries into a very rough 8-sector classification. We believe that the biases coming from the different treatment concerning industry and product can be cancelled out to some extent under this aggregation.

(1) China Northeast	(A) Agriculture
(2) China West	(B) Mining
(3) China Central	(C) Life-related products
(4) China Coast	(D) Material and processing products
(5) Japan	(E) Assembly products
(6) United States	(F) Construction
(7) EU27	(G) Utility
(8) ROW	(H) Services

For detailed information on the above classifications and the original data sources, please see Appendix 1 and 2.

The Chinese customs data cover 31 domestic provinces. We use the BEC commodity classification system to rearrange the Harmonized System eight-digit customs import and export data into three categories: intermediate products, consumption products, and capital products. This information will help to more reliably split the Chinese regional import and export data by country of origin and destination in our EMIIO framework.

4.2 Measuring China's bilateral trade balance and RCA at the regional level

By incorporating China's interregional IO information with the embedded WIOT, we can re-calculate China's bilateral trade balance in terms of TiVA. Figure 4 shows China's bilateral trade balance based on three different measurements. The blue bar shows China's bilateral trade balance in terms of traditional trade statistics (gross exports). The orange bar shows China's bilateral trade balance in terms of TiVA based on the original WIOT data in which China is treated as a whole, and the dark red bar shows China's bilateral trade balance in terms of TiVA based on the EMIIO table in which China's 4 domestic regions are linked with other countries.

We can see that China's bilateral trade balance with the world shows the same figure for all three measurements. This is by definition, since the TiVA measure does not change a country's total trade balance with the world. However, when looking at China's bilateral trade with the United States, we see that the measure based on gross exports gives an overestimation of almost 25% when compared with the TiVA measure. This conclusion is close to that of some existing studies (WTO-IDE, 2011; OECD-WTO, 2013). However, a finding of the present study is that the EMIIO-based TiVA suggests that the current international IO-based TiVA may also be an overestimation. For example, the difference between EMIIO and WIOT when estimating the China-U.S. trade balance is 3.2%, while China's trade balances with the ROW and Japan are 4.9% and 38.7%, respectively. The large difference for Japan is partly due to the small absolute level of the China-Japan bilateral trade balance. In addition, as explored by Koopman et al. (2008), when separating exports into normal and processing trade in China's IO table, the resulting measure of the value added export or the import content of exports differs dramatically when compared to the traditional IO-based result. Firms engaged in processing trade use more intermediate imports to produce exported goods. This heterogeneity of firms may also appear in the regional breakouts, since most firms engaged in processing trade are located in the coastal region. This may partly explain the differences we see in the bilateral trade balance between the EMIIO- and WIOT-based measurement results.

In addition, it should be noted that in our estimates China's trade balance with Japan changes from a deficit to a surplus. This suggests that using gross exports to measure bilateral trade balances may be misleading. Furthermore, when using the measure based on gross exports, China's trade surplus comes mainly from the United States, followed by the EU27 and the ROW. However, the TiVA-based measure tells a very different story. In this measure, China has a much larger trade surplus with the ROW than with the EU27.

Figure 4 China's bilateral trade balance with other countries (year: 2007)

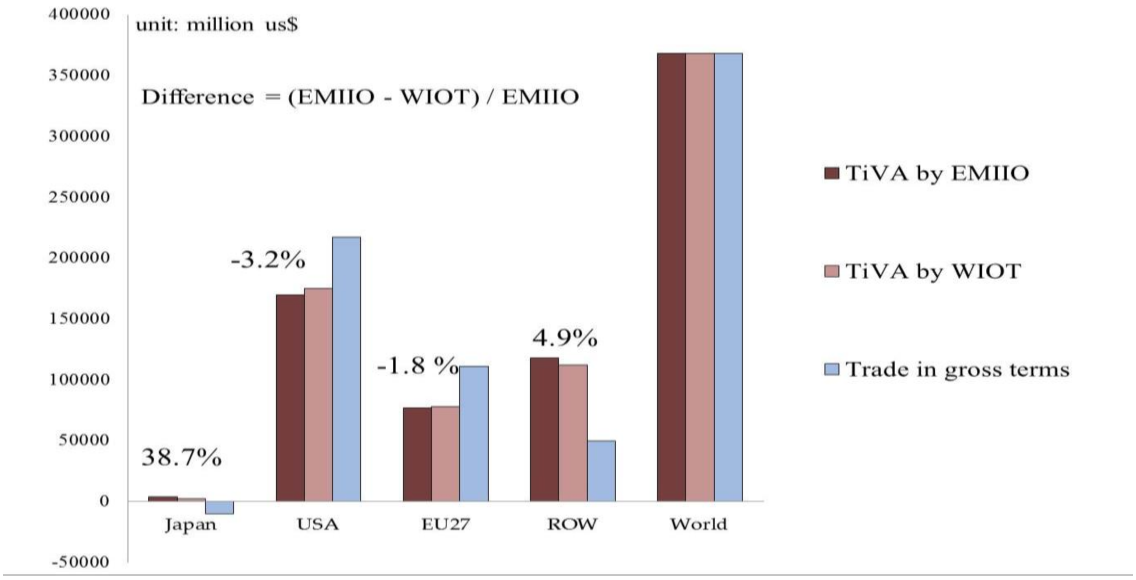


Figure 5 China's international bilateral trade balance decomposed by domestic region (year: 2007)

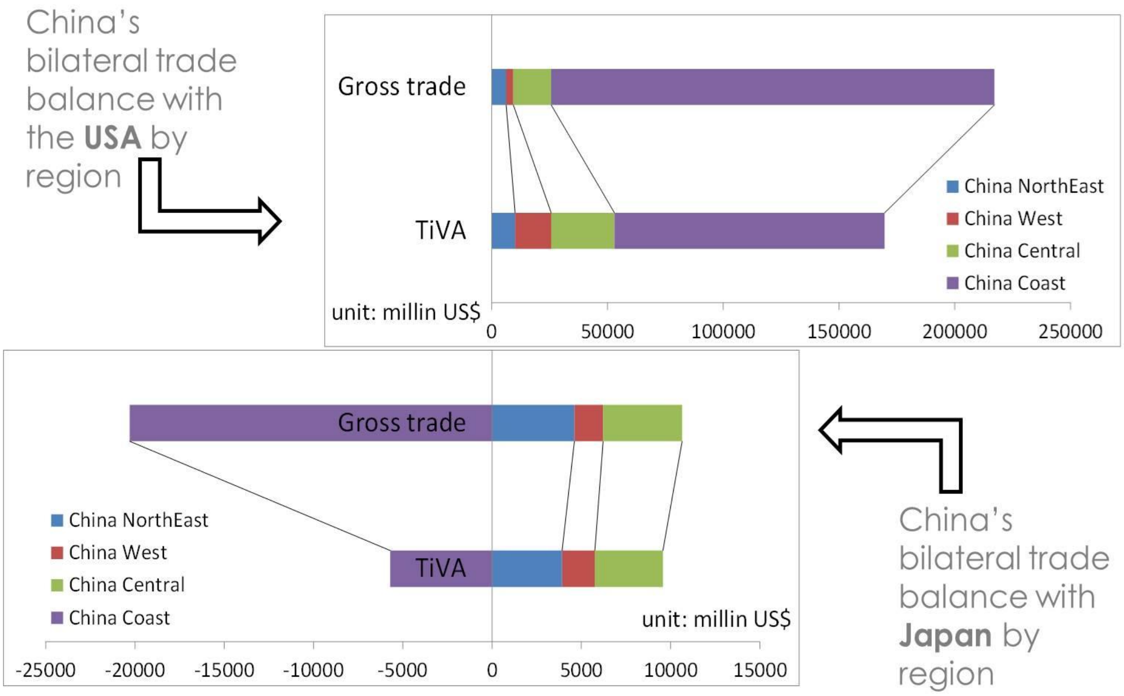


Table 5 Comparing gross export based RCA with TiVA based RCA for Chinese domestic regions referring to a specific foreign country (year: 2007)

	China NorthEast RCA based on gross exports	China NorthEast RCA based on TiVA	China West RCA based on gross exports	China West RCA based on TiVA	China Center RCA based on gross exports	China Center RCA based on TiVA	China Coast RCA based on gross exports	China Coast RCA based on TiVA
Referring to Japan								
Agriculture	2.79	1.24	4.46	1.63	1.16	1.34	0.60	0.79
Mining and quarrying	0.52	2.20	4.80	2.55	6.84	1.26	0.30	0.51
Life-related industry	0.57	0.48	0.23	0.42	0.50	0.63	1.14	1.25
Process industry	0.88	0.82	2.04	0.94	1.77	1.23	0.89	0.99
Assembly Industry	1.21	1.27	0.24	0.31	0.20	0.37	1.09	1.21
Other services	1.18	0.90	3.58	1.16	3.92	1.25	0.56	0.93
Referring to the US								
Agriculture	5.65	1.13	10.98	1.81	1.32	1.63	0.45	0.74
Mining and quarrying	4.78	3.28	7.32	2.66	1.38	1.20	0.61	0.54
Life-related industry	0.57	0.37	0.32	0.49	0.86	0.80	1.05	1.17
Process industry	1.04	0.86	1.07	0.89	1.54	1.21	0.96	0.98
Assembly Industry	0.77	0.76	0.60	0.41	0.40	0.42	1.07	1.22
Other services	3.25	1.10	4.64	1.18	4.63	1.22	0.52	0.92
Referring to EU								
Agriculture	2.62	1.06	8.35	1.75	1.15	1.52	0.42	0.74
Mining and quarrying	2.97	2.84	7.63	2.45	1.60	1.11	0.40	0.54
Life-related industry	0.58	0.39	0.37	0.49	0.72	0.78	1.09	1.20
Process industry	1.11	0.82	0.97	0.82	1.74	1.22	0.91	1.00
Assembly Industry	0.49	0.65	0.38	0.38	0.29	0.41	1.15	1.29
Other services	2.87	1.24	3.14	1.19	2.63	1.15	0.58	0.91
Referring to the ROW								
Agriculture	4.43	1.30	3.33	1.64	1.07	1.40	0.55	0.74
Mining and quarrying	1.60	2.68	3.19	2.18	3.91	1.13	0.40	0.54
Life-related industry	0.65	0.48	0.53	0.56	0.58	0.75	1.12	1.21
Process industry	1.07	0.83	0.92	0.79	1.39	1.18	0.95	1.02
Assembly Industry	0.70	0.83	0.53	0.47	0.36	0.46	1.14	1.26
Other services	1.84	1.04	2.60	1.18	2.57	1.16	0.61	0.92

In addition, following equation (), China's regional RAC indictors based on both gross export and TiVA referring to a specific foreign country can be shown in Table ?. Obviously, these two indicators represent very different ranking. For example, when consider Japan as the reference country and look at the gross export based RCA for China's Northeast region, the Agriculture sector ranks first. However, TiVA based RCA shows Mining sector has the top comparative advantage for this region. The most considerable reason is that, Northeast exports relatively more agriculture goods to Japan directly, but indirectly the mining goods embodied in other products first used as intermediate input by other domestic regions then export to Japan. Therefore, at the TiVA base, the value added export for mining goods ranks the top for the Northeast region. Clearly, the TiVA based RCA can both remove the double counting problem happened in gross export statistics and correct the true value added export which may be embodied in other region's export, then reveal the true comparative advantage in GVCs.

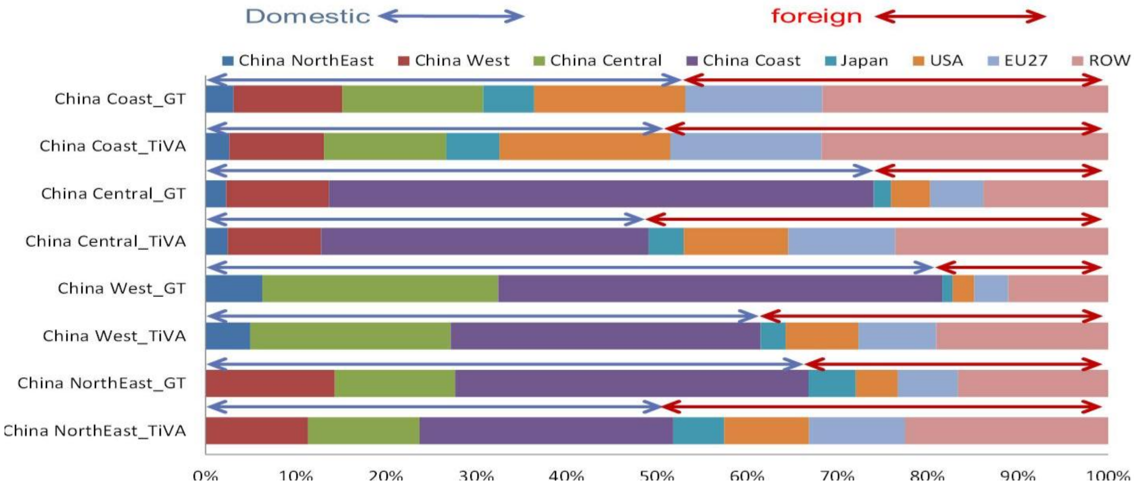
4.3 China's bilateral trade balance at the regional level

An advantage of using the EMIIO table is that a country's TiVA-based bilateral trade balance can be measured at the domestic regional level. This can provide information about which regions are the main contributors to or drivers of a country's trade balance or imbalance in GVCs.

Figure 5 shows domestic-region-level information on China's gross-export-based and TiVA-based trade balance with the United States and Japan, respectively. In the China-U.S. case, we can see that China's gross-export-based trade surplus is mainly due to the contribution of the coastal region. A similar pattern can be observed in the TiVA-based measure. However, in the TiVA-based measure, China's inner regions (China Central, West and North East) make relatively large contributions to the China-U.S. trade balance when compared to the measure based on gross exports. This implies that the contribution of the inner regions in the China-U.S. trade balance is underestimated if one relies on gross-export statistics. This finding highlights the extent to which China's inland regions indirectly engage in GVCs by providing parts and components to the coastal region's exporting firms, rather than exporting products directly to the United States. While this is not surprising in and of itself, our method allows us to estimate the extent of this phenomenon and through which mechanisms it occurs. More detailed estimates of this phenomenon will be provided in a later section.

When looking at the China-Japan case in the same figure, we see a markedly different story. The results of the gross-export-based measurement show how the coastal region's trade deficit with Japan makes the overall China-Japan trade balance a deficit. However, in the TiVA-based result we see that the coastal region's contribution is likely overestimated. In addition, there is only a small difference between the gross-export-based and TiVA-based measures for inland regions. This implies that gross exports from China's coastal regions to Japan incorporate more foreign than domestic content in their value added. This can be explained by the fact that Japan-oriented exporting firms are located primarily in coastal regions and use more intermediate inputs from coastal regions themselves or the ROW than from domestic inland regions.

Figure 6 China's regional export/outflow of value added by country/region of destination (year: 2007)



Note: GT means export in gross terms, TiVA means trade in value added.

4.4 China's regional value added export by country/region of destination

To investigate details of the bilateral structure of China's regional export of value added, we calculate the share of value added exports of a specific destination by country/region using both gross-export and TiVA measures. From Figure 6, we can confirm that there is no great difference between the gross-export-based and TiVA-based measures for the export shares of China's coastal region. However, we can see a significant difference in China's central region. This result implies that the central region does not directly export a great deal to foreign countries in terms of gross exports, but that it can participate in GVCs by providing intermediate products to coastal regions, thereby exporting more value added overseas. This finding provides support to explain the phenomenon observed in Figure 5 concerning the bilateral trade balance between China and Japan. A similar situation can be observed for other inland regions. Thus, China's coastal regions have been an important bridge linking together GVCs and China's DVCs. Through this linkage, the inland regions can take part in GVCs indirectly by providing support to the coastal regions' DVCs, even though the inland regions may not have an advantage in accessibility to overseas markets when compared with the coastal regions.

4.5 Applying KWW decomposition method to China's regional export of value added

As shown in Figure 1, domestic value added exports can be decomposed into three parts, based on the different types of international production networks. Applying this decomposition method to China's EMIIO table, the position and degree of participation of China's domestic regions in both DVCs and GVCs can be measured.

Figure 7 Decomposition of China Coast's value added exports/outflow (year: 2007)

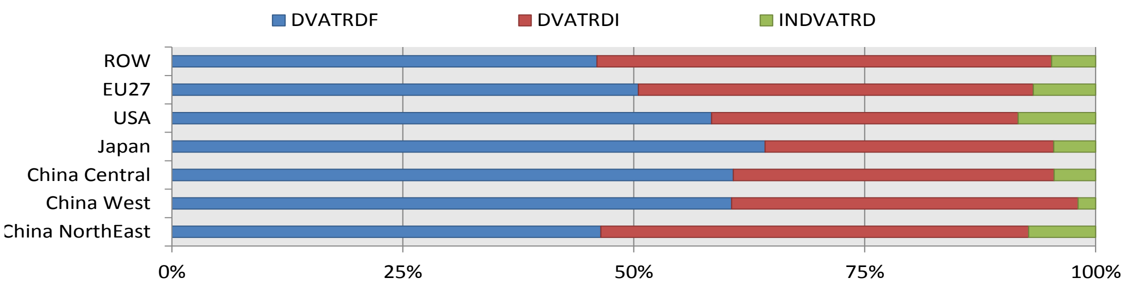
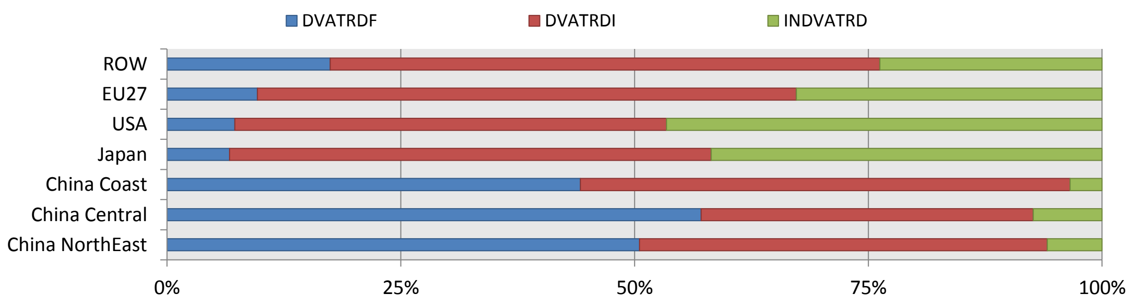


Figure 8 Decomposition of China West's value added exports/outflow (year: 2007)

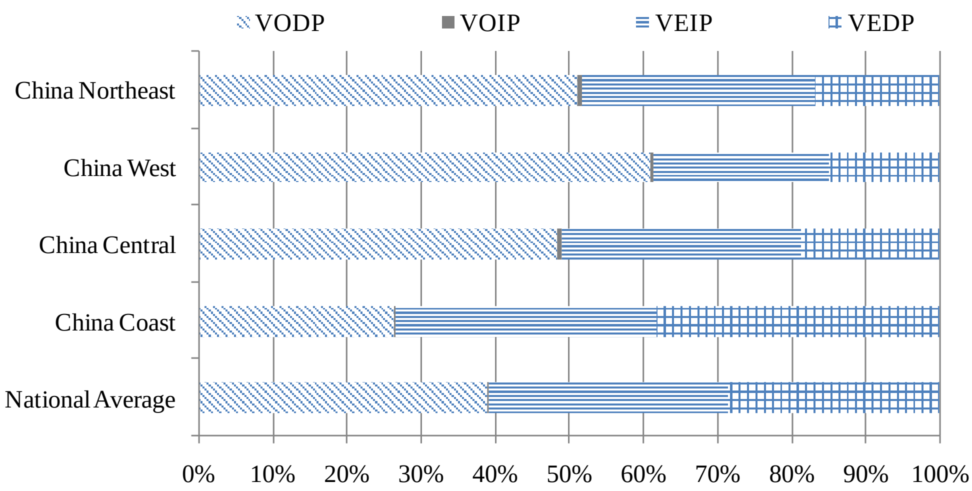


Figures 7 and 8 show the decomposition at the regional level. For simplicity, we limit ourselves to a comparison between China's coastal region and the western region. The coastal region's value added exports to Japan and the United States through its direct export of final products (DVATRDF) account for about 60% of its total value added exports. This is similar to its value added outflow to the central and western region through direct outflow of final products. A similar situation can also be seen when comparing the coastal region's DVATRDF for the EU27 and the ROW with China's Northeast region. This implies that the degree of participation of China's coastal region in GVCs is similar in magnitude to its degree of participation in DVCs.

However, when looking at the western region's DVATRDF, we can observe a large difference between foreign countries and other domestic regions. The western region's value added exports to foreign countries through the direct export of final products accounts for a small portion of its total value added exports. This is very different from its value added outflow to other domestic regions in terms of DVATRDF. However, when looking at the western region's value added export through intermediate products directly imported by its partner countries or regions (DVATRDI), there is not a great difference between foreign countries and other domestic regions. Therefore, China's western region takes part in GVCs mainly through intermediate rather than through final products. In addition, the western region's value added exports to foreign countries through re-exported intermediates by third countries and other domestic regions account for a relatively large share when compared with the coastal region. This is unsurprising, because the western region can join GVCs indirectly by providing parts and components to support the coastal region's exports to foreign countries. The western region's degree of participation in GVCs through this indirect pattern for value added exports to the United States is higher than the direct pattern of exports of final products and is similar in magnitude to its direct intermediate exports. In other words, the linkage of intermediate transactions between domestic inland regions and coastal regions provides a way for all domestic regions to be involved in GVCs.

As shown in Figure 3, regional outflows and exports of value added can be further decomposed into four parts according to the route, or segment, of GVCs. Based on calculations using China's 2007 EMIIO table, we show these four parts in Figure 9. Regional outflows of value added are mainly achieved through the domestic segment of GVCs (VODP), especially for inland regions. Because of the export-oriented nature of the China Coast region, its domestic segment accounts for just 26% of its total GVCs. Regional outflows of value added created in the international segment of GVCs (VOIP) are extremely small for all regions. For example, the value added induced in China's Guandong province when a household in Shanghai consumes final products produced in the United States should be very small. The main reasons are 1) Chinese regional demand for foreign final products is still low; 2) given the large domestic production capacity and the relatively low price of final goods, most final demand can be satisfied through domestic supply; and 3) China's regional (Guandong) demand for foreign (U.S.) products can induce foreign (U.S.) production to some extent. However, when foreign countries (U.S.) produce final goods to satisfy Chinese regional demand, they may not require intermediate goods from other Chinese regions (Shanghai). The feedback effect caused by domestic demand for foreign goods that return to other Chinese regions through the international segment of GVCs is therefore very small. However, when looking at regional value added exports, we can see that there is not a large difference between the international (VEIP) and domestic segment (VEDP) for all regions in comparison with the difference between VODP and VOIP. China's inland regions seem to export value added mainly through the international segment of GVCs, while China Coast exports value added through the domestic segment of GVCs. This is not surprising if we recall the definition of VEDP (Eq. 40). China Coast participates in GVCs mainly by providing final products directly to the world market, whereas China's inland regions join GVCs mainly by providing intermediate products to foreign suppliers. In addition, the above four parts can be further separated into more detailed descriptions (see Appendix 3).

Figure 9 China's regional outflow and export of value added by GVC routes (year: 2007)



5 Conclusion

The existing IO-based measurements for GVCs treated country as the minimum unit or target. This is sufficient only if we are studying the country-to-country relationship in GVCs. However, given the rapid deepening and spreading of globalization in terms of the reduction of various trade costs, a country's territory has become less and less relevant for firms that take part in GVCs. The difference between one country and another in terms of territory has become less important, since GVCs can be fragmented and extended not only at the international level, but also at a domestic regional level. In fact, even if a domestic region does not engage in much direct trade with foreign countries, it can nonetheless be an important supporting player of global production networks by providing parts, components, and intermediate services to more export-oriented regions.

To better understand the linkage between DVCs and GVCs, the information provided by the current international IO tables is insufficient, as these tables completely ignore the regional heterogeneity inside a target country. This paper proposed a new IO framework, the EMIIO table in which a country's domestic interregional IO table is consistently embedded into an international IO table. As an exercise, we used China's 2007 multi-regional IO table, WIOT, and China's regional customs statistics to compile the EMIIO table.

To examine the validity and usefulness of this new approach, we applied an extension of the KWW gross export decomposition method to China's EMIIO table. Most empirical results shown in the previous section helped us better understand how global production is fragmented and extended across China's domestic regions, as well as how value added is created and distributed in both domestic and international segments of GVCs.

It should be noted, however, that customs statistics at the detailed regional level provide the most important information for compiling the EMIIO table. Statistics from different sources, such as national IO tables, domestic regional IO tables and customs data, may have their own uses. However, when combining these data systematically and consistently, some information that cannot be obtained directly can be estimated. Since the performance of the EMIIO table with China's regional information has been demonstrated in this paper, future work will include the use of a similar method to embed China's national IO table with firm ownership information (state-owned firms, foreign-owned firms, normal export, processing export) into an international IO table. In addition, there are many possible applications based on the EMIIO table, such as computable general equilibrium models and environmental analyses.

Appendix 1 Sector classification

		Sector classification used in the paper							
		1	2	3	4	5	6	7	8
Code	**Sectors in China's MRIO table**	Agriculture	Mining and quarrying	Life-related industry	Process industry	Assembly Industry	Electricity, Gas and Water Supply	Construction	Other services
1	Agriculture	1							
2	Mining and quarrying		1						
3	Food products and tobacco			1					
4	Textile and garment			1					
5	Wooden products and furniture				1				
6	Pulp, paper and printing				1				
7	Chemical				1				
8	Non-metallic mineral products				1				
9	Metal products				1				
10	General mechinary					1			
11	Transport equipment					1			
12	Electric apparatus, electronic and telecommunications equipment					1			
13	Other manufacturing products			1					
14	Electricity, gas, and water supply						1		
15	Construction							1	
16	Trade and transportation								1
17	Other services								1
Code	**Sectors in WIOT**								
1	Agriculture, Hunting, Forestry and Fishing	1							
2	Mining and Quarrying		1						
3	Food, Beverages and Tobacco			1					
4	Textiles and Textile Products			1					
5	Leather, Leather and Footwear			1					
6	Wood and Products of Wood and Cork				1				
7	Pulp, Paper, Paper , Printing and Publishing				1				
8	Coke, Refined Petroleum and Nuclear Fuel				1				
9	Chemicals and Chemical Products				1				
10	Rubber and Plastics				1				
11	Other Non-Metallic Mineral				1				
12	Basic Metals and Fabricated Metal				1				
13	Machinery, Nec					1			
14	Electrical and Optical Equipment					1			
15	Transport Equipment					1			
16	Manufacturing, Nec; Recycling					1			
17	Electricity, Gas and Water Supply						1		
18	Construction							1	
19	Sale, Maintenance and Repair of Motor Vehicles and Motorcycles; Retail Sale of Fuel								1
20	Wholesale Trade and Commission Trade, Except of Motor Vehicles and Motorcycles								1
21	Retail Trade, Except of Motor Vehicles and Motorcycles; Repair of Household Goods								1
22	Hotels and Restaurants								1
23	Inland Transport								1
24	Water Transport								1
25	Air Transport								1
26	Other Supporting and Auxiliary Transport Activities; Activities of Travel Agencies								1
27	Post and Telecommunications								1
28	Financial Intermediation								1
29	Real Estate Activities								1
30	Renting of M&Eq and Other Business Activities								1
31	Public Admin and Defence; Compulsory Social Security								1
32	Education								1
33	Health and Social Work								1
34	Other Community, Social and Personal Services								1
35	Private Households with Employed Persons								1

Appendix 2 Country and Chinese domestic region classification

	Countries or country-group used in the paper				
Countries in WIOT	CHN	JPN	USA	EU	RoW
AUS					1
AUT				1	
BEL				1	
BGR				1	
BRA					1
CAN					1
CHN	1				
CYP				1	
CZE				1	
DEU				1	
DNK				1	
ESP				1	
EST				1	
FIN				1	
FRA				1	
GBR				1	
GRC				1	
HUN				1	
IDN					1
IND					1
IRL				1	
ITA				1	
JPN		1			
KOR					1
LTU				1	
LUX				1	
LVA				1	
MEX					1
MLT				1	
NLD				1	
POL				1	
PRT				1	
ROM				1	
RUS					1
SVK				1	
SVN				1	
SWE				1	
TUR					1
TWN					1
USA			1		
RoW					1

	Region classification used in the paper			
Provinces in China	NorthEast	West	Center	Coast
Beijing				1
Tianjin				1
Hebei				1
Shanxi			1	
Neimenggu		1		
Liaoning	1			
Jilin	1			
heilongjiang	1			
Shanghai				1
Jiangsu				1
Zhejiang				1
Anhui			1	
Fujian				1
Jiangxi			1	
Shangdong				1
Henan			1	
Hubei			1	
Hunan			1	
Guandong				1
Guangxi		1		
Hainan				1
Chongqing		1		
Sichuan		1		
Guizhou		1		
Yunnan		1		
Tibet		1		
Shaaxi		1		
Ganxu		1		
Qinghai		1		
Ninxia		1		
Xinjiang		1		

Appendix 3 Regional value added outflow and export by GVC routes

	(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)	(16)	(17)
	VODP1	VODP2	VODP3	**VODP=(1)+(2)+(3)**	VOIP1	VOIP2	**VOIP=(5)+(6)**	**VOP=(4)+(7)**	VEIP1	VEIP2	VEIP3	**VEIP=(9)+(10)+(11)**	VEDP1	VEDP2	**VEDP=(13)+(14)**	**VEP=(12)+(15)**	**Total=VOP+VEP =(8)+(16)**
China Northeast	32,540	35,837	5,667	**74,044**	23	769	**793**	**74,837**	40,811	4,514	350	**45,675**	13,957	10,261	**24,218**	**69,893**	**144,730**
Share	22.48%	24.76%	3.92%	**51.16%**	0.02%	0.53%	**0.55%**	**51.71%**	28.20%	3.12%	0.24%	**31.56%**	9.64%	7.09%	**16.73%**	**48.29%**	**100.00%**
China West	88,641	80,891	8,482	**178,013**	34	1,077	**1,112**	**179,125**	62,264	6,613	521	**69,398**	14,385	28,671	**43,056**	**112,454**	**291,579**
share	30.40%	27.74%	2.91%	**61.05%**	0.01%	0.37%	**0.38%**	**61.43%**	21.35%	2.27%	0.18%	**23.80%**	4.93%	9.83%	**14.77%**	**38.57%**	**100.00%**
China Central	48,028	89,241	8,908	**146,177**	52	1,496	**1,548**	**147,725**	87,659	9,339	733	**97,731**	19,566	36,476	**56,042**	**153,773**	**301,498**
Share	15.93%	29.60%	2.95%	**48.48%**	0.02%	0.50%	**0.51%**	**49.00%**	29.07%	3.10%	0.24%	**32.42%**	6.49%	12.10%	**18.59%**	**51.00%**	**100.00%**
China Coast	139,358	86,304	8,472	**234,134**	281	1,874	**2,155**	**236,289**	273,813	34,573	2,708	**311,094**	333,201	5,196	**338,397**	**649,491**	**885,781**
Share	15.73%	9.74%	0.96%	**26.43%**	0.03%	0.21%	**0.24%**	**26.68%**	30.91%	3.90%	0.31%	**35.12%**	37.62%	0.59%	**38.20%**	**73.32%**	**100.00%**
Total	**308,566**	**292,273**	**31,529**	**632,368**	**391**	**5,217**	**5,608**	**637,976**	**464,548**	**55,038**	**4,312**	**523,898**	**381,110**	**80,603**	**461,712**	**985,610**	**1,623,587**
Average	**19.01%**	**18.00%**	**1.94%**	**38.95%**	**0.02%**	**0.32%**	**0.35%**	**39.29%**	**28.61%**	**3.39%**	**0.27%**	**32.27%**	**23.47%**	**4.96%**	**28.44%**	**60.71%**	**100.00%**

Appendix 4: An example to explain why the measuring results of bilateral Trade in Value-Added between using the WIOD and EIIOM may be different.

Table A

WIOD	Intermedaite demand		Final demand		Total output
	Country 1	Country 2	Country 1	Country 2	
Country 1	100	10	65	25	200
Country 2	30	120	10	140	300
Value added	70	170			
Total input	200	300			

Table B

EMIIO		Imtermediate demand			Final demand			Total output
		Country 1		Country 2	Country 1		Country 2	
		Region 1	Region 2		Region 1	Region 2		
Country 1	Region 1	40	5	4	26	5	20	100
	Region 2	10	45	6	4	30	5	100
Country 2		20	10	120	4	6	140	300
Value added		30	40	170				
Total input		100	100	300				

Let's consider a very simple case to explain why using the EMIIO data to calculate bilateral TiVA can get different result comparing to using the WIOD data.

As shown in Table A, for simplicity, we consider that the WIOD data has 2 countries; every country just has one sector. When country 1 is separated into two regions, we can get the EMIIO table as shown in Table B.

Using the IO notation to express Table A:

International intermediate inputs in WIOD: $\mathrm{x}_{ij} = \begin{pmatrix} 100 & 10 \\ 30 & 120 \end{pmatrix}$

Total output in WIOD: $X_i = \begin{pmatrix} 200 \\ 300 \end{pmatrix}$

International input coefficients in WIOD: $\mathrm{A}_{ij} = \begin{pmatrix} 100/200 & 10/300 \\ 30/200 & 120/300 \end{pmatrix} = \begin{pmatrix} 0.500 & 0.033 \\ 0.150 & 0.400 \end{pmatrix}$

Value added in WIOD: $V_j = (70{,}170)$

Value added ratios in WIOD: $\mathrm{v}_j = \left(\frac{70}{200}, \frac{170}{300}\right) = (0.350{,}0.567)$

Final demand in WIOD: $Y_{ij} = \begin{pmatrix} 65 & 25 \\ 10 & 140 \end{pmatrix}$, in which $\begin{pmatrix} 65 \\ 10 \end{pmatrix}$ is country 1's final demand, $\begin{pmatrix} 25 \\ 140 \end{pmatrix}$ is country 2's final demand.

Exports in WIOD: $E_i = \begin{pmatrix} 10+25 \\ 30+10 \end{pmatrix} = \begin{pmatrix} 35 \\ 40 \end{pmatrix}$, in which country 1's export to country 2 equals 35, country 2's export to country 1 equals 40, then country 1's trade deficit with country 2 equals $35 - 40 = -5$.

Following Johnson and Noguera (2012)'s definition to calculate country 1's value-added export to country 2 (country 1's value added induced by country 2's final demand):

$$\mathrm{TiVA}^{1,2} = (\mathrm{v}_1, 0)\left(I - A_{ij}\right)^{-1} Y_{i2}$$

$$= (0.350,0)\begin{pmatrix} 1-0.500 & -0.033 \\ -0.150 & 1-0.400 \end{pmatrix}^{-1}\begin{pmatrix} 25 \\ 140 \end{pmatrix}$$

$$= (0.350,0)\begin{pmatrix} 2.034 & 0.113 \\ 0.508 & 1.695 \end{pmatrix}\begin{pmatrix} 25 \\ 140 \end{pmatrix}$$

$$= 23.333$$

Country 2's value-added export to country 1 (country 2's value added induced by country 1's final demand):

$$\mathrm{TiVA}^{2,1} = (0, \mathrm{v}_2)\left(I - A_{ij}\right)^{-1} Y_{i1}$$

$$= (0,0.567)\begin{pmatrix} 1-0.500 & -0.033 \\ -0.150 & 1-0.400 \end{pmatrix}^{-1}\begin{pmatrix} 65 \\ 10 \end{pmatrix}$$

$$= (0,0.567)\begin{pmatrix} 2.034 & 0.113 \\ 0.508 & 1.695 \end{pmatrix}\begin{pmatrix} 65 \\ 10 \end{pmatrix}$$

$$= 28.333$$

Therefore, country 1's trade deficit with country 2 based on TiVA equals $23.333 - 28.333 = -5$.

Using the IO notation to express Table B:

International intermediate inputs in EMIIO: $\mathrm{x}_{ij}' = \begin{pmatrix} 40 & 5 & 4 \\ 10 & 45 & 6 \\ 20 & 10 & 120 \end{pmatrix}$

Total output in WIOD: $X_i' = \begin{pmatrix} 100 \\ 100 \\ 300 \end{pmatrix}$

International input coefficients in WIOD: $\mathrm{A}_{ij}' = \begin{pmatrix} 40/100 & 5/100 & 4/300 \\ 10/100 & 45/100 & 6/300 \\ 20/100 & 10/100 & 120/300 \end{pmatrix} =$

$$\begin{pmatrix} 0.400 & 0.050 & 0.013 \\ 0.100 & 0.450 & 0.020 \\ 0.200 & 0.100 & 0.400 \end{pmatrix}$$

Value added in WIOD: $V_j' = (30,40,170)$

Value added ratios in WIOD: $\mathrm{v}_j' = \left(\frac{30}{100}, \frac{40}{100}, \frac{170}{300}\right) = (0.300,0.400,0.567)$

Final demand in WIOD: $Y_{ij}' = \begin{pmatrix} 26 & 5 & 20 \\ 4 & 30 & 5 \\ 4 & 6 & 140 \end{pmatrix}$, in which $\begin{pmatrix} 26 \\ 4 \\ 4 \end{pmatrix}$ is region 1's final demand, $\begin{pmatrix} 5 \\ 30 \\ 6 \end{pmatrix}$ is region 2's final demand, $\begin{pmatrix} 20 \\ 5 \\ 140 \end{pmatrix}$ is country 2's final demand.

Exports in WIOD: $E_i' = \begin{pmatrix} 4+20 \\ 6+5 \\ 20+10+4+6 \end{pmatrix} = \begin{pmatrix} 24 \\ 11 \\ 40 \end{pmatrix}$, in which region 1's export to country 2 equals 24; region 2's export to country 2 equals 11; then country 1's export to country 2 equals $24 + 11 = 35$; country 2's export to country 1 equals 40; country 1's trade deficit with country 2 equals $35 - 40 = -5$.

Following Johnson and Noguera (2012)'s definition to calculate region 1's value-added export to country 2 in the EMIIO framework:

$$\mathrm{TiVA}'^{1,3} = (\mathrm{v}_1', 0,0)\left(I - A_{ij}'\right)^{-1} Y_{i3}'$$

$$= (0.300,0,0)\begin{pmatrix} 1-0.400 & -0.050 & -0.013 \\ -0.100 & 1-0.450 & -0.020 \\ -0.200 & -0.100 & 1-0.400 \end{pmatrix}^{-1} \begin{pmatrix} 20 \\ 5 \\ 140 \end{pmatrix}$$

$$= (0.300,0,0)\begin{pmatrix} 1.708 & 0.163 & 0.043 \\ 0.333 & 1.861 & 0.069 \\ 0.625 & 0.365 & 1.693 \end{pmatrix} \begin{pmatrix} 20 \\ 5 \\ 140 \end{pmatrix}$$

$$= 12.318$$

Region 2's value-added export to country 2:

$$\mathrm{TiVA}'^{2,3} = (0, \mathrm{v}_2', 0)\left(I - A_{ij}'\right)^{-1} Y_{i3}'$$

$$= (0,0.400,0)\begin{pmatrix} 1-0.400 & -0.050 & -0.013 \\ -0.100 & 1-0.450 & -0.020 \\ -0.200 & -0.100 & 1-0.400 \end{pmatrix}^{-1} \begin{pmatrix} 20 \\ 5 \\ 140 \end{pmatrix}$$

$$= (0,0.400,0)\begin{pmatrix} 1.708 & 0.163 & 0.043 \\ 0.333 & 1.861 & 0.069 \\ 0.625 & 0.365 & 1.693 \end{pmatrix} \begin{pmatrix} 20 \\ 5 \\ 140 \end{pmatrix}$$

$$= 10.278$$

Country 2's value-added export to region 1:

$$\mathrm{TiVA}'^{3,1} = (0,0, \mathrm{v}_3')\left(I - A_{ij}'\right)^{-1} Y_{i1}'$$

$$= (0,0,0.567)\begin{pmatrix} 1-0.400 & -0.050 & -0.013 \\ -0.100 & 1-0.450 & -0.020 \\ -0.200 & -0.100 & 1-0.400 \end{pmatrix}^{-1}\begin{pmatrix} 26 \\ 4 \\ 4 \end{pmatrix}$$

$$= (0,0,0.567)\begin{pmatrix} 1.708 & 0.163 & 0.043 \\ 0.333 & 1.861 & 0.069 \\ 0.625 & 0.365 & 1.693 \end{pmatrix}\begin{pmatrix} 26 \\ 4 \\ 4 \end{pmatrix}$$

$$= 13.872$$

Country 2's value-added export to region 2:

$$\mathrm{TiVA}'^{3,2} = (0,0,\mathrm{v}_3{}')\left(I - A_{ij}{}'\right)^{-1} Y_{i2}{}'$$

$$= (0,0,0.567)\begin{pmatrix} 1-0.400 & -0.050 & -0.013 \\ -0.100 & 1-0.450 & -0.020 \\ -0.200 & -0.100 & 1-0.400 \end{pmatrix}^{-1}\begin{pmatrix} 5 \\ 30 \\ 6 \end{pmatrix}$$

$$= (0,0,0.567)\begin{pmatrix} 1.708 & 0.163 & 0.043 \\ 0.333 & 1.861 & 0.069 \\ 0.625 & 0.365 & 1.693 \end{pmatrix}\begin{pmatrix} 5 \\ 30 \\ 6 \end{pmatrix}$$

$$= 13.724$$

Then, based on the EMIIO model, country 1's (region 1 and region 2) export of value added to country 2 is

$\mathrm{TiVA}'^{1,3} + \mathrm{TiVA}'^{2,3} = 12.318 + 10.278 = 22.595$,

which does not equal the figure ($\mathrm{TiVA}^{1,2} = 23.333$) calculated by the WIOD model.

Similarly, country 2's export of value added to country 1 (region 1 and region 2) equals based on EMIIO is

$\mathrm{TiVA}'^{3,1} + \mathrm{TiVA}'^{3,2} = 13.872 + 13.724 = 27.595$,

which also does not equal the figure ($\mathrm{TiVA}^{2,1} = 28.333$) calculated by WIOD. However, country 1's trade deficit with country 2 based on EMIIO is

$(\mathrm{TiVA}'^{1,3} + \mathrm{TiVA}'^{2,3}) - \left(\mathrm{TiVA}'^{3,1} + \mathrm{TiVA}'^{3,2}\right) = 22.595 - 27.595 = -5$,

which equals the figure ($\mathrm{TiVA}^{1,2} - \mathrm{TiVA}^{2,1} = -5$) calculated by WIOD.

The above fact clearly shows that there is no difference in a country's trade balance with the world no matter we use gross export, WIOD or EMIIO data (this has been pointed out by Johnson and Noguera (2012)). However, when calculating bilateral Trade in Value-Added, the result depends on the data used. As shown in the above example, in the WIOD model, country 1 is treated as a single country in which the domestic regional heterogeneity in production function (regional input coefficients) is ignored. However, when using the EMIIO model, this regional heterogeneity information can be fully reflected into the calculation of Leontief inverse, which impacts on the calculation result of bilateral Trade in Value-Added.

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