2024

Trade and flow of value in global value chains

Wang, P

10.1002/ijfe.2980
International Journal of Finance & Economics
Wiley

International Journal of Finance and Economics
https://doi.org/10.1002/ijfe.2980
Received: 21 September 2022, Revised: 15 March 2024, Accepted: 31 March 2024
First published: 25 April 2024

Trade and Flow of Value in Global Value Chains

Peijie Wang[1,2] | Zhiyuan Liu[3]

[1] Plymouth Business School, University of Plymouth

[2] Economics, IÉSEG School of Management

[3] Department of International Economics and Trade, Business School, Beijing Language and Culture University

Correspondence

Peijie Wang, University of Plymouth, Plymouth, UK. peijie.wang@plymouth.ac.uk

Abstract: This paper examines flow of value that goes with trade flows in global value chains (GVCs) by a residence-based domestic value-added trade measure. Accordingly, the paper puts forward a concept of residence-based domestic value-added exports from activity domains and develops a corresponding trade measure. Export activities of G20 economies are scrutinized empirically, with which sizeable differences are observed between figures in the proposed residence-based domestic value-added trade measure and the conventional domestic value-added trade measure. This calls for new measures, to which the present study responds. It has been demonstrated that the developed G20 gains persistently in residence-based domestic value-added exports, increasing from the conventional domestic value-added exports measure. Whereas trade performance of the developing G20 deteriorates with considerably reduced surpluses in the new measure. Considerable additional value flows out from developing to developed economies in GVCs. Developed economies continue to gain from international trade as a matter of fact.

Key words: residence-based domestic value-added exports; domestic valued-added exports; TiVA; FDI

1. Introduction

Global inequality deepens beyond global imbalances subject to different interpretations. With the rise of emerging economies, gross export statistics depict a bright picture for them. It has dimmed soon through the lens of the newly framed and fairer trade measures – value-added trade. Imported intermediates are embedded in gross exports, the volume of which has become phenomenal in ever expanding global production chains (GPCs). The removal of double counted elements reduces export figures, however unevenly between countries. Foreign value-added content has now made up a substantial proportion in gross exports while globalization intensifies. Increasingly, conventional measures of international trade based on gross exports and imports distort the actual flows of goods and services in GPCs or global supply chains (GSCs), calling for new approaches. Trade in value-added (TiVA) has arrived that considers the value-added by each country in the production of goods and services that are consumed worldwide (OECD 2018, 2022).

It is nonetheless worthwhile noting that value-added trade measures have yet to discern and detach foreign value-added content in gross exports to a fuller extent. While accounting actual flows of goods and services is vaguely regarded as the same as accounting actual flows of value, GPCs are often considered to be equivalent to global value chains (GVCs) in the literature. This needs a more precise clarification for flow of value, flow of goods and services and TiVA in GVCs, which the present paper articulates. Increasingly substantial income in value-added, or wealth, generated domestically goes foreign nowadays, while foreign direct investment (FDI) intensifies. FDI income receipts and payments have grown faster than exports and imports, measured in either gross or value-added terms, which are more than proportionate. Table A1 in Appendix 1 shows the growth and development in OECD exports and FDI income with the world, utilizing OECD's TiVA databases (OECD.Stat 2021). Both gross exports and value-added exports have experienced a 7% year on year growth during the period. In contrast,

inward FDI income has on average increased 30% annually, whereas outward FDI income has grown even faster by 35% annually. Figure A1 in Appendix 1 additionally demonstrates the phenomenal growth in FDI income relative to trade and as a percentage of GDP, illuminating that FDI income has been growing much faster than trade volumes and GDP. This calls for new measures to account for this kind of value-added embedded in value-added trade that goes with trade flows in GVCs. Flow of value is thus the total value-added that travels in GVCs, including and more than the actual flows of goods and services captured by that of the newly framed value-added trade measure.

We thereby propose a residence-based domestic value-added trade approach in this study to attributing domestic value-added in gross exports to income factors. A new line of inquiry hence opens in this study, in which we take on the distributions of value-added based on activities taking place in the domestic domain that defines residence. This echoes the remark of Timmer *et al*. (2019) "Yet, value added trade statistics only capture part of the new reality of global production as they are silent on the nature of the activities that are performed in trade". Albeit we pursue different activities in contesting value added trade measures – activities by occupation in Timmer *et al*. (2019) versus activities by domain in the present study. The primary income factors are labor and capital, whereas the income of labor is wages and that of capital is earnings. On the balance of payments, these capital earnings are primarily distributed income and reinvested earnings of corporations on the primary income account (IMF 2009). The difference between GNP/GNI and GDP is equal to the difference of primary income receivable from non-residents and primary income payable to non-residents - net income from abroad (IMF 2009). Income for labor is compensation of employees and income for financial resources includes dividends, reinvested earnings and interest, which US BEA classifies them as investment income, including income from direct investment, portfolio investment and other investment. On the export side, US investment income in 2022, at $1,210,399, accounts for

more than 99 percent of its primary income receipts of $1,217,478; while compensation of employees is merely $7,079, statistics of US International Transactions show (BEA 2023). The residence-based measure accounts for investment income but not compensation of employees, the latter is practically negligible as well. Residence and citizenship or nationality are distinguishable in pollical rights and legal status but often blurred in employment activities, the statistics of the latter are practically based on residence than nationality. Indeed, IMF (2009) defines that "Cross-border employees include seasonal or other short-term workers (less than one year) and border workers who are residents of one economy and work in another economy". To a similar extent, Upward *et al*. (2013) decompose the skill-and technology-intensity contributions in value added exports, contributing to further slice up value added exports in global value chains, from which our approaches also differ. It will be shown that the concept and method of our residence-based domestic value-added trade reflect the value-added principle to a fuller extent. They are consistent with the definition of exports and imports, which associate the financial account activity with the current account consequences on the balance of payments. Meanwhile, they stick to the principle of activity and residence in addressing the different and pertinent income flow to and from abroad, in contrast to nationality-based approaches that lead to GNP. Our measures attribute value-added by income factors objectively and fairly in recognition of activity that generates value.

The present study stipulates residence-based domestic value-added content in gross exports first, and then examine and compare exports in various measures. The rest of the paper proceeds as follows. The next section reviews the developments in research on trade in value-added that breaks down gross exports into domestic value-added content and foreign value-added content for better measuring actual trade flows. The framework for residence-based domestic value-added exports is presented and discussed in the next section, taking in activity domains. An empirical inquiry follows, which contrasts figures in residence-based domestic

value-added exports and other trade measures and between emerging economies and developed countries. The last section summarizes this study.

2. Trade in value-added versus flow of value in global value chains

The concept and measures of value-added trade arise from the increasingly evident fact that gross export statistics take in imported intermediates, which should be accounted and removed to reflect correctly the actual domestic value-added in gross exports. Input-output models have been widely adopted to trace down cross-border value-added in GPCs. Value-added trade measures remove double counting in gross trade. They take off the imported intermediates in GPCs or GSCs) that distort and obscure actual trade flows. For example, the construct of TiVA considers the value-added by each country in the production of goods and the provision of services that are consumed worldwide. These trade measures have manifested a string of prior studies. Hummels *et al*. (2001) are among the first to investigate vertical specialization in international trade, involving imported goods that are used as inputs to produce a country's export goods. They have noted "the increasing interconnectedness of production processes in a vertical trading chain that stretches across many countries, with each country specializing in particular stages of a good's production sequence" (ibid). Puzzled by the striking growth in the trade share of output in the world economy since World War II, Yi (2003) calibrates a two-country dynamic Ricardian trade model that offers a resolution. His simulation results suggest that the growth of world trade can be explained by vertical specialization that propagates the effects of tariff reductions. Official trade statistics measured in gross terms are inconsistent with the System of National Accounts (SNA[1]) accounting standards, point out Koopman *et al.* (2014). The problem arises as gross trade includes both intermediate inputs and final products,

[1] United Nations, European Commission, International Monetary Fund, Organisation for Economic Co-operation and Development, and World Bank (2009), *System of National Accounts 2008*, New York

while GDP counts only final products that are value-added. As a result, gross trade data "double count the value of intermediate goods that cross international borders more than once" (ibid). Specifically, Antrà and Chor (2013) model and analyze the organization of GVCs. As Johnson and Noguera (2012) point out that "trade in intermediate inputs accounts for as much as two thirds of international trade", who probe accounting for intermediates in the global input-output framework. The increasing amount or portion of intermediate goods involved in international trade, as well as the increasing number of times for intermediate goods to cross international borders, makes gross trade data increasingly misrepresent the actual activity and value-added in trade. Value-added trade measures have been called upon.

Utilizing World Input-Output Database (WIOD), Los *et al*. (2015) derive the distribution of value-added with 40 countries and 14 manufacturing product groups. They find that foreign value-added from outside the region is increasing much faster than that from inside the region since 1995 in almost all product chains, suggesting the process becomes more global than regional. It has been observed as the current trend that domestic content in exports has been declining over the last three decades in most countries. Johnson and Noguera (2017) have characterized changes in gross versus value-added trade over four decades between 1970 and 2009. "Value-added exports are falling relative to gross exports, implying that double counting in gross trade data is more pervasive today than in the past", they conclude (ibid). The four decades have witnessed an accelerated declining ratio of value-added to gross exports, by about 10 percentage points on average over four decades. The ratio of value-added to gross exports has been found to have fallen by almost 20 percentage points within manufacturing but has risen outside manufacturing. Significantly, fast-growing countries have seen larger declines on average. Seung (2022) decomposes the global value added of fish production for ten selected countries generated along GVC, i.e., portions the foreign value-added share and domestic value-added share in these ten countries. It is found that the share of the global value added

from fish production accounted for by foreign countries increases significantly between 2000 and 2014. In other words, the domestic value-added share has fallen sharply, which would transpire to a fallen domestic value-added share in exports, thereby consistent with the findings of Johnson and Noguera (2017) who have observed "an accelerated declining ratio of value-added to gross exports, by about 10 percentage points on average over four decades." Timmer *et al*. (2014) work to "slice up the global value chain" and trace the value added by all labor and capital that is directly and indirectly needed for the production of final manufacturing goods. They have told a broad story in which firms in mature economies relocate their unskilled-labor-intensive production activities to lower-wage countries, while keeping strategic and high-value-added functions concentrated at home where the skilled workers and intangible capital they need are available. Digging deeper into the matter, Timmer *et al*. (2019) make a case for a new generation of statistics that tracks what they refer to as "functional specialisation" in trade, which is conceived of as a set of tasks carried out by a particular occupational class of workers. "To this end we develop in this article a new, third, generation of trade statistics that not only traces value-added but also characterises the activity a country performs in its exports" (ibid). To a similar extent, Upward *et al*. (2013) decompose the skill- and technology-intensity contributions in value-added exports, contributing to further slice up value-added exports in GVCs. Modeling with China's input-output tables for 2007 and 2010 along with 2008 census data for both manufacturing and service firms, the study of Tang *et al*. (2020) tracks inter-sector transactions between different types of firms in a domestic economy where firms are categorized into four groups based on their ownership and size. Using data for 24 emerging market economies over the period 1995-2011, Jangam and Rath (2021) examine whether the participation in GVCs enhance the economic upgrading in the form of improvements in domestic value-added exports. Their findings reveal that both forward and backward participation in GVCs have significantly improved the domestic value-added in

exports for emerging market economies, with labor productivity and capital intensity mediating the economic upgrading process in these countries.

Efforts have been made to capture flow of value in GVCs precisely. "[T]here is no single, accepted standard among GVC scholars over how to conceptualize, define, and measure value or its distribution between firms", Dallas (2015) remarks. Whereas "economists and sociologists are engaged in … conceptualizing and measuring the division of 'value' in borderless production systems, which entails the development of new methods for estimating the portion of 'value-added' in a country's gross trade values" (ibid). Specifically, albeit more than a decade ago, Duménil and Lévy (2004) have remarked: "Since World War II, [the US] remained consistently a country of large direct investment abroad". As a result, "[b]oth direct investment abroad and portfolio investment contribute extensively to the remuneration of capital in [the US], under the form of interest, dividends and profits of transnational corporations retained abroad". Adopting a Marxian approach to inspecting the recent transformations of GVCs, Starosta (2010) shows, expectedly, that the Marxian 'law of value' can provide solid foundations for the comprehension of the constitution and dynamics of GVCs. Articulating the distribution of surplus value in GVCs as for example between Apple and Foxconn, Quentin and Campling (2018) contest "… a lead firm may use intellectual property over brands, design and/or technology to pass on costs and risk and to capture surplus value from firms desperately competing to supply components and services to their outsourced global production network". The global interpersonal inequality measure of Lakner and Milanovic (2016) treats persons the same irrespective of their country of residence, which captures between-country inequality and within-country inequality. Specifically, Wang and Lee (2023) find that the impact of FDI deteriorates income distribution in countries with high country risk, but FDI improves income distribution under the condition of low country risk. They also suggest that the effect of FDI on income inequality may vary over the sample period for certain

countries. Remarking against a commonly referred phenomenon, Wade (2004) cautions a scenario of declining world income inequality based on China's continued fast growth. "But whether or not China does substantially upgrade the value-added of its exports, it will continue to cause a widening of income inequality between many other developing countries and the West", he continues. Pertinent to the issues examined in the present paper, "China still relies heavily on foreign investment and imported components for its higher-tech manufactured output" (ibid). This pattern of global inequality does not seem to have changed much a decade on. Agreeable to the above analysis, Warner *et al*. (2014) show a steady decline in global inequality over the years 1993 to 2005. However, this pattern of declining inequality is ascribed to China and India. "… excluding China leads to greater world inequality. The effect of excluding India is less clear cut" (ibid). Atkinson and Brandolini (2010) point out astutely that "these impressive rates of growth have not yet translated into absolute increases in income comparable with those of developed economies, given the very different levels of GDP per capita. Thus, world income gaps must have risen". Our study aims to corroborate these views by scrutinizing flow of value in GVCs.

The above review demonstrates that concerns in the use of official gross trade figures, which distorts actual trade flows and activity, have been noted and dealt with in the last two decades. Value-added trade measures have been developed and acknowledged as the objective and improved measures for recording actual trade activity, guiding effectual trade policy formulation. Nonetheless, certain amounts of domestic value-added content in gross exports can be foreign capital earnings. Consequently, domestically generated value is not equal to domestically created wealth. The distributions of value added attributed by income factors have yet to be addressed, to reflect that value added comes from factors of production that generate factor income. The conventional GVC literature seems to be quiet in this respect and in engaging with political economy research. Thus, the present paper develops a concept and

analytical framework for assessing residence-based domestic value-added exports to connect the two strands of literature. It contributes to advancing the understanding and communication in this important interdisciplinary area of international political economy and international economics.

3. Flow of value in global value chains – residence-based domestic value-added attributions in trade

The concept and method of our residence-based domestic value-added trade, reflecting the value-added principle to a fuller extent, is consistent with the definition of exports and imports, wherein two primary elements are FDI income payments and receipts. The current account of the balance of payments includes the balance of trade and income accounts. FDI income receipts capture the value of exports of capital. Whereas FDI income payments are the payment to imported capital embedded in domestic production. This share of foreign content in gross exports should be removed, in the same way as imported intermediates embedded in gross exports are removed by value-added trade measures. Consider value-added, the production measure of GDP, in conjunction with various measures of GDP. The production measure of GDP is a value-added approach, derived as the value of output less intermediates consumed in production. In the income measure of GDP, value added consists of compensation of employees, gross operating surplus and mixed income[2]. Net operating surplus is derived by subtracting consumption of fixed capital from gross operating surplus. It is a profits-like measure of returns to corporations, some of which involve foreign ownership in the form of FDI by foreign multinational enterprises (MNEs).

[2] More exactly, the production measure of GDP is derived as the value of output less intermediate consumption plus any taxes less subsidies on products not already included in the value of output. The expenditure measure of GDP is derived as the sum of expenditure on final consumption plus gross capital formation plus exports less imports. The income measure of (GDP is derived as compensation of employees plus gross operating surplus plus gross mixed incomes plus taxes less subsidies on both production and imports.

The present study thus decomposes domestic value-added content into payments to primary factors – labor and capital or income of factors, i.e., wages and earnings – with the proposed approach and analytical framework. It augments value-added trade measures by apportioning foreign and domestic contributions to value added by factors of income. It is a residence-based approach. Wages paid to workers who are residents[3] in the domestic country are the domestic factor whether they work at domestic or foreign owned enterprises. Whereas earnings attributed to foreign capital and domestic capital are differentiated. The former is the income earned by non-residents appearing in the current account alongside imports on the balance of payments, while the latter is for the residents in the domestic country. Thus, the approach differs from the studies that split exports according to firm ownership, such as Ma *et al*. (2015) and Tang *et al.* (2020) who study the distribution of value-added exports between foreign owned firms and domestic firms. Their latter category is further divided into state-owned, large private, and small and medium-sized private enterprises. In Tang *et al*. (2020) and similar studies, wages paid to workers employed by foreign owned firms are considered foreign owned, with their contribution to value-added exports being categorized into the group of foreign owned firms. Moreover, a firm is classified as foreign above the FDI ownership threshold. Its ownership however consists of a mixture of foreign and domestic capital, which is bundled together to be foreign. It is clearly set apart in our approach, because our approach is built on activity taking place in the domestic domain that defines residence wherein all activities and only activities in the domain are covered. The world production system in the form of the input-output model can be expressed in block matrix operations:

$$\boldsymbol{X} = \boldsymbol{AX} + \boldsymbol{Y} \tag{1}$$

[3] We include all workers or employees as residents, whether they are permanent or temporary. The latter is conventionally classified as non-resident employees (IMF 2009). Therefore, compensation of employees in the primary income account and remittances in the secondary income account will not be added or deducted, which lead to GNP, in our measures that are purely domestic activity based. We adjust for capital earnings by FDI of non-resident owners.

where $\boldsymbol{X}$ is an $(N \times M) \times N$ vector of world gross output, $\boldsymbol{A}$ is an $(N \times M) \times (N \times M)$ matrix of technical coefficients for the world input-output table that capture direct requirements, and $\boldsymbol{Y}$ is an $(N \times M) \times N$ vector of world final demand, for an N country M sector system. We keep the derivation of the conventional domestic value-added content in gross exports simple to focus on our new measures. Equation (1) can be expanded to a version of country model as:

$$\begin{bmatrix} \boldsymbol{X_1} \\ \vdots \\ \boldsymbol{X_N} \end{bmatrix}_{(N\times M)\times N} = \begin{bmatrix} \boldsymbol{A_{11}} & \cdots & \boldsymbol{A_{1N}} \\ \vdots & \ddots & \vdots \\ \boldsymbol{A_{N1}} & \cdots & \boldsymbol{A_{NN}} \end{bmatrix}_{(N\times M)\times(N\times M)} \begin{bmatrix} \boldsymbol{X_1} \\ \vdots \\ \boldsymbol{X_N} \end{bmatrix}_{(N\times M)\times N} + \begin{bmatrix} \boldsymbol{Y_1} \\ \vdots \\ \boldsymbol{Y_N} \end{bmatrix}_{(N\times M)\times N} \quad (1')$$

Numbers of rows and columns of matrixes are indicated on the right bottom corner. Each country comprises M sectors and its gross output and final demand in each sector may be consumed in all N countries[4]:

$$\boldsymbol{X_i} = \begin{bmatrix} x_{i1,1} & \cdots & x_{i1,N} \\ \vdots & \ddots & \vdots \\ x_{iM,1} & \cdots & x_{iM,N} \end{bmatrix}_{M\times N}$$

$$\boldsymbol{Y_i} = \begin{bmatrix} y_{i1,1} & \cdots & y_{i1,N} \\ \vdots & \ddots & \vdots \\ y_{iM,1} & \cdots & y_{iM,N} \end{bmatrix}_{M\times N}$$

Elements of $\boldsymbol{A_{ij}}$, $a_{ik,jh}$, shows the direct requirements of inputs from industry k in country i for the production of one unit of output for final demand by industry h in country j:

$$\boldsymbol{A_{ij}} = \begin{bmatrix} a_{i1,j1} & \cdots & a_{i1,jM} \\ \vdots & \ddots & \vdots \\ a_{iM,j1} & \cdots & a_{iM,jM} \end{bmatrix}_{M\times M}$$

It is the direct requirements of inputs from industry k for the production of one unit of output for final demand by industry h in the same, domestic country when $j = i$. We need the Leontief inverse and the value-added vector for the derivation of domestic value-added content. The

[4] Usual presentation of gross output, unlike final demand, is $\boldsymbol{X_i} = \begin{bmatrix} x_{i1} \\ \vdots \\ x_{iM} \end{bmatrix}_{M\times 1}$ without destination countries 1, … N being separated, which shows the lack of interest in intermediate consumption across countries in the past and value-added trade measures arise to count it.

Leontief inverse is an $(N \times M) \times (N \times M)$ matrix of output multipliers or total requirements coefficients:

$$\boldsymbol{X} = (\boldsymbol{I} - \boldsymbol{A})^{-1}\boldsymbol{Y} = \boldsymbol{B}\boldsymbol{Y} \tag{2}$$

where $\boldsymbol{B} = (\boldsymbol{I} - \boldsymbol{A})^{-1}$ is an $(N \times M) \times (N \times M)$ matrix of output multipliers or total requirements coefficients, known as the Leontief Inverse:

Similarly, equation (2) can be expended to country model:

$$\begin{bmatrix} \boldsymbol{X_1} \\ \boldsymbol{X_2} \\ \vdots \\ \boldsymbol{X_N} \end{bmatrix}_{(N\times M)\times 1} = \begin{bmatrix} \boldsymbol{B_{11}} & \cdots & \boldsymbol{B_{1N}} \\ \vdots & \ddots & \vdots \\ \boldsymbol{B_{N1}} & \cdots & \boldsymbol{B_{NN}} \end{bmatrix}_{(N\times M)\times(N\times M)} \begin{bmatrix} \boldsymbol{Y_1} \\ \boldsymbol{Y_2} \\ \vdots \\ \boldsymbol{Y_N} \end{bmatrix}_{(N\times M)\times 1} \tag{2'}$$

Elements of $\boldsymbol{B_{ij}}$, $b_{ik,jh}$, shows the direct and indirect, or the total requirements of inputs from industry k in country i for the production of one unit of output for final demand by industry h in country j:

$$\boldsymbol{B_{ij}} = \begin{bmatrix} b_{i1,j1} & \cdots & b_{i1,jM} \\ \vdots & \ddots & \vdots \\ b_{iM,j1} & \cdots & b_{iM,jM} \end{bmatrix}_{M\times M}$$

Similarly, it is the total requirements of inputs from industry k for the production of one unit of output for final demand by industry h in the same, domestic country when $j = i$. The world value-added ratio matrix is presented as:

$$\boldsymbol{V} = \begin{bmatrix} \boldsymbol{V_1} & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & \boldsymbol{V_N} \end{bmatrix}_{(N\times M)\times(N\times M)}$$

with the country value-added ratio matrix being:

$$\boldsymbol{V_i} = \begin{bmatrix} v_{i1} & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & v_{iM} \end{bmatrix}_{M\times M}$$

The value-added ratio of sector k in country i is a secular number between zero and one:

$$v_{ik} = 1 - \sum_{j=1}^{n}\left(a_{j1,ik} - \cdots a_{jM,ik}\right)$$

The domestic value-added share matrix of country i is the product of its value-added ratio matrix and its Leontief inverse:

$$\boldsymbol{dva_i = V_i B_{ii}} = \begin{bmatrix} v_{i1} & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & v_{iM} \end{bmatrix}_{M\times M} \begin{bmatrix} b_{i1,i1} & \cdots & b_{i1,iM} \\ \vdots & \ddots & \vdots \\ b_{iM,i1} & \cdots & b_{iM,iM} \end{bmatrix}_{M\times M}$$

$$= \begin{bmatrix} v_{i1}b_{i1,i1} & \cdots & v_{i1}b_{i1,iM} \\ \vdots & \ddots & \vdots \\ v_{iM}b_{iM,i1} & \cdots & v_{i1}b_{iM,iM} \end{bmatrix}_{M\times M} \quad (3)$$

The sum of elements in each column is the domestic share of value added in the corresponding sector of the country:

$$dva_{ik} = \sum_{h=1}^{M} v_{i1}b_{ih,ik}$$

Then the foreign value-added share matrix of country j in country i is the product of its value-added ratio matrix and its Leontief inverse – the total requirements of inputs from the country for the production of one unit of output for final demand by country i:

$$\boldsymbol{fva_{ji} = va_{ji} = V_j B_{ji}} = \begin{bmatrix} v_{j1} & \cdots & 0 \\ \vdots & \ddots & \vdots \\ 0 & \cdots & v_{jM} \end{bmatrix}_{M\times M} \begin{bmatrix} b_{j1,i1} & \cdots & b_{j1,iM} \\ \vdots & \ddots & \vdots \\ b_{jM,i1} & \cdots & b_{jM,iM} \end{bmatrix}_{M\times M}$$

$$= \begin{bmatrix} v_{j1}b_{i1,i1} & \cdots & v_{j1}b_{i1,iM} \\ \vdots & \ddots & \vdots \\ v_{jM}b_{iM,i1} & \cdots & v_{j1}b_{iM,iM} \end{bmatrix}_{M\times M} \quad (4)$$

The sum of elements in each column is the foreign share of value added in the corresponding sector from country j. Total foreign value-added share in country i is:

$$\boldsymbol{fva_i} = \sum_{j=1}^{N} \boldsymbol{fva_{ji}} \quad (5)$$

The sum of elements in each column is the foreign share of value added in the corresponding sector of the country:

$$fva_{ik} = \sum_{j\neq i, j=1}^{N} \sum_{h=1}^{M} v_{j1}b_{jh,ik}$$

"Because all value added must be either domestic or foreign, the sum along each column is unity" as Koopman *et al.* (2014) have deliberated, $dva_{ik} + fva_{ik}, k = 1, \ldots M$. Table A2 in

Appendix 1 demonstrates this attribute. Values in each column sum to one; cells in green denote domestic value-added shares/elements while cells in blue represent foreign value-added shares/elements. Table A3 in Appendix 1 provides a value-added representation of N country M sector system for input-output relationships in global value chains, revealing where value added is derived and intermediate goods are consumed. $Z_{ik,jh} = a_{ik,jh}X_{jh}$, where X_{jh} is the gross output from sector h in country j, $Z_{ik,jh}$ is the flow of goods from producing sector k in country i to the purchasing sector h in country j. $a_{ik,jh}$ is the input coefficient, the elements in $\boldsymbol{A}$, an $(N \times M) \times (N \times M)$ matrix of technical coefficients for the world input-output table that capture direct requirements in equation (1). Meanwhile, domestic value-added content in gross exports from sector k in country i to country j is derived as follows:

$$DVAE_{ik,j} = dva_{ik}GE_{ik,j} \tag{6}$$

where $GE_{ik,j}$ is the gross exports from sector k in country i to country j.

With our approach, domestic value-added volume is further decomposed into residence-based domestic value-added and investment income payments to MNEs:

$$DVA_{ik} = RDVA_{ik} + IIP_{ik} \tag{7}$$

where $RDVA_{ik}$ is residence-based domestic value-added volume of sector k in country i, and IIP_{ik} is the investment income payments (IIP) of sector k in country i to MNEs. Removing the investment payment from the domestic valued added leads to the residence-based domestic value-added. Note that not all of IIP_{ik} has an effect on value-added exports. By means of Koopman *et al*. (2014), country 1' domestic value added is $va_{11} + va_{12} = v_1x_{11} + v_1x_{12}$, where $va_{11} = v_1x_{11}$ is the domestic value added that is ultimately absorbed at home, and $va_{12} = v_1x_{12}$ is the domestic value added that is ultimately absorbed abroad, i.e., domestic value-added exports from country 1 to country 2. We consider the effect of investment income payments on $va_{12} = v_1x_{12}$ as domestic value-added exports. The OECD FDI database provides FDI income payments by partner and industry and FDI income receipts by partner

and industry for OECD countries. They are denoted as investment income. Specifically, denote $IIP_{ik,j}$ the IIP of sector k in country i to MNEs of country j, some of which can be exported. This share of foreign content in gross exports should be removed, in the same way as imported intermediates embedded in gross exports are removed by value-added trade measures. Meanwhile, $IIR_{ik,j}$ the investment income receipts (IIR) of sector k in country i from its MNEs in country j, captures the value of exports of capital from sector k of country i to country j. Taking into account the contributions of investment income payments and investment income receipts, the residence-based domestic value-added content in gross exports of sector k in country i to country j is derived as follows:

$$RDVAE_{ik,j} = DVAE_{ik,j}\left(1 - \frac{IIP_{ik}}{DVA_{ik}}\right) + IIR_{ik,j} \quad (8)$$

We use Example 1 in Koopman *et al.* (2014) to demonstrate how our proposed residence-based value-added export measures work and differ (*cf.* pp 473-475). Now let us assume that z units of CHN's imported intermediate goods are financed by USA's capital or the imported capital from USA in its production and USA uses all its own capital. With $v_1 = 0.5$, the production associated with this capital has generated z units of value added and 2z units of gross output. f out of these z units of "domestic value added" in CHN go to USA in the form of CHN's IIP. The other (z-f) units are divided between compensation of employees and consumption of fixed capital plus taxes and minus subsidies, which remain or have been expended in CHN. The total expenses associated with this production are z + (z-f) = 2z-f units of FDI capital of USA. The (net income) return to this FDI is $\frac{f}{2z-f}$. Let us extend the case with our analytical framework and formulae and assuming the following: $IIP = 5$ and $IIR = 0$ for CHN, whereas $IIP = 0$ and $IIR = 5$ for USA. CHN's 5 units of IIP go to USA, reducing CHN's residence based domestic value-added exports by 2.33 units: $RDVAE_{CHN,USA} = DVAE_{CHN,USA}\left(1 - \frac{IIP_{CHN,USA}}{DVA_{CHN}}\right) + IIR_{CHN,USA} = 46.67\left(1 - \frac{5}{100}\right) + 0 = 44.33$. USA's 5 units

of IIR paid by or received from CHN increase USA's residence based domestic value-added exports by 5 units: $RDVAE_{USA,CHN} = DVAE_{USA,CHN}\left(1 - \frac{IIP_{USA,USA}}{DVA_{USA}}\right) + IIR_{USA,CHN} = 46.67\left(1 - \frac{0}{100}\right) + 5 = 51.67$. Appendix 2 summarizes the input-output relationships in Example 1 of Koopman *et al.* (2014) and embeds FDI in the input-output system of this case.

The residence-based domestic value-added content in gross exports from sector k of country i to the world is derived by aggregating the residence based domestic content in exports from sector k of country i to countries $j \neq i \; \forall j \in C$ across all countries of the world. The residence-based domestic content in *gross* exports of country i to country j can be derived by aggregating the domestic content in exports from sector k of country i to country $j \; \forall k \in S$ across all sectors of country i. We will scrutinize flow of value in GVCs between developed and developing economies through the lens of residence-based domestic value-added trade in the next section, in contrast with figures gross trade and value-added trade measures. value-added that goes with trade flows in GVCs.

4. Landscape of global imbalances and global unfairness through the domain lenses

Global imbalances do not quite stand when they are thought of exports versus imports globally as the jargon implies. Global exports and imports are always balanced out, at any time, all times. There can be considerable imbalances for an individual country or countries and between two or several countries though. Meanwhile, global inequality and unfairness hidden in global imbalances are realities and do not seem to recede any sooner, which can be more severe in more precise and objective measures. To reveal the degree and scale of global inequality and unfairness in global imbalances, OECD's TiVA databases (OECD.Stat 2021a) and FDI statistics (OECD.Stat 2021b) are utilized for empirical analysis in this study. FDI income payments by industry and FDI income receipts by industry are available for most OECD countries. For non-OECD countries, data can be obtained on FDI income payments and receipts

by OECD partner country only. OECD FDI datasets provide directional FDI statistics on reporting countries to partner countries for FDI financial flows, FDI positions and FDI income. Inward FDI income is the IIP of the reporting country paid to MNEs of the partner country. Outward FDI income is the IIR of MNEs of the reporting country received from the partner country. FDI income total comprises of income on equity and interests from income on debt, the former in turn includes dividends and reinvested earnings. Foreign investors are not all MNEs. We use FDI income total for the empirical work in this study. In many cases this is the only statistics available on OECD.Stat. This however might be mitigated by the fact that FDI income on equity is by far the largest. For instance, German outward FDI income total in 2012 is $15,624 million; its income on equity is $15,204 million, consisting of $9,184 million of dividends and $6,020 million of reinvested earnings; interests from income on debt are as small as $421 million. Statistics on the latest OECD TiVA indicators 2021 edition are available up to 2018.

These databases enable the analysis of residence-based domestic value-added exports between, and for, OECD and non-OECD countries for aggregate activities, which are examined in this study. Specifically, G20 countries are chosen for empirical investigations. The G20 accounts for three quarters of global exports and 60 percent of the world population, and produces 80 percent of global GDP (G20 Indonesia 2022). The G20 includes 11 OECD countries and eight non-OECD countries. On the other hand, there are 11 developing countries and eight developed economies in the G20. G20 OECD countries are Australia, Canada, France, Germany, Italy, Japan, Mexico, South Korea, Turkey, United Kingdom, United States. Among them, Mexico and Turkey are classified as developing economies while South Korea was regarded as a high-income developing economy until as recently as June 10, 2021 and then was made a developed economy later in that year (UNCTADSTAT 2021). The G20 non-OECD countries consist of Argentina, Brazil, China, India, Indonesia, Russia, Saudi Arabia, South

Africa. We adopt the line of developed G20 and developing G20 countries in this study for empirical investigations. South Korea in the whole sample period is a developing economy; so it is on the side of the developing G20 in the study.

Table 1 – Table 4 present the analysis of G20 cases, with Table 1 and Table 3 for the developed G20 and Table 2 and Table 4 for the developing G20, where the developed G20 and the developing G20 are the exclusive trading partners to each other. OECD.Stat FDI statistics have non-zero entries since 2005[5], while its trade data starting in 1995. So, there are 24 annual observations between 1995 and 2018 inclusive for gross exports and domestic value-added exports; and 14 annual observations between 2005 and 2018 inclusive for FDI income payments and receipts to match the trade data time range, though FDI statistics are also available until 2020. Table 1 and Table 2 report absolute figures for the developed G20 and the developing G20 respectively, including gross exports GE, domestic value-added exports DVAE, FDI income payments IIP, FDI income receipts IIR, and residence-based domestic value-added exports RDVAE, plus the domestic value-added exports to gross exports ratio DVAE/GE. Whereas Table 3 and Table 4 cover net exports in the three trade measures and net exports as a percentage of exports in the three measures for the developed G20 and the developing G20 respectively. Covered in Table 3 and Table 4 are net exports in the three trade measures, and net exports as a percentage of exports in the three measures. They are net gross exports NGE and NGE as a percentage of GE, %GE; net domestic value-added content in gross exports NDVAE and NDVAE as a percentage of DVAE, %DVAE; and net residence-based domestic value-added exports NRDVAE and NRDVAE as a percentage of RDVAE, %RDVAE. The corresponding net export figures in Table 2 and Table 4 mirror each other as the developed G20 and the developing G20 are the exclusive trading partners to each

[5] FDI statistics since 2005 remain patchy. Significantly, there are missing US and UK FDI income statistics in various years in the period (https://stats.oecd.org/Index.aspx?QueryId=86003#). We retrieved and used data on BEA and ONS accordingly.

other. While the ratios differ slightly as the base of the ratio, i.e., GE, DVAE or RDVAE, differs for the developed and developing G20. They differ when viewed from the perspective of the developed G20 and of the developing G20.

{Table 1}

{Table 2}

Figures in Table 1 and Table 2 indicate that there is a general trend that the share of domestic value-added content in gross exports falls slightly over time for all G20 countries, with the share for the developed G20 being slightly higher than that for the developing G20 nonetheless. Herewith the domestic value-added content in gross exports drops more in the developing G20 than the developed G20. The flows of investment income demonstrate that the investment income payments from the developing G20 to the developed G20 are considerably larger than the investment income receipts of the developing G20 from the developed G20. The former is more than 10 times of the latter in all years. This reflects the spatialization of GVC linkages across the North-South divide argued by Mahutga (2012). "When these chains cross the North-South divide, the model process will be FDI" (ibid). Neumayer and Spess (2005) find that a higher number of bilateral investment treaties, with which developing countries accept restrictions on their sovereignty, raises the FDI that flows to a developing country. This asymmetric pattern in investment income flows leads to the consequence that the residence-based domestic value-added content in gross exports, RDVAE, decreases from the domestic value-added content in gross exports, DVAE, for the developing G20. In contrast, RDVAE increases from DVAE for the developed G20.

{Table 3}

{Table 4}

Table 3 and Table 4 reveal and contract the disparities in trade performance between the developed G20 and the developing G20, in moving from one export measure to another in net terms and percentages. These disparities in trade performance are displayed by the right panel of Figure 1 and Figure 2 for the developed G20 and the developing G20 respectively. It can be observed that year 2006 is a turning point when the trade deficits of the developed G20 and the trade surpluses of the developing G20 peaked. In the first few years since 2005 when the statistics of residence-based domestic value-added exports become available, the figures in the two measures of domestic value-added exports and residence-based domestic value-added exports are not much different. The differences have gradually widened and become considerable – the latter has dropped to below the half of the former on average in the latest three years. This changing pattern shows the significance of the new measure proposed in the present paper on the one hand. It reflects the changing landscape of international trade between developed and developing economies in the last two decades on the other hand, which is exhibited by all the three trade measures. Trade imbalances are nonetheless exaggerated by the gross trade measures, which are reduced and corrected somewhat by the domestic value-added trade measure, and are further reduced and corrected precisely by the residence-based domestic value-added trade measure. Trade performance is much less optimistic for developing countries, viewed in the lens of residence-based domestic value-added trade and compounded by the development trend. On the other hand, international trade of developed economies, associated with its benefits, is actually robust, improving and in good shape.

{Figure 1}

{Figure 2}

The G20 seems to be in a celebrated trade balance among them at the beginning of the sample period from 1995 to 1997, measured in gross exports. The trade deficits of developed G20 countries have since deteriorated but alleviated from the run-up to the financial crisis. The worst figure is a trade deficit of 36.49% in net gross exports in 2006 from the perspective of developed G20, which indicates the best year for the developing G20 with a trade surplus of 26.73% in net gross exports. However, the developed G20 actually enjoy modest trade surpluses in most of the 1990s, measured by domestic value-added content in gross exports. The trade deficit drops to 27.61% in terms of net domestic value-added exports from a trade deficit of 36.49% in net gross exports in 2006 for the developed G20. In contrast, the trade surplus falls to 21.64% in net domestic value-added exports from a trade surplus of 26.73% in net gross exports in 2006 for the developing G20. The trade deficit of the developed G20 to the developing G20 is persistently reduced, moving from gross exports to domestic value-added exports, and then to residence-based domestic value-added exports on the one hand. The trade deficit of the developed G20 to the developing G20 in all three trade measures keeps falling since 2006 on the other hand. The statistics for the developing G20 mirror the above fact and pattern that the trade surplus of the developing G20 from the developed G20 is persistently reduced over time since 2006 and moving from gross exports to domestic value-added exports, and then to residence-based domestic value-added exports. In the latest three years the trade surplus of the developing G20 has been reduced to a single digit in net domestic value-added exports; and the surplus is as small as 2.42%, 0.20% and 3.51% in net residence-based domestic value-added exports. So is the trade deficit of the developed G20. That is, trade has almost become balanced between the developed G20 and the developing G20 recently.

{Figure 3}

The last three columns of Table 3 summarize the gains made by the developed G20, moving from gross exports GE to domestic value-added exports DVAE, from domestic value-added exports DVAE to residence-based domestic value-added exports RDVAE, and overall gains from gross exports GE to residence-based domestic value-added exports RDVAE. Likewise, the last three columns of Table 4 mirror that in Table 3 and summarize the deterioration in trade performance by the developing G20. These changing patterns are exhibited in the left panel of Figure 1 and Figure 2 for the developed G20 and the developing G20 respectively. It can be observed, as acknowledged in prior studies, that the trade performance of the developed G20 improves when measured in domestic value-added exports rather than gross exports while the developing G20 suffers. The trade performance improves by an average of eight percent between 1995 and 2018 and over six percent between 2005 and 2018. The new findings in this study show additional gains by the developed G20 when measured in residence-based domestic value-added exports and the overall gains have always been in excess of 10 percent and are on average nearly 13 percent between 2005 and 2018. Corresponding to the right panel of Figure 1 and Figure 2, the improvement made in moving from the domestic value-added trade measure to the residence-based domestic value-added trade measure is in the similar size as the improvement made in from moving the gross trade measure to the domestic value-added trade measure. It is larger in some years, e.g., 2007, 2015 and smaller in some other years, e.g., 2006, 2016. On average the former is slightly greater at 6.56 percent than the latter of 6.31 percent. This observation implies that the domestic value-added trade measure has become increasingly less accountable, the newly available FDI income data having revealed. Likewise, trade performance of the developing G20 suffer additional deterioration in the domestic value-added trade measure and the further deterioration becomes increasingly considerable. Figure 3 further shows the proportions, i.e., the relative contributions to the deterioration suffered by the developing G20 in panel (a) and the

improvements made by the developed G20 in panel (b), moving from one trade measure to another. It is clear that the conventional domestic value-added trade measure has become increasingly inefficient in correcting distortions in trade flows since the last decade in accounting for value of flow that travels with trade, which calls for new trade measures that account for all flow of value that goes with trade flows in GVCs. This study is an attempt that responds to the call.

5. Summary

This paper puts forward a concept of residence-based domestic value-added exports from activity domains to contemplate flow of value that goes with trade flows in GVCs. The subsequently formulated measure covers exclusively all activities and only activities taking place in the domain under consideration. This residence-based approach to value-added exports offers inclusive outlooks and estimates of trading flows between countries and around the world. It takes in the additional contributing factors, i.e., foreign capital and investment income, to value in trade and GVCs. Applying the new measure empirically, disparities between developing and developed economies become evident.

One empirical observation in this study suggests that the conventional domestic value-added trade measure works well in earlier years. It removes double counting in gross trade and thus the value goes with such double counting. It however has not accounted for all flow of value in GVCs. As time goes by and globalization intensifies, it has become clear that the conventional domestic value-added trade measure has become increasingly less accountable, and it is inefficient in correcting distortions in trade flows since the last decade. This confirms the need for new trade measures that are not only justified by theory but also account for emerging practical issues in the real world.

It has been observed that the developed G20 gains in residence-based domestic value-added exports, scrutinizing G20 economies with the new-fangled measure. The claim that trade deficits of developed economies vis-à-vis developing countries have been widened is overstated. They have been narrowing in the last decade even in terms of gross exports, much so in value-added trade measures. In fact, trade has almost become balanced between the developed G20 and the developing G20 in terms of residence-based domestic value-added exports in the latest three years. The trade deficit of the developed G20 to the developing G20 is persistently reduced, moving from gross exports to domestic value-added exports, and then to residence-based domestic value-added exports.

Moreover, the trade deficit of the developed G20 to the developing G20 in all three trade measures keeps falling since 2006. The mirrored statistics for the developing G20 show that the trade surplus of the developing G20 from the developed G20 is persistently reduced over time since 2006 and moving from gross exports to domestic value-added exports, and then to residence-based domestic value-added exports. Consistent with the prior research, the trade performance of the developed G20 has found to improve when measured in domestic value-added exports rather than gross exports. Significantly, the new findings in this study show additional gains by the developed G20 when measured in residence-based domestic value-added exports and the overall gains are considerable. Meanwhile the trade performance of the developing G20 deteriorates as trading partners.

The present paper contributes to discern and detach foreign value-added content in gross exports to a fuller extent, reflecting the value-added principle to a fuller extent. The paper scrutinizes flow of value that goes with trade flows in GVCs rather than trade flows themselves that have been amended to be actual with value-added trade measures by removing double counting or correcting distortions in gross trade data. Proposing a residence-based value-added approach and sticking to the principle of activity and residence, flow of value is the total value-added that travels in GVCs, including and more than the actual flows of goods and services captured by

that of the newly framed value-added trade measure. It has significant welfare implications as to who gain more and the extent of gains between different groups of economies in GVCs, as the results and findings in the paper have demonstrated.

The paper is limited to the OECD perspective, though non-OECD economies are studied as counterparts of OECD economies, given the availability of OECD TiVA databases on OECD.Stat, currently the most comprehensive data sources for value-added trade. Together with TiVA and under the theme of "Globalisation" on OECD.Stat, FDI financial flow, stock and income statistics are available, enabling this study. Albeit certain data, especially investment income with individual non-OECD economies or groups of economies, can be incomplete. Therefore, FDI data availability, in particular for disaggregate FDI income, is on the agenda, which OECD and other international organizations are further developing. On the agenda primarily in the near future is to extend the residence-based value-added measures to research beyond trade, on whole economies and/or particular industries of interest. Given that not the entire but part of FDI income flows with trade, so its effects and welfare implications are not limited to trade in the name of residence-based value-added trade, it impacts a wide range of economic and social life considerably. Future research can also include portfolio investment income to evaluate its part in cross-border flows of value.

Acknowledgements

The authors would like to thank the IJFE Team, five anonymous reviewers and the Associate Editor for their insightful and constructive comments and suggestions, which considerably helped improve the manuscript. In particular, the authors thank Reviewer 1 for the very comprehensive, constructive, critical and helpful comments and Reviewer 3 for the very knowledgeable comments and intense expertise to detail. Their knowledge, insights and

critique have helped improve the manuscript greatly. Any remaining errors are our own responsibilities.

References

Antràs, Pol, and Davin Chor (2013), Organizing the Global Value Chain, *Econometrica* 81 (6): 2127-2204.

Atkinson, Anthony B., and Andrea Brandolini (2010), On Analyzing the World Distribution of Income, *World Bank Economic Review* 24(1): 1-37.

BEA (2023), *U.S. International Transactions in Primary Income*, Bureau of Economic Analysis, Washington, D.C.

Dallas, Mark P. (2015) 'Governed' Trade: Global Value Chains, Firms, and the Heterogeneity of Trade in an Era of Fragmented Production, *Review of International Political Economy* 22(5): 875-909.

Duménil, Gérard, and Dominique Lévy (2004) The Economics of US Imperialism at the Turn of the 21st Century, *Review of International Political Economy* 11(4): 657-676.

G20 Indonesia (2022), *G20 Presidency of Indonesia*, Jakarta, Indonesia.

Hummels, David, Jun Ishii, and Kei-Mu Yi (2001), The Nature and Growth of Vertical Specialization in World Trade, *Journal of International Economics* 54(1): 75-96.

IMF (2009), *Balance of Payments and International Investment Position Manual 6th edition* (*BMP6*), International Monetary Fund, Washington, D.C.

Jangam, Bhushan Praveen, and Badri Narayan Rath (2021), Does Global Value Chain Participation Enhance Domestic Value-Added in Exports? Evidence From Emerging Market Economies, *International Journal of Finance and Economics* 26(2): 1681-1694.

Johnson, Robert C., and Guillermo Noguera (2012), Accounting for Intermediates: Production Sharing and Trade in Value Added, *Journal of International Economics* 86 (2): 224-236.

Johnson, Robert C., and Guillermo Noguera (2017), A Portrait of Trade in Value-Added over Four Decades, *Review of Economics and Statistics* 99(5): 896-911.

Koopman, Robert, Zhi Wang, and Shang-Jin We (2014), Tracing Value-Added and Double Counting in Gross Exports, *American Economic Review* 104(2): 459-494.

Lakner, Christoph, and Branko Milanovic (2016), Global Income Distribution: From the Fall of the Berlin Wall to the Great Recession, *World Bank Economic Review* 30(2): 203-232.

Los, Bart, Marcel P. Timmer, and Gaaitzen J. de Vries (2015), How Global Are Global Value Chains? A New Approach to Measure International Fragmentation, *Journal of Regional Science* 55(1): 66-92.

Ma, Hong, Zhi Wang, and Kunfu Zhu (2015), Domestic Content in China's Exports and its Distribution by Firm Ownership, *Journal of Comparative Economics* 43(1): 3-18.

Mahutga, Matthew C. (2012), When Do Value Chains Go Global? A Theory of the Spatialization of Global Value Chains, *Global Networks* 12(1): 1-21.

Neumayer, Eric, and Laura Spess (2005), Do Bilateral Investment Treaties Increase Foreign Direct Investment to Developing Countries? *World Development* 33(10): 1567-1585.

OECD (2018), *Trade in Value Added*, Organisation for Economic Co-operation and Development, Paris. (https://www.oecd.org/sti/ind/measuring-trade-in-value-added.htm#access)

OECD (2022), *Guide to OECD's Trade in Value Added (TiVA) Indicators 2021 edition*, Directorate for Science, Technology and Innovation, Organisation for Economic Co-operation and Development, Paris.

OECD.Stat (2021a), *Access to the TiVA database (oecd.stat)*, Organisation for Economic Co-operation and Development, Paris. (https://stats.oecd.org/Index.aspx?DataSetCode=TIVA_2021_C1)

OECD.Stat (2021b), *FDI Statistics by Partner Country and by Industry*, Organisation for Economic Co-operation and Development, Paris. (https://stats.oecd.org/Index.aspx?QueryId=64226)

Quentin, David, and Liam Campling (2018), Global inequality chains: integrating mechanisms of value distribution into analyses of global production, *Global Networks* 18(1): 33-56.

Seung, Chang K. (2022), Decomposing Global Value Chain (GVC) Income for World Fisheries, *Marine Policy* (Available online 7 January 2022. https://doi.org/10.1016/j.marpol.2021.104950).

Starosta, Guido (2010), The Outsourcing of Manufacturing and the Rise of Giant Global Contractors: A Marxian Approach to Some Recent Transformations of Global Value Chains, *New Political Economy* 15(4): 543-563.

Tang, Heiwai, Fei Wang, and Zhi Wang (2020), Domestic Segment of Global Value Chains in China under State Capitalism, *Journal of Comparative Economics* 48(4): 797-821.

Timmer, Marcel P., Abdul Azeez Erumban, Bart Los, Robert Stehrer, and Gaaitzen J. de Vries (2014), Slicing Up Global Value Chains, *Journal of Economic Perspectives* 28(2): 99-118.

Timmer, Marcel P., Sébastien Miroudot, and Gaaitzen J. de Vries (2019), Functional Specialisation in Trade, *Journal of Economic Geography* 19(1):1-30.

UNCTADSTAT (2021), Groups of Economies, *Classifications*, UNCTADSTAT, Geneva, Switzerland. (https://unctadstat.unctad.org/EN/Classifications/DimCountries_All_Hierarchy.pdf)

United Nations, European Commission, International Monetary Fund, Organisation for Economic Co-operation and Development, and World Bank (2009), *System of National Accounts 2008*, New York.

Upward, Richard, Zheng Wang, and Jinghai Zheng (2013), Weighing China's Export Basket: The Domestic Content and Technology Intensity of Chinese exports, *Journal of Comparative Economics* 41(2): 527-543.

Wade, Robert Hunter (2004), On the Causes of Increasing World Poverty and Inequality, or Why the Matthew Effect Prevails, *New Political Economy* 9(2): 163-188.

Wang, En-Ze, and Chien-Chiang Lee (2023), Foreign Direct Investment, Income Inequality and Country Risk, *International Journal of Finance and Economics* 28(3): 2227-3466. (First published: 08 February 2021. https://doi.org/10.1002/ijfe.2542)

Warner, David, D.S. Prasada Rao, William E. Griffiths, and Duangkamon Chotikapanich (2014), Global Inequality; Levels and Trends, 1993–2005: How Sensitive Are These to the Choice of PPPs and Real Income Measures? *Review of Income and Wealth* 60(S2): S281-S304.

Yi, Kei-Mu (2003), Can Vertical Specialization Explain the Growth of World Trade? *Journal of Political Economy* 111(1): 52-102.

Table 1. Trade statistics in four measures and FDI income for G20 developed countries – volume (in $million)

Year	GE	DVAE	DVAE/GE	IIP	IIR	RDVAE
1995	414,239	368,225	0.8889			
1996	455,797	403,573	0.8854			
1997	503,670	443,840	0.8812			
1998	459,902	405,633	0.8820			
1999	463,148	408,267	0.8815			
2000	558,619	486,860	0.8715			
2001	533,664	467,106	0.8753			
2002	536,091	470,626	0.8779			
2003	611,926	536,118	0.8761			
2004	759,173	656,880	0.8653			
2005	867,397	739,247	0.8523	2,307	49,715	788,911
2006	1,002,616	842,657	0.8405	2,496	53,581	896,179
2007	1,168,480	972,839	0.8326	3,385	67,085	1,039,839
2008	1,405,322	1,153,198	0.8206	2,664	62,277	1,215,401
2009	1,132,463	970,943	0.8574	1,823	56,937	1,027,835
2010	1,444,517	1,213,637	0.8402	4,139	76,397	1,289,910
2011	1,759,169	1,447,358	0.8228	14,715	102,624	1,549,493
2012	1,789,748	1,476,029	0.8247	11,846	90,470	1,566,096
2013	1,837,531	1,524,301	0.8295	13,930	83,530	1,607,347
2014	1,926,171	1,600,039	0.8307	13,872	90,944	1,690,487
2015	1,761,456	1,482,184	0.8415	9,354	77,744	1,559,600
2016	1,667,730	1,423,168	0.8534	6,545	79,321	1,502,274
2017	1,861,077	1,574,546	0.8460	8,434	94,038	1,668,289
2018	1,992,974	1,669,506	0.8377	10,135	101,443	1,770,594

GE – gross exports; DVAE – domestic value-added exports; IIP – investment income payments; IIR – investment income receipts; RDVAE – residence-based domestic value-added exports

Table 2. Trade statistics in four measures and FDI income for G20 developing countries – volume (in $million)

Year	GE	DVAE	DVAE/GE	IIP	IIR	RDVAE
1995	409,376	339,099	0.8283			
1996	446,783	368,684	0.8252			
1997	494,329	404,502	0.8183			
1998	487,308	392,752	0.8060			
1999	531,832	425,045	0.7992			
2000	657,119	518,620	0.7892			
2001	626,793	495,895	0.7912			
2002	666,828	527,037	0.7904			
2003	772,519	605,638	0.7840			
2004	980,189	760,936	0.7763			
2005	1,162,001	908,228	0.7816	49,715	2,307	904,821
2006	1,368,475	1,075,321	0.7858	53,581	2,496	1,071,632
2007	1,535,927	1,209,843	0.7877	67,085	3,385	1,206,113
2008	1,770,110	1,397,066	0.7893	62,277	2,664	1,393,251
2009	1,350,434	1,087,482	0.8053	56,937	1,823	1,084,540
2010	1,724,515	1,372,440	0.7958	76,397	4,139	1,370,008
2011	2,097,779	1,659,271	0.7910	102,624	14,715	1,665,047
2012	2,158,584	1,706,584	0.7906	90,470	11,846	1,710,790
2013	2,168,343	1,726,257	0.7961	83,530	13,930	1,733,517
2014	2,256,699	1,803,712	0.7993	90,944	13,872	1,810,275
2015	2,036,711	1,640,679	0.8056	77,744	9,354	1,644,119
2016	1,912,695	1,538,698	0.8045	79,321	6,545	1,539,599
2017	2,094,557	1,669,677	0.7972	94,038	8,434	1,671,560
2018	2,308,591	1,832,104	0.7936	101,443	10,135	1,835,001

GE – gross exports; DVAE – domestic value-added exports; IIP – investment income payments; IIR – investment income receipts; RDVAE – residence-based domestic value-added exports

Table 3. Trade statistics in four measures for G20 developed countries – net (volume figures in $million)

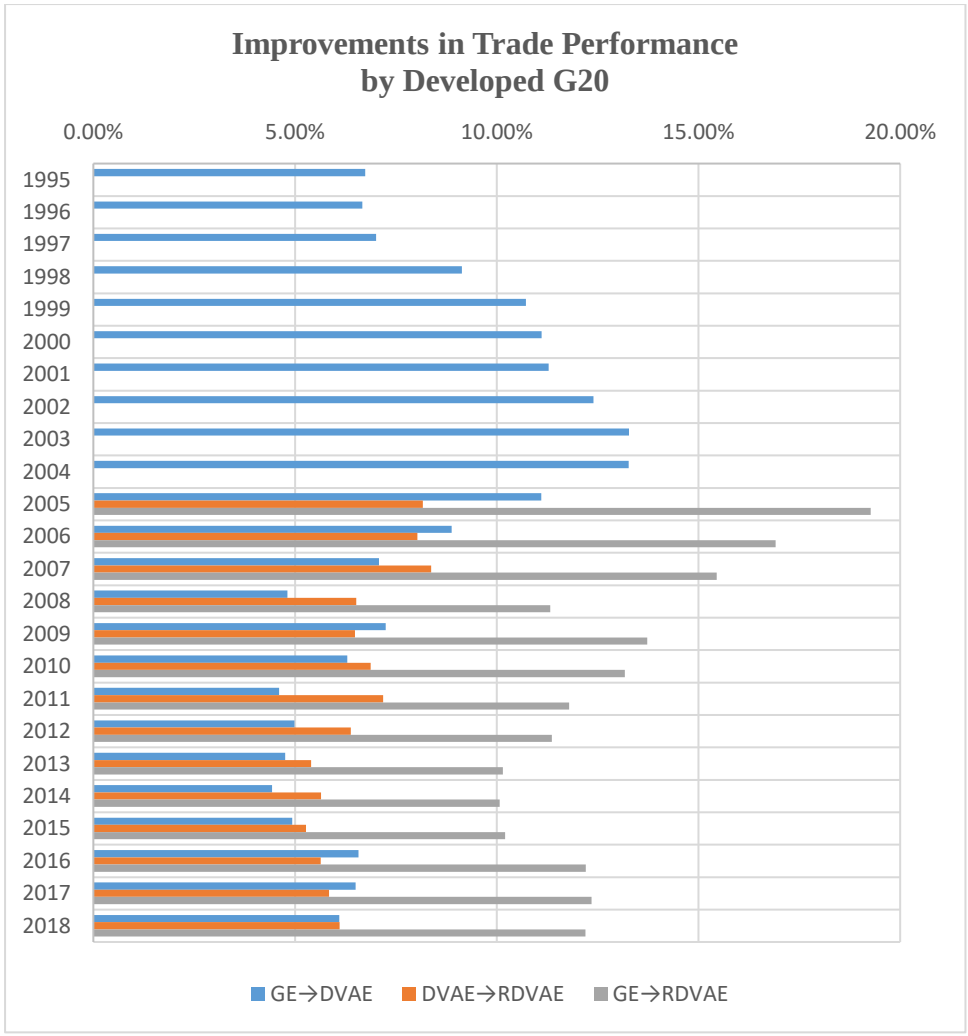
Year	NGE	% GE	NDVAE	% DVAE	NRDVAE	% RDVAE	GE→ DVAE	DVAE→ RDVAE	GE→ RDVAE
1995	4,862	1.17%	29,126	7.91%			6.74%		
1996	9,013	1.98%	34,889	8.64%			6.67%		
1997	9,342	1.85%	39,338	8.86%			7.01%		
1998	-27,406	-5.96%	12,881	3.18%			9.13%		
1999	-68,684	-14.83%	-16,779	-4.11%			10.72%		
2000	-98,500	-17.63%	-31,760	-6.52%			11.11%		
2001	-93,130	-17.45%	-28,789	-6.16%			11.29%		
2002	-130,737	-24.39%	-56,411	-11.99%			12.40%		
2003	-160,593	-26.24%	-69,520	-12.97%			13.28%		
2004	-221,016	-29.11%	-104,057	-15.84%			13.27%		
2005	-294,605	-33.96%	-168,982	-22.86%	-115,910	-14.69%	11.11%	8.17%	19.27%
2006	-365,859	-36.49%	-232,664	-27.61%	-175,454	-19.58%	8.88%	8.03%	16.91%
2007	-367,447	-31.45%	-237,005	-24.36%	-166,274	-15.99%	7.08%	8.37%	15.46%
2008	-364,787	-25.96%	-243,867	-21.15%	-177,850	-14.63%	4.81%	6.51%	11.32%
2009	-217,971	-19.25%	-116,539	-12.00%	-56,706	-5.52%	7.24%	6.49%	13.73%
2010	-279,998	-19.38%	-158,803	-13.08%	-80,098	-6.21%	6.30%	6.88%	13.17%
2011	-338,609	-19.25%	-211,913	-14.64%	-115,553	-7.46%	4.61%	7.18%	11.79%
2012	-368,836	-20.61%	-230,556	-15.62%	-144,693	-9.24%	4.99%	6.38%	11.37%
2013	-330,812	-18.00%	-201,956	-13.25%	-126,170	-7.85%	4.75%	5.40%	10.15%
2014	-330,528	-17.16%	-203,673	-12.73%	-119,788	-7.09%	4.43%	5.64%	10.07%
2015	-275,255	-15.63%	-158,495	-10.69%	-84,519	-5.42%	4.93%	5.27%	10.21%
2016	-244,965	-14.69%	-115,530	-8.12%	-37,325	-2.48%	6.57%	5.63%	12.20%
2017	-233,480	-12.55%	-95,131	-6.04%	-3,271	-0.20%	6.50%	5.85%	12.35%
2018	-315,617	-15.84%	-162,598	-9.74%	-64,407	-3.64%	6.10%	6.10%	12.20%

NGE – net gross exports; NDVAE – net domestic value-added exports; NRDVAE – net residence-based domestic value-added exports; GE→DVAE – gains from GE to DVAE; DVAE→RDVAE – gains from DVAE to RDVAE; GE→RDVAE – overall gains from GE to RDVAE

Table 4. Trade statistics in four measures for G20 developing countries – net (volume figures in $million)

Year	NGE	% GE	NDVAE	% DVAE	NRDVAE	% RDVAE	GE→ DVAE	DVAE→ RDVAE	GE→ RDVAE
1995	-4,862	-1.19%	-29,126	-8.59%			-7.40%		
1996	-9,013	-2.02%	-34,889	-9.46%			-7.45%		
1997	-9,342	-1.89%	-39,338	-9.72%			-7.84%		
1998	27,406	5.62%	-12,881	-3.28%			-8.90%		
1999	68,684	12.91%	16,779	3.95%			-8.97%		
2000	98,500	14.99%	31,760	6.12%			-8.87%		
2001	93,130	14.86%	28,789	5.81%			-9.05%		
2002	130,737	19.61%	56,411	10.70%			-8.90%		
2003	160,593	20.79%	69,520	11.48%			-9.31%		
2004	221,016	22.55%	104,057	13.67%			-8.87%		
2005	294,605	25.35%	168,982	18.61%	115,910	12.81%	-6.75%	-5.80%	-12.54%
2006	365,859	26.73%	232,664	21.64%	175,454	16.37%	-5.10%	-5.26%	-10.36%
2007	367,447	23.92%	237,005	19.59%	166,274	13.79%	-4.33%	-5.80%	-10.14%
2008	364,787	20.61%	243,867	17.46%	177,850	12.77%	-3.15%	-4.69%	-7.84%
2009	217,971	16.14%	116,539	10.72%	56,706	5.23%	-5.42%	-5.49%	-10.91%
2010	279,998	16.24%	158,803	11.57%	80,098	5.85%	-4.67%	-5.72%	-10.39%
2011	338,609	16.14%	211,913	12.77%	115,553	6.94%	-3.37%	-5.83%	-9.20%
2012	368,836	17.09%	230,556	13.51%	144,693	8.46%	-3.58%	-5.05%	-8.63%
2013	330,812	15.26%	201,956	11.70%	126,170	7.28%	-3.56%	-4.42%	-7.98%
2014	330,528	14.65%	203,673	11.29%	119,788	6.62%	-3.35%	-4.67%	-8.03%
2015	275,255	13.51%	158,495	9.66%	84,519	5.14%	-3.85%	-4.52%	-8.37%
2016	244,965	12.81%	115,530	7.51%	37,325	2.42%	-5.30%	-5.08%	-10.38%
2017	233,480	11.15%	95,131	5.70%	3,271	0.20%	-5.45%	-5.50%	-10.95%
2018	315,617	13.67%	162,598	8.87%	64,407	3.51%	-4.80%	-5.37%	-10.16%

NGE – net gross exports; NDVAE – net domestic value-added exports; NRDVAE – net residence-based domestic value-added exports; GE→DVAE – gains from GE to DVAE; DVAE→RDVAE – gains from DVAE to RDVAE; GE→RDVAE – overall gains from GE to RDVAE



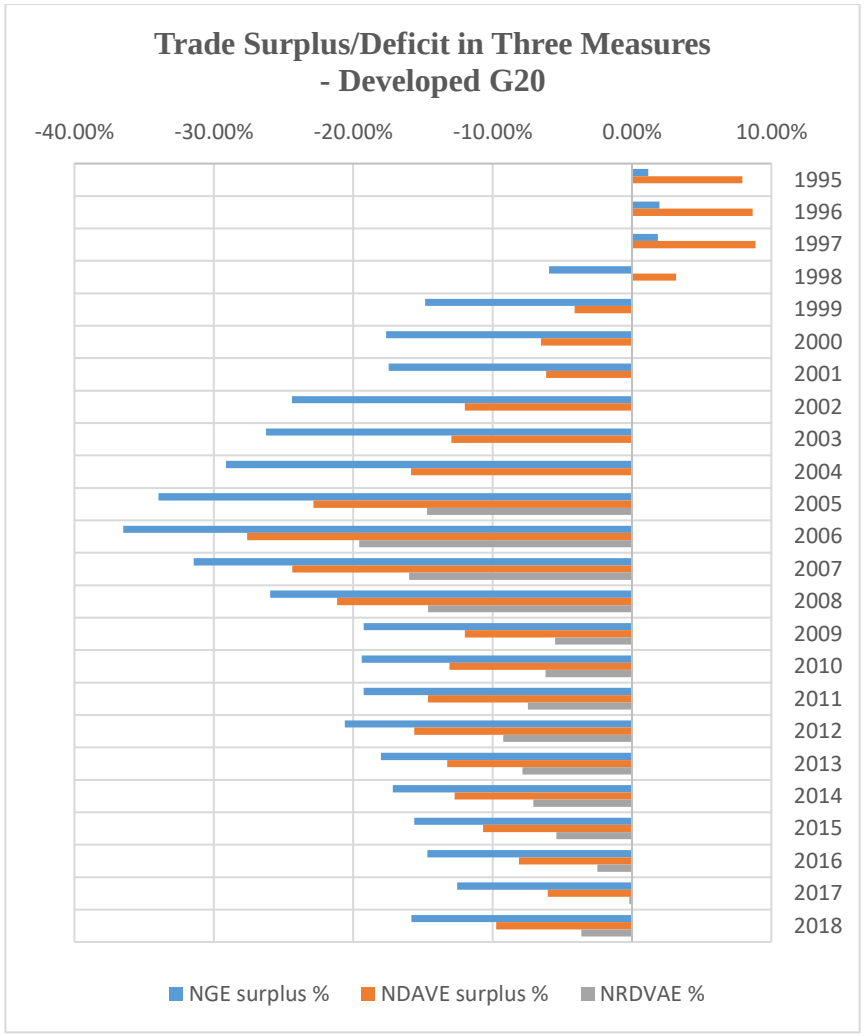


Figure 1. Gains and Reduced Deficits by Developed G20 in Three Measures: GE→DVAE→RDVAE

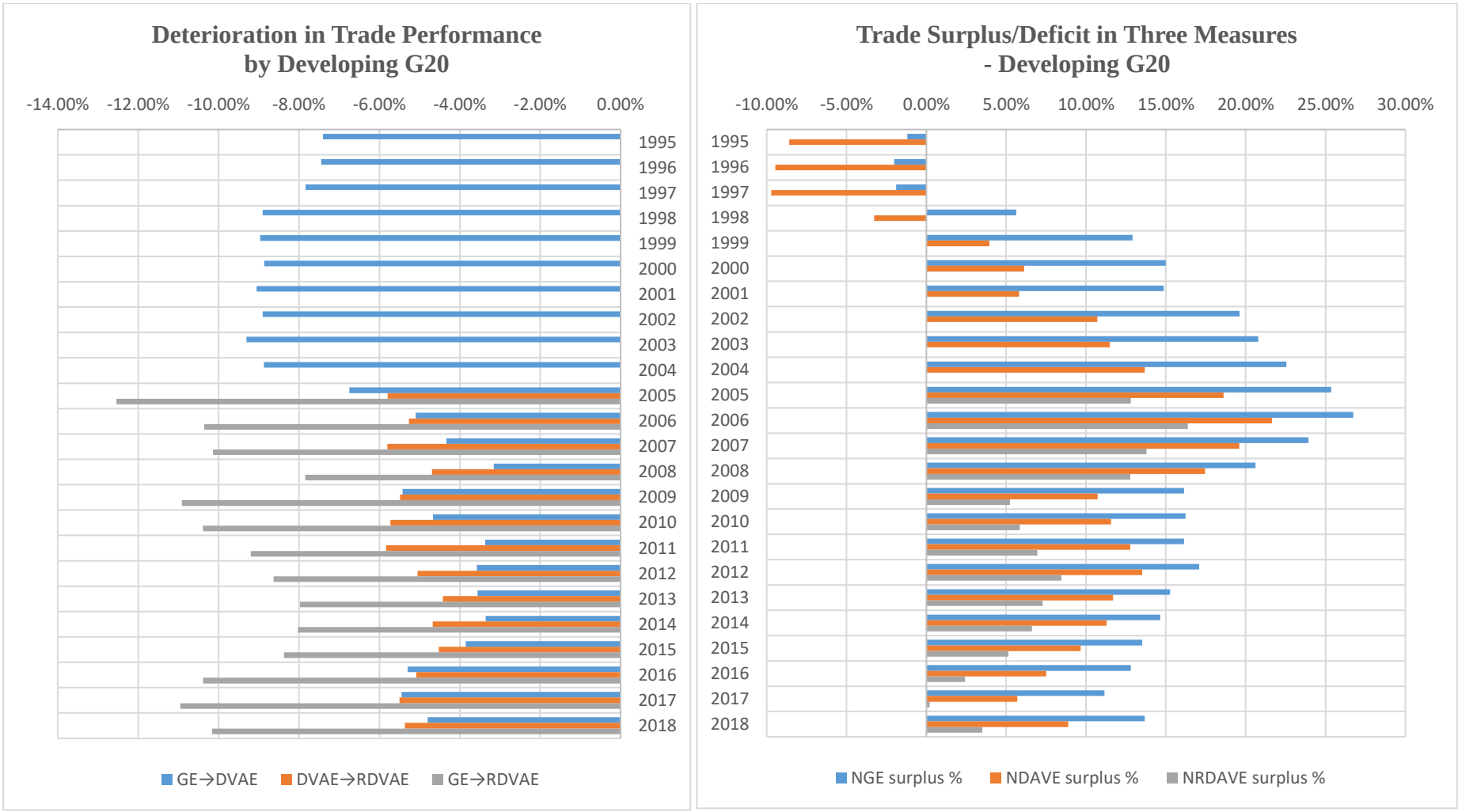
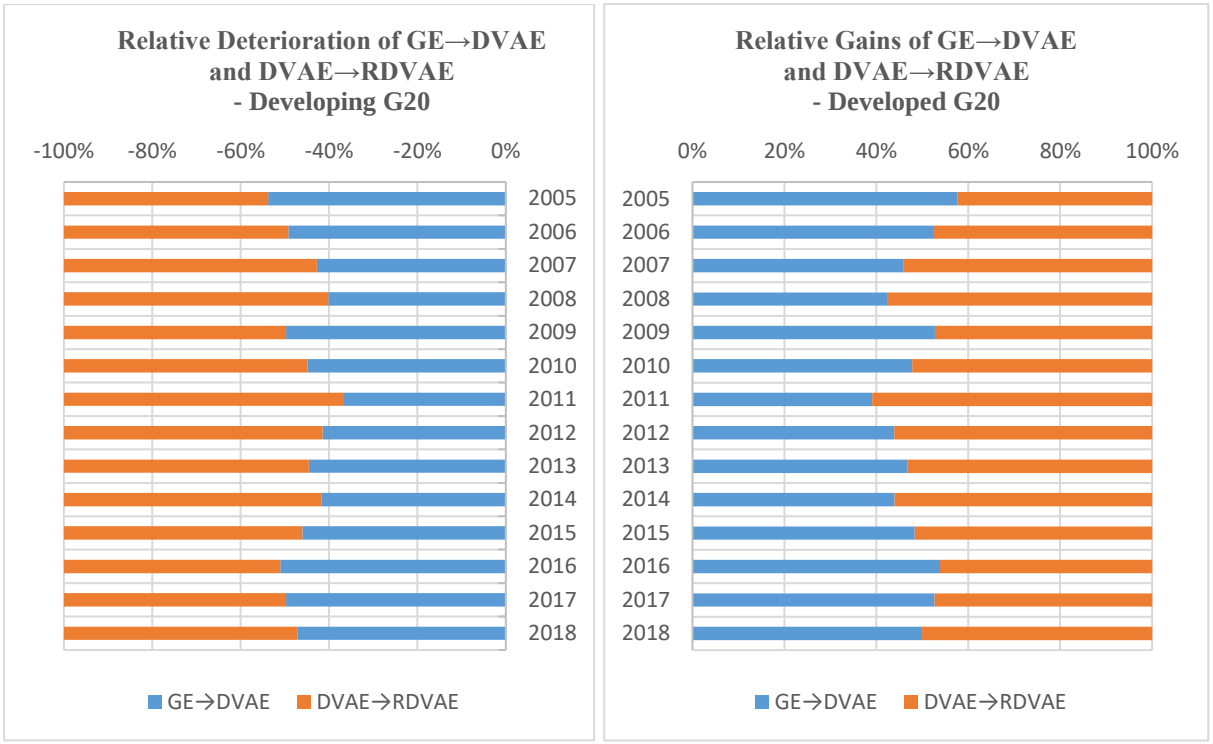


Figure 2. Deterioration and Reduced Surpluses by Developing G20 in Three Measures: GE→DVAE→RDVAE



(a) (b)

Figure 3. Relative Contributions to Deterioration and Gains

Appendix 1. Supplementary illustrations

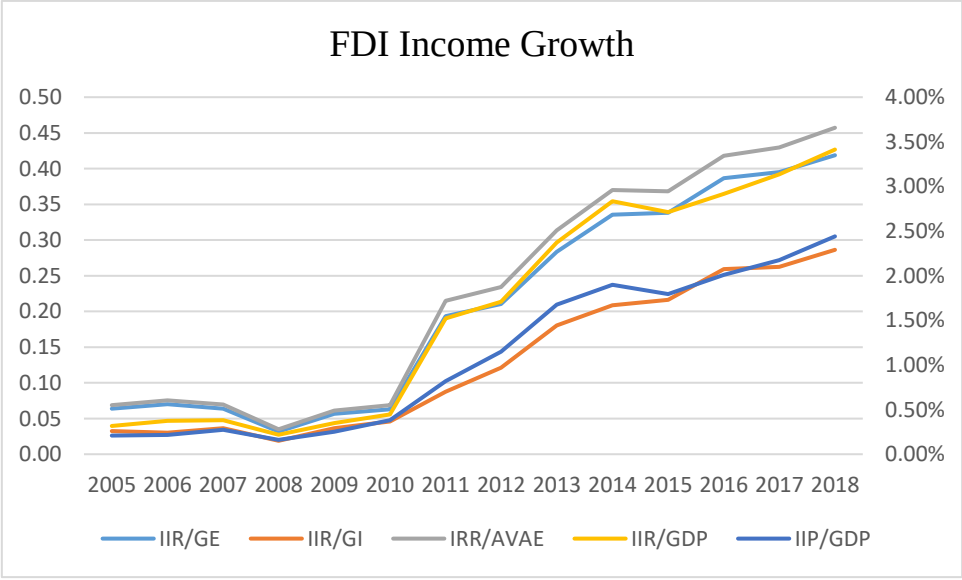


Figure A1. Phenomenal FDI Income Growth Relative to Trade and GDP: OECD with World

Table A1. Growth and development of exports and FDI income: OECD with world (volume figures in $million)

	2011	2012	2013	2014	2015	2016	2017	2018
Gross Exports (GE)	3,675,025	3,797,454	3,959,585	4,082,382	3,657,936	3,510,303	3,849,569	4,179,207
Gross Imports (GI)	4,373,427	4,435,037	4,390,741	4,394,820	3,780,093	3,602,696	4,020,242	4,370,608
Domestic value-added exports (DVAE)	3,306,545	3,414,235	3,580,839	3,703,306	3,360,146	3,248,163	3,540,370	3,827,103
Outward FDI income (IIR)	710,465	798,881	1,121,807	1,370,015	1,236,757	1,356,864	1,520,713	1,749,788
Inward FDI income (IIP)	382,771	537,257	792,127	917,095	817,505	934,154	1,055,217	1,251,081
IIR/ GE	0.1933	0.2104	0.2833	0.3356	0.3381	0.3865	0.3950	0.4187
IIP/ GI	0.0875	0.1211	0.1804	0.2087	0.2163	0.2593	0.2625	0.2862
IIR/ DVAE	0.2149	0.2340	0.3133	0.3699	0.3681	0.4177	0.4295	0.4572

Table A2. Illustration of domestic and foreign value-added shares – each column sums to one

$v_{11}b_{11,11}$	⋯	$v_{11}b_{11,1M}$	$v_{11}b_{11,21}$	⋯	$v_{11}b_{11,2M}$	⋯	⋯	$v_{11}b_{11,N1}$	⋯	$v_{11}b_{11,NM}$
⋮	⋱	⋮	⋮	⋱	⋮	⋱	⋱		⋱	⋮
$v_{1M}b_{1M,11}$	⋯	$v_{1M}b_{1M,1M}$	$v_{1M}b_{1M,21}$	⋯	$v_{1M}b_{1M,2M}$	⋯	⋯	$v_{1M}b_{1M,N1}$	⋯	$v_{1M}b_{1M,NM}$
$v_{21}b_{21,11}$	⋯	$v_{21}b_{21,1M}$	$v_{21}b_{21,21}$	⋯	$v_{21}b_{21,2M}$	⋯	⋯	$v_{21}b_{21,N1}$	⋯	$v_{21}b_{21,NM}$
⋮	⋱			⋱		⋱	⋱		⋱	⋮
$v_{2M}b_{2M,11}$	⋯	$v_{2M}b_{2M,1M}$	$v_{2M}b_{2M,21}$	⋯	$v_{2M}b_{2M,2M}$	⋯	⋯	$v_{2M}b_{2M,N1}$	⋯	$v_{2M}b_{2M,NM}$
⋮			⋮					⋮		
⋮			⋮					⋮		
$v_{N1}b_{N1,11}$	⋯	$v_{N1}b_{N1,1M}$	$v_{N1}b_{N1,21}$	⋯	$v_{N1}b_{N1,2M}$	⋯	⋯	$v_{N1}b_{N1,N1}$	⋯	$v_{N1}b_{N1,NM}$
⋮	⋱			⋱		⋱	⋱		⋱	⋮
$v_{NM}b_{NM,11}$	⋯	$v_{NM}b_{NM,1M}$	$v_{NM}b_{NM,21}$	⋯	$v_{NM}b_{NM,2M}$	⋯	⋯	$v_{NM}b_{NM,N1}$	⋯	$v_{NM}b_{NM,NM}$
$\sum\sum_{*=1}$	⋯	$\sum\sum_{*=1}$	$\sum\sum_{*=1}$	⋯	$\sum\sum_{*=1}$	⋯	⋯	$\sum\sum_{*=1}$		$\sum\sum_{*=1}$

- domestic value-added, - foreign value-added

Table A3. Value-added representation of N country M sector system for input-output relationships in global value chains ($Z_{ik,jh} = a_{ik,jh}X_{jh}$)

X_{11} =	$Z_{11,11}$	⋯	$Z_{11,1M}$	$Z_{11,21}$	⋯	$Z_{11,2M}$	⋯	⋯	$Z_{11,N1}$	⋯	$Z_{11,NM}$	$Y_{11,1}$	$Y_{11,2}$	⋯	$Y_{11,N}$
	⋮	⋱	⋮	⋮	⋱	⋮	⋱	⋱		⋱	⋮	⋮	⋮		⋮
X_{1M} =	$Z_{1M,11}$	…	$Z_{1M,1M}$	$Z_{1M,21}$	⋯	$Z_{1M,2M}$	⋯	⋯	$Z_{1M,N1}$	⋯	$Z_{1M,NM}$	$Y_{1M,1}$	$Y_{1M,2}$	⋯	$Y_{1M,N}$
X_{21} =	$Z_{21,11}$	⋯	$Z_{21,1M}$	$Z_{21,21}$	⋯	$Z_{21,2M}$	⋯	⋯	$Z_{21,N1}$	⋯	$Z_{21,NM}$	$Y_{21,1}$	$Y_{21,2}$	⋯	$Y_{21,N}$
	⋮	⋱			⋱		⋱	⋱		⋱	⋮	⋮	⋮		⋮
X_{2M} =	$Z_{2M,11}$	…	$Z_{2M,1M}$	$Z_{2M,21}$	…	$Z_{2M,2M}$	…	…	$Z_{2M,N1}$	…	$Z_{2M,NM}$	$Y_{2M,1}$	$Y_{2M,2}$	⋯	$Y_{2M,N}$
	⋮			⋮					⋮						
	⋮			⋮					⋮						
X_{N1} =	$Z_{N1,11}$	⋯	$Z_{N1,1M}$	$Z_{N1,21}$	⋯	$Z_{N1,2M}$	⋯	⋯	$Z_{N1,N1}$	⋯	$Z_{N1,NM}$	$Y_{N1,1}$	$Y_{N1,2}$	⋯	$Y_{N1,N}$
	⋮	⋱			⋱		⋱	⋱		⋱	⋮	⋮	⋮		⋮
X_{NM} =	$Z_{NM,11}$	…	$Z_{NM,1M}$	$Z_{NM,21}$	…	$Z_{NM,2M}$	…	…	$Z_{NM,N1}$	…	$Z_{NM,NM}$	$Y_{NM,1}$	$Y_{NM,2}$	⋯	$Y_{NM,N}$
	$va_{11,1}$	⋯	$va_{1M,1}$	$va_{21,1}$	⋯	$va_{2M,1}$	⋯	⋯	$va_{N1,1}$	⋯	$va_{NM,1}$				
	⋮	⋱	⋮	⋮	⋱	⋮	⋱	⋱	⋮	⋱	⋮				
	$va_{11,N}$	…	$va_{1M,N}$	$va_{21,N}$	…	$va_{2M,N}$	⋯	⋯	$va_{N1,N}$	…	$va_{NM,N}$				
	$= X_{11}$		$= X_{1M}$	$= X_{21}$		$= X_{2M}$			$= X_{N1}$		$= X_{NM}$				

Appendix 2. Input-output matrix illustration of the case

Example 1 in Koopman *et al.* (2014). The input-output relationships can be summarized as follows:

$$\boldsymbol{X} = \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} = \begin{bmatrix} 200 \\ 200 \end{bmatrix},\ \boldsymbol{A} = \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} = \begin{bmatrix} 100/200 & 50/200 \\ 0/200 & 50/200 \end{bmatrix} = \begin{bmatrix} 0.5 & 0.25 \\ 0 & 0.25 \end{bmatrix},$$

$$\boldsymbol{X} = \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} = \begin{bmatrix} 0.5 & 0.25 \\ 0 & 0.25 \end{bmatrix} \begin{bmatrix} 200 \\ 200 \end{bmatrix} + \begin{bmatrix} 30 + 20 \\ 70 + 80 \end{bmatrix}$$

$$\boldsymbol{V} = \begin{bmatrix} v_1 & 0 \\ 0 & v_2 \end{bmatrix} = \begin{bmatrix} 100/200 & 0 \\ 0 & 100/200 \end{bmatrix} = \begin{bmatrix} 0.5 & 0 \\ 0 & 0.5 \end{bmatrix}$$

$$\boldsymbol{B} = \begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{bmatrix} = \begin{bmatrix} 2 & 0.67 \\ 0 & 1.33 \end{bmatrix},\ \boldsymbol{BV} = \begin{bmatrix} v_1 b_{11} & v_1 b_{12} \\ v_2 b_{21} & v_2 b_{22} \end{bmatrix} = \begin{bmatrix} 1 & 0.33 \\ 0 & 0.67 \end{bmatrix}$$

$$\boldsymbol{X} = \begin{bmatrix} x_{11} & x_{12} \\ x_{21} & x_{22} \end{bmatrix} = \begin{bmatrix} b_{11} & b_{12} \\ b_{21} & b_{22} \end{bmatrix} \begin{bmatrix} y_{11} & y_{12} \\ y_{21} & y_{22} \end{bmatrix} = \begin{bmatrix} b_{11}y_{11} + b_{12}y_{21} & b_{11}y_{12} + b_{12}y_{22} \\ b_{21}y_{11} + b_{22}y_{21} & b_{21}y_{12} + b_{22}y_{22} \end{bmatrix}$$

$$= \begin{bmatrix} 2 & 0.667 \\ 0 & 1.333 \end{bmatrix} \begin{bmatrix} 30 & 20 \\ 70 & 80 \end{bmatrix} = \begin{bmatrix} 60 + 46.67 & 40 + 53.33 \\ 0 + 93.33 & 0 + 106.67 \end{bmatrix} = \begin{bmatrix} 106.67 & 93.33 \\ 93.33 & 106.67 \end{bmatrix}$$

$$\boldsymbol{VA} = \begin{bmatrix} va_{11} & va_{12} \\ va_{21} & va_{22} \end{bmatrix} = \begin{bmatrix} v_1 & 0 \\ 0 & v_2 \end{bmatrix} \begin{bmatrix} x_{11} & x_{12} \\ x_{21} & x_{22} \end{bmatrix}$$

$$= \begin{bmatrix} 0.5 & 0 \\ 0 & 0.5 \end{bmatrix} \begin{bmatrix} 106.67 & 93.33 \\ 93.33 & 106.67 \end{bmatrix} = \begin{bmatrix} 53.33 & 46.67 \\ 46.67 & 53.33 \end{bmatrix}$$

Beyond the analytical framework in this study and going further, let us embed FDI in the input-output system. Let us assume that z units of CHN's imported intermediate goods are financed by USA's capital or the imported capital from USA in its production and USA uses all its own capital. With $v_1 = 0.5$, the production associated with this capital has generated z units of value added and 2z units of gross output. f out of these z units of "domestic value added" in CHN go to USA in the form of CHN's IIP. The other (z-f) units are divided between compensation of employees and consumption of fixed capital plus taxes and minus subsidies, which remain in CHN.

Let us split the gross output of 2z units associated with this FDI between CHN and UAS in the same proportions as value added, i.e., 2f units for USA and 2(z-f) units for CHN. Assuming $f = 5$ and $z = 10$, USA's value added is increased by 5 units to be 105 and USA's

gross output is increased by 10 units to be 210. CHN's value added is decreased by 5 units to 95, while its gross output is decreased by 10 units to 190. a_{11} decreases (to $\frac{100}{210} = 0.476$) and a_{12} and a_{22} increase (to $\frac{50}{190} = 0.263$). v_1 and v_2 remain the same ($= \frac{105}{210} = \frac{95}{190} = 0.5$). The corresponding matrixes of Koopman *et al*. (2014) become:

$$\boldsymbol{X} = \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} = \begin{bmatrix} 210 \\ 190 \end{bmatrix}, \boldsymbol{A} = \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} = \begin{bmatrix} 100/210 & 50/190 \\ 0/210 & 50/190 \end{bmatrix} = \begin{bmatrix} 0.476 & 0.263 \\ 0 & 0.263 \end{bmatrix},$$

$$\boldsymbol{V} = \begin{bmatrix} v_1 & 0 \\ 0 & v_2 \end{bmatrix} = \begin{bmatrix} 105/210 & 0 \\ 0 & 95/190 \end{bmatrix} = \begin{bmatrix} 0.5 & 0 \\ 0 & 0.5 \end{bmatrix}$$

$$\boldsymbol{X} = \begin{bmatrix} x_{11} & x_{12} \\ x_{21} & x_{22} \end{bmatrix} = \begin{bmatrix} 106.67 & 103.33 \\ 88.67 & 101.33 \end{bmatrix}$$

$$\boldsymbol{Y} = \begin{bmatrix} y_{11} & y_{12} \\ y_{21} & y_{22} \end{bmatrix} = \begin{bmatrix} 1 - a_{11} & -a_{12} \\ -a_{21} & 1 - a_{22} \end{bmatrix} \begin{bmatrix} x_{11} & x_{12} \\ x_{21} & x_{22} \end{bmatrix}$$

$$= \begin{bmatrix} 0.524 & -0.263 \\ 0 & 0.737 \end{bmatrix} \begin{bmatrix} 106.67 & 103.33 \\ 88.67 & 101.33 \end{bmatrix} = \begin{bmatrix} 32.54 & 27.46 \\ 65.33 & 74.67 \end{bmatrix}$$

$$\boldsymbol{VA} = \begin{bmatrix} va_{11} & va_{12} \\ va_{21} & va_{22} \end{bmatrix} = \begin{bmatrix} v_1 & 0 \\ 0 & v_2 \end{bmatrix} \begin{bmatrix} x_{11} & x_{12} \\ x_{21} & x_{22} \end{bmatrix}$$

$$= \begin{bmatrix} 0.5 & 0 \\ 0 & 0.5 \end{bmatrix} \begin{bmatrix} 106.67 & 103.33 \\ 88.67 & 101.33 \end{bmatrix} = \begin{bmatrix} 53.33 & 51.67 \\ 44.33 & 50.67 \end{bmatrix}$$

Gross output is of less relevance while the above allocation can be seen as arbitrary. Let us not split the gross output of 20 units associated with FDI and all of them remain in CHN. USA's value added is increased by 5 units to 105 and CHN's value added is decreased by 5 units to 95. a_{11}, a_{12} and a_{22} remain the same. v_1 increases (to $\frac{105}{200} = 0.525$) and v_2 decreases (to $\frac{95}{200} = 0.475$), implying FDI altered efficiencies – changed value-added ratios. The corresponding matrixes of Koopman *et al*. (2014) become:

$$\boldsymbol{X} = \begin{bmatrix} x_1 \\ x_2 \end{bmatrix} = \begin{bmatrix} 200 \\ 200 \end{bmatrix}, \boldsymbol{A} = \begin{bmatrix} a_{11} & a_{12} \\ a_{21} & a_{22} \end{bmatrix} = \begin{bmatrix} 100/200 & 50/200 \\ 0/200 & 50/200 \end{bmatrix} = \begin{bmatrix} 0.5 & 0.25 \\ 0 & 0.25 \end{bmatrix},$$

$$\boldsymbol{V} = \begin{bmatrix} v_1 & 0 \\ 0 & v_2 \end{bmatrix} = \begin{bmatrix} 105/200 & 0 \\ 0 & 95/200 \end{bmatrix} = \begin{bmatrix} 0.525 & 0 \\ 0 & 0.475 \end{bmatrix}$$

$$\boldsymbol{X} = \begin{bmatrix} x_{11} & x_{12} \\ x_{21} & x_{22} \end{bmatrix} = \begin{bmatrix} 101.59 & 98.41 \\ 93.33 & 106.67 \end{bmatrix}$$

$$\boldsymbol{Y} = \begin{bmatrix} y_{11} & y_{12} \\ y_{21} & y_{22} \end{bmatrix} = \begin{bmatrix} 1 - a_{11} & -a_{12} \\ -a_{21} & 1 - a_{22} \end{bmatrix} \begin{bmatrix} x_{11} & x_{12} \\ x_{21} & x_{22} \end{bmatrix}$$

$$= \begin{bmatrix} 0.5 & -0.25 \\ 0 & 0.75 \end{bmatrix} \begin{bmatrix} 101.59 & 98.41 \\ 93.33 & 106.67 \end{bmatrix} = \begin{bmatrix} 27.46 & 22.54 \\ 70 & 80 \end{bmatrix}$$

$$\boldsymbol{VA} = \begin{bmatrix} va_{11} & va_{12} \\ va_{21} & va_{22} \end{bmatrix} = \begin{bmatrix} v_1 & 0 \\ 0 & v_2 \end{bmatrix} \begin{bmatrix} x_{11} & x_{12} \\ x_{21} & x_{22} \end{bmatrix}$$

$$= \begin{bmatrix} 0.525 & 0 \\ 0 & 0.475 \end{bmatrix} \begin{bmatrix} 101.59 & 98.41 \\ 93.33 & 106.67 \end{bmatrix} = \begin{bmatrix} 53.33 & 51.67 \\ 44.33 & 50.67 \end{bmatrix}$$

The results are exactly identical to that by our analytical framework and approach.