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Tracing Value Added in the Presence of Foreign Direct Investment
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ABSTRACT

We develop a unified framework to trace value added along global supply chains in the presence of foreign direct investment by decomposing either GDP based on forward linkages or final production based on backward linkages. The new framework accounts for the presence of foreign invested enterprises (FIEs), their interactions with local firms in the host countries as well as their activities in international trade. The size of the GVC activities identified with this framework roughly doubles that in the previous literature that treats FIEs the same as local firms. The "missing GVC activities" are more serious for high-tech sectors than for those with a lower R&D intensity, and more serious for high-income economies than for middle-income economies.

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1. Introduction

Multinational firms (MNEs) are major participants in global value chains. Combining cross border trade and foreign direct investment (FDI), MNEs and their affiliates organize and coordinate GVC operations. However, their role has not been formally incorporated in the existing frameworks for value added accounting in the GVC activities. The required frameworks for value added accounting in either GDP or gross exports, while related, are also distinct. The goal of this paper is to develop a framework for tracing value added in GDP accounting. For illustration, we will apply the accounting framework to characterize the patterns of FDI-related GVC activities, trade-related GVC activities, and GVC activities that involve both FDI and trade. We will compare their patterns in the high-tech and medium- tech sectors. One interesting (and new) finding is that FDI-related GVC activities are quantitatively bigger than purely trade-related GVC activities, and the gap is especially big in high-tech industries. As the decomposition framework for gross exports is related but still different, we present such a framework in an appendix but leave a more detailed discussion to a separate, companion paper.

The intended contribution of the paper is a measurement framework – decomposing a country's GDP and final production to different value added terms related to pure domestic activities, classic trade that does not involve factor content crossing national borders for production activities, trade-related GVC activities that involve trade in intermediate inputs but not FDI, and FDI-related GVC activities. The measurement framework does not involve explicit behavioral equations or optimization problems. However, similar to Koopman, Wang, and Wei (2014) and Wang, Wei, Yu and Zhu (2017), the framework produces potentially important new data that can be valuable inputs into other research. For example, if one wishes to study how a reduction in investment barriers due to a bilateral investment treaty or an investment chapter commonly embedded in regional trade agreements affects a country's participation in global value chains, our framework provides necessary measurement on the different types of GVC activities that is not available from the existing literature or database that only accounts for trade-related GVC activities.

The MNEs, while accounting for less than 15 percent of all trading firms on average, capture almost 80 percent of total global trade (World Bank, 2020). But the local sales of the MNEs in host countries are often more important than their exports. A pair of data patterns helps to illustrate

these points. First, in Figure 1, we plot the total volumes of global trade and FDI (in stock), respectively, from 1980 to 2019 (with the 1980 values normalized to be 100)[2]. One takeaway is that the global stock of FDI has been growing much faster than trade. Second, the sales of overseas affiliates of US MNEs, split between local sales, exports back to the US, and exports to third countries in selected host countries and the world as a whole, are presented in Table 1. The overseas affiliates of US MNEs sell about 59% of their total output in their host countries, 12% of the output back to the United States, and 29% to other countries. Based on the sales numbers, horizontal FDI appears twice as important as vertical FDI. However, we will point out that the traditional distinction between horizontal and vertical FDI is problematic as a sizable part of the local sales by the local affiliates of MNEs are intermediate inputs to local firms. Local affiliates of MNEs also often buy intermediate inputs from local firms. Somewhat surprisingly, this pattern is true not only for high-income host countries such as Japan, Germany, and Canada, but also for developing country hosts such as China and Mexico.

<Insert Figure 1 here>

<Insert Table 1 here>

If GVC activities are defined as production activities that involve factor content from more than one country, then the production activities by FIEs for the local market that use inputs from local firms are part of the GVC activities. Similarly, the production activities by local firms that use intermediate inputs produced by FIEs are also part of the GVC activities. Neither shows up in the official international trade statistics, nor in standard input-output tables. Our framework aims to over these shortcomings.

The rest of the paper is organized as follows: Section II discusses how the new framework fits in the literature on measurement of global value chains. Section III presents the new production activity decomposition framework and defines GVC participation index based on both forward and backward linkages, respectively. To illustrate the framework's applications, Section IV reports some empirical results generated from the new framework based on the OECD AMNE ICIO

[2] Stock of FDI is used because FDI-related GVC activities in a given year are proportional to the stock of FDI, but trade-related GVC-activities are proportion to the (flow of) trade. If we are to plot both flow of FDI and trade, we will see a faster increase in FDI than in trade.

database (2019 version) with 60 countries and 34 industries (Cadestin, C., et al., 2018); Section V provides concluding remarks.

2. Placing the Paper in the Literature

The existing literature on measuring GVC activities focuses on those activities involving international trade, and ignores GVC activities involving domestic trade between the affiliates of foreign MNEs and local firms in the host countries. The data pattern described earlier provides hints that the existing measures may have missed a quantitatively significant part of the GVC activities. The relative importance of trade and FDI in the R&D intensive sector may vary across countries (e.g. China vs USA) and industries (e.g. Advanced manufacturing vs IT services). However, the absence of FDI in the existing measurement frameworks creates a bias in accounting for the true extent of GVC activities and in computing the local content of trade as the local affiliates of foreign MNEs are mistakenly treated as the same as local firms. Furthermore, the gap in the GVC participation by the foreign invested firms (FIEs) versus local firms can also vary between high-tech versus low-tech sectors, and between technology leading countries and developing countries. The framework developed here aims to fill these gaps.

How to identify and measure GVC activities has been a key focus in the recent literature on global value chains. As much of this literature focuses on decomposing gross exports, we start our review in this line of research. The seminal contribution to this issue in economic literature is Hummels, Ishii and Yi (2001). Their study highlights three conditions needed for GVC production (Vertical Specialization): a product or service is produced in a sequential process with several stages; new value is added in at least two countries; and at least one country uses intermediate inputs from other country in its production of exports. Using single-country input-output tables, they computed the earliest two economy-wide indicators of GVC participation in the literature: the share of imported inputs used in a country's production for exports (VS), and the share in total exports of a country's intermediate goods exports that are used by other countries for their production for the world market (VS1). However, they did not discuss the relationship between the VS measure and the domestic value-added in exports.

Koopman, Wang and Wei (2012) have developed the connection between the VS and domestic value-added (DVA). In particular, the concepts of VS and of foreign content in gross exports are identical, and a country's gross exports can be decomposed into DVA and VS two components. Koopman, Powers, Wang, and Wei (2010) decompose gross exports into mutually exclusive terms, "domestic content" and "foreign content," according to the country of origin and country of final absorption. However, these measures are gross-value based, including both value-added and items that cross national borders several times along the production process.

Johnson and Noguera (2012) propose a net measure of value added in trade: value-added exports (VAX), which is the value added created by the exporting country but consumed by another country, or the part of the exporting country's GDP that is consumed abroad. Note that the VAX concept only measures a portion of a country's domestic value added embodied in its gross exports. In particular, for the remainder of the gross exports, it does not separately identify the portion of DVA embodied in the exports of intermediates that is later re-imported back to and consumed in the source country.

Koopman, Wang and Wei (2014) propose a gross trade accounting framework, that decomposes a country's gross exports into four parts: domestic value added that is exported and consumed abroad (VAX); domestic value added that is exported first but is later re-imported home (RDV); foreign value added used in the production of exports (FVA); and pure double counted items (PDC) arising from multiple border crossing of value added in intermediate inputs that has already been counted in one of the previous terms. These four terms are mutually exclusive and add up to be 100% of the gross exports. This decomposition builds a bridge between two important and commonly reported statistics (GDP in national account and gross trade in custom statistics) and makes precise the relationship between each component of gross exports to GDP statistics[3] : VAX is the home country's GDP used to satisfy foreign demand, in which the factor content embodied in gross exports crosses national borders at least once. RDV, while in the initial gross exports, differs from VAX as it is eventually consumed at home. Note that the domestic factor content in RDA crosses national borders at least twice. FVA is a part of other countries' GDP, which means that the associated factor content has also crossed national borders at least

[3] These relationships are given in equations (15) to (18) of KWW for the two-country case and are extended to the G country, N sector case in Wang, Wei and Zhu (2013).

twice. PDC, the remaining part of the gross exports, has been recorded already by one of the previous three terms in some country's exports, and the associated factor content has crossed national borders at least three times.

By identifying which parts of the gross trade statistics are double counted relative to GDP statistics and whether they are domestic or foreign in origin, the KWW method provides a way to interpret gross trade transactions in value-added terms (relative to GDP) that is fully consistent with the System of National Accounts (SNA) standard. In other words, the framework establishes a precise relationship between components of officially reported trade statistics (measured in gross terms) and GDP (in net terms).

Following KWW's contribution, the work on GVC measurement can be roughly divided into two strands. The one that has attracted the most work focuses on decomposing gross trade, and, in particular, decomposing the VAX and the non-VAX terms into sub-components, as well as refining the measures of foreign value-added and double counted terms (See Nagengast and Stehrer, 2016; Johnson 2018; Borin and Mancini, 2019; Arto, Dietzenbacher and Rueda-Cantuche,2019; Miroudot and Ye, 2020 among others). As the aim of this branch of the literature differs from our current paper, we will leave a more detailed discussion to a separate paper[4].

The second strand of literature focuses on a decomposition of the value-added (GDP) or final goods production beyond trade. This includes measures of global production fragmentation or GVC participation in net terms. Los, Timmer and de Vries (2016) uses "hypothetic extraction", a mathematical method as an alternative way to compute DVA in gross exports and provided an intuitive interpretation for why the DVA term defined by KWW(2014, equation 37) is a part of GDP generated in the production for gross exports. This measure is labeled as VAX-D in Los and Timmer (2018). Their "hypothetic extraction" method is also extended to compute value-added exports proposed by Johnson and Noguera (2012), labeled as VAX-C, and an additional measure of domestic value added used abroad in the final stage of production, labeled as VAX-P. They show that the three different measures of value-added in trade differ both conceptually and empirically. For instance, "VAX-D in manufacturing exports captures all domestic value-added in products exported by the manufacturing sector". "In contrast, the manufacturing VAX-C

[4] In Appendix C, we provide an extension of KWW gross trade accounting equation with attention to Affiliates of Foreign MNEs.

measure captures how much value added is generated in the manufacturing industry that is ultimately consumed abroad, embodied in exports by all industries. Put otherwise, while the measurement of VAX-C is based on tracing forward linkages in the use of manufacturing value added, VAX-D is based on tracing backward linkages in the production of manufacturing exports" (Pahl and Timmer, 2019). These characterizations have implications for how to use them in trade analysis. These authors suggest that VAX-D[5] is more appropriate than VAX-C in quantifying the effects of trade agreements and measure global production fragmentation because VAX-D is always associated with bilateral gross trade flows passing through national borders among countries that sign the trade agreements, while VAX-C include value-added indirectly traded though third counties outside the treaty members. For example, a reduction in trade barriers among treaty members may have a smaller effect on VAX-C than VAX-D[6] .

We are aware of only two studies that decompose value-added (GDP) or final goods production beyond trade. Los, Timmer, and De Vries (2015) decompose final goods production according to value-added sources and use the share of foreign value-added (defined as all value-added outside the country of completion) embodied in final goods production as a measure of international production fragmentations. However, their decomposition is based on backward linkage only and does not distinguish between GVC and non-GVC production activities.

The framework by Wang, Wei, Yu, and Zhu (2017) traces both the absorption of GDP components via forward linkages and the value added origins in the final goods production activities via backward linkages in a way that facilitates identification and measurement of GVC activities. Value-added creation is classified as related to GVC activities when the factor content embodied in the products crosses national border for production purposes. They are classified into four broad categories: (a) Pure domestic production activities are completely produced and consumed within one country. (b) For "classic" trade, production occurs completely in one country but consumption occurs in another. (c) Value-added from one country is embodied in intermediate

[5] Wang, Wei and Zhu (2013, 2018) also proposed a similar measure labeled as VAX_G. While that measure is the same as VAX-D at the country aggregate level, it differs at the sector, bilateral, or bilateral-sector level. Note that VAX_G is consistent with GDP accounting at all levels of disaggregation, with the property of additivity, a feature that the VAX-D measure does not have.

[6] Note that VAX-D is impacted by trade barriers in downstream third countries including those outside the trade agreements. In quantifying the effects of trade agreements, the VAX_D captures only the first order but not higher order effects.

goods are exported to another country. The last category is value added in GVC activities, and can be further decomposed into simple and complex GVC activities based on the number of border crossings by factor content.

In simple GVC activities, factor content crosses national borders only once during the production process, with no indirect exports via third countries or re-export/re-import activities involved. Horizontal FDI would be an example of simple GVC activities. In complex GVCs, the factor content embodied in the products crosses national borders at least twice. Vertical FDIs often engage in complex GVC activities.

WWYZ (2017) also make a distinction between forward and backward linkages. In forward linkage-based accounting, the value added embodied in the production of intermediate goods for a given country-sector would be classified as "related to GVC activities" if it is exported to and used in the production by another country, and "unrelated to GVCs" if it stays within the national boundary during the entire production process. In the decomposition of final production based on backward linkages, value added is traced back to its country-sector origin, and would be classified as GVC related if and only if the associated factor content crosses national borders at least once for production purpose. (Factor content in the final goods exports by domestic firms also crosses national borders, but it is consumed/absorbed in the direct importing country, the associated production activity is not considered related to GVC.)

Note that none of the decomposition frameworks in the existing literature using the ICIO tables distinguishes between domestically owned and foreign owned firms. Implicitly, they all use a residence-based national account rules that treat all foreign firms within national borders the same way as domestic firms. In other words, the value-added creation by foreign affiliates in a country is treated as a part of the pure domestic production if it does not engage in cross border trade. Given the large and growing stocks of FDI in the world and the large sales by MNE affiliates in host country markets (without going through the international trade channel), the importance of global supply chains may be significantly underestimated by the existing literature. Our framework and the new data generated from the framework can help to overcome this limitation.

The two strands of the literatures are motivated by two separate questions.[7] First, how to connect gross trade statistics to GDP according to SNA standard? (This has motivated the framework developed in KWW 2014.) Second, how to decompose GDP and final goods production to properly identify GVC and non-GVC activities? This has motivated WWYZ 2017 (without consideration of FDI). The two questions are related but also distinct. The answer to the second question will help to define GVC participation indicators that are also consistent with the SNA standard. This paper addresses the second question with an explicit account of the presence of foreign firms in local economies.

The paper makes several contributions to the literature. First, incorporating the role of foreign-invested firms greatly improves the measurement of GVC activities. Antras (2020) notes that the existing estimates of the GVC activities seem too small relative to one's intuition. Our framework roughly doubles the size of estimated GVC activities relative to the existing estimates.

Second, to the literature on foreign direct investment, we expand the standard taxonomy of FDI by going beyond horizontal versus vertical FDI (e.g., Alfaro and Charlton 2009, Ramondo, Rodriguez-Clare, and Tintelnot, 2015; Blanchard, Bown, and Johnson 2016; Alfaro, et al. 2019; Andrenelli, A. et al. 2019; Ramondo, Natalia, 2020). Earlier studies in this literature aim to address the question of why firm invest abroad and become MNEs. This literature distinguishes between market-seeking (horizontal) FDI that follows foreign demand and input (or efficiency)-seeking (vertical) FDI that explores lower-cost local production factors for the world market. More recent studies find increasingly complex arrangements made by MNEs for GVC activities, using a combination of FDI and trade, as well as a range of non-equity, contract-based partnerships (Andrenelli, A. et al. 2019). Using firm-level data with ownership information in many countries from Dun & Bradstreet that records whether a plant produces for local or international market, Ramondo (2020) finds that "vertical FDI should be understood more broadly as production fragmentation - not necessarily between two parties of the same corporation (like Intel), but between unrelated parties (like Apple–Foxconn) and hence, involving all types of trade flows." Most recent studies follow the methodology introduced by Alfaro and Charlton (2009), Antràs and Chor (2013) and Alfaro, et al. (2019), and combine firm-reported production activities with

[7] Only "Macro" GVC measures, as defined by Antras(2020), are discussed here. For review of "micro" GVC measures based on firm level data, one may read Antras (2020), and Atras and Chor (2021).

information from standard single country input-output tables. By measuring a firm's position on the supply chains (or "upstreamness"), this literature tests aspects of the property rights theory of firm boundaries and studies their integration choices along the GVCs. There are no "macro-level" measures at the economy-wide or sector-level to quantify the extent of FIE engagement in GVC activities serving local and global markets, respectively.

With our framework, we re-estimate the GVC activities related to foreign invested enterprises in 34 industries across 60 countries. We find that at the global level, FDI related GVC activities create about 14% of global GDP, of which the GVC activities involve both FDI and cross border trade create about 4.5 % of global GDP, while the trade-related GVC activities create only about 8% of the global GDP.

There are interesting variations by country income groups and by industry R&D Intensities. We find that the FDI-related GVC participation is consistently higher than trade related GVC participation worldwide, particularly in the R&D intensive high-tech sectors. We follow OECD's definition of high, mid, and low-tech sectors (based on R&D expenditure as a share of total input costs of a sector).

3. Foreign-invested Enterprises and GVC Activity

3.1 Accounting Framework

Suppose there are G economies and N industries, with two types of firms in each economy-sector: domestically owned enterprises (DOEs) and foreign invested enterprises (FIEs). The FIEs are affiliates of foreign MNEs. The inter-firm type, inter-industry, and cross-country linkages are described by an expanded inter-country inter-industry input-output (ICIO) table with firm type information described below in Table 2.

Table 2 Inter-Country Input-Output Account with Firm Ownership Information

Output / Input			Intermediate Uses							Final Uses				Outputs
			Country 1		Country 2		⋯	Country g		Country 1	Country 2	⋯	Country g	
			D	F	D	F	⋯	D	F					
Intermediate Inputs	Country 1	D	Z_{DD}^{11}	Z_{DF}^{11}	Z_{DD}^{12}	Z_{DF}^{12}	⋯	Z_{DD}^{1g}	Z_{DF}^{1g}	Y_D^{11}	Y_D^{12}	⋯	Y_D^{1g}	X_D^1
		F	Z_{FD}^{11}	Z_{FF}^{11}	Z_{FD}^{12}	Z_{FF}^{12}	⋯	Z_{FD}^{1g}	Z_{FF}^{1g}	Y_F^{11}	Y_F^{12}	⋯	Y_F^{1g}	X_F^1
	Country 2	D	Z_{DD}^{21}	Z_{DF}^{21}	Z_{DD}^{22}	Z_{DF}^{22}	⋯	Z_{DD}^{2g}	Z_{DF}^{2g}	Y_D^{21}	Y_D^{22}	⋯	Y_D^{2g}	X_D^2
		F	Z_{FD}^{21}	Z_{FF}^{21}	Z_{FD}^{22}	Z_{FF}^{22}	⋯	Z_{FD}^{2g}	Z_{FF}^{2g}	Y_F^{21}	Y_F^{22}	⋯	Y_F^{2g}	X_F^2
	⋮	⋮	⋮	⋮	⋮	⋮	⋱	⋮	⋮	⋮	⋮	⋱	⋮	⋮
	Country g	D	Z_{DD}^{g1}	Z_{DF}^{g1}	Z_{DD}^{g2}	Z_{DF}^{g2}	⋯	Z_{DD}^{gg}	Z_{DF}^{gg}	Y_D^{g1}	Y_D^{g2}	⋯	Y_D^{gg}	X_D^g
		F	Z_{FD}^{g1}	Z_{FF}^{g1}	Z_{FD}^{g2}	Z_{FF}^{g2}	⋯	Z_{FD}^{gg}	Z_{FF}^{gg}	Y_F^{g1}	Y_F^{g2}	⋯	Y_F^{gg}	X_F^g
Value added			Va_D^1	Va_F^1	Va_D^2	Va_F^2	⋯	Va_D^g	Va_F^g					
Total Inputs			X_D^1	X_F^1	X_D^2	X_F^2	⋯	X_D^g	X_F^g					

where Z is a $N\times N$ matrix of intermediate input flows across firm types, sectors, and countries. The two superscripts represent the supply country and the demand (using) county, respectively. The two subscripts represent the types of the supplying and using firms, respectively, where D and F indicate domestically owned firms and FIEs, respectively. For example, Z_{FD}^{sr} represents an intermediate use matrix of products that are produced by FIEs in country *s* and used as inputs by domestically owned firms in country *r*. Y is a $N\times 1$ final use vector, with the superscripts representing the supplying and using counties, respectively, and the subscripts representing the ownership types of the producing firms. For instance, Y_D^{sr} represents final products produced by DOEs in country *s* and consumed in country *r*; X is a $N\times 1$ vector of gross outputs, X_D^s giving gross outputs of the DOEs in country *s*; and Va denotes a $1\times N$ vector of direct value added, Va_F^s represents direct value-added created by the FIEs in country *s*.

With such an ICIO account, the input coefficient matrix can be computed as

$A = Z\hat{X}^{-1} = \begin{bmatrix} A_{DD}^{11} & A_{DF}^{11} & \cdots & A_{DD}^{1g} & A_{DF}^{1g} \\ A_{FD}^{11} & A_{FF}^{11} & \cdots & A_{FD}^{1g} & A_{FF}^{1g} \\ \vdots & \vdots & \ddots & \vdots & \vdots \\ A_{DD}^{g1} & A_{DF}^{g1} & \cdots & A_{DD}^{gg} & A_{DF}^{gg} \\ A_{FD}^{g1} & A_{FF}^{g1} & \cdots & A_{FD}^{gg} & A_{FF}^{gg} \end{bmatrix}$, representing the value of intermediate inputs required to produce one unit of gross output by DOEs or FIEs, respectively, in a given sector and country. For example, A_{DF}^{sr} represents the value of intermediate inputs produced by DOEs in country s required to produce a unit gross output by FIEs in country r; where $\hat{X}$ denotes a diagonal matrix with the output vector *X* in its diagonal.

The classical Leontief (1936) inverse matrix reflecting the cross country, inter-industry, and between firm types linkages can be expressed as $B = (I - A)^{-1}$, which is also called the global total requirement coefficient matrix, giving the value of output of each firm type in each country-sector that is needed to satisfy one unit increase in the final demand anywhere in the world, where I is a G×N×2 by G×N×2 identity matrix.

Define a value-added coefficient vector as $V = Va\hat{X}^{-1} = \begin{bmatrix} V_D^1 & V_F^1 & \cdots & V_D^g & V_F^g \end{bmatrix}$. We can decompose global GDP production into a G×N×2 by G×N×2 square matrix $\hat{V}B\hat{Y}$ according to the source of value-added and place of final production(WWYZ, 2017), where $\hat{V}$ denotes a G×N×2 by G×N×2 diagonal matrix with elements of V at the diagonal, and $\hat{Y}$ represents another G×N×2 by G×N×2 diagonal matrix of final production of each country/sector/firm type pair as:

$$\hat{Y} = \begin{bmatrix} \hat{Y}_D^1 & 0 & \cdots & 0 & 0 \\ 0 & \hat{Y}_F^1 & \cdots & 0 & 0 \\ \vdots & \vdots & \ddots & \vdots & \vdots \\ 0 & 0 & \cdots & \hat{Y}_D^g & 0 \\ 0 & 0 & \cdots & 0 & \hat{Y}_F^g \end{bmatrix}$$

Where Y_D^i （$Y_D^i = \sum_k^G Y_D^{ik}$） and Y_F^i （$Y_F^i = \sum_k^G Y_F^{ik}$） are the final production vectors of the DOEs and FIEs in country *i*, respectively.

According to WWYZ (2017), a country-sector's GDP and production can each be decomposed into four types of supply-chain activities based on whether the factor content embodied in the products crosses national borders for production purpose and by how many times the border crossing takes place. Purely domestic value chains involve no factor content crossing national borders from production to consumption. "Classic trade" takes place when a product is

made in one country with domestic factors from that country alone and consumed in another countries. Simple global value chains take place when domestic value added embodied in a country-sector's intermediate inputs is exported and used in the production of the direct importing country and eventually consumed there. Finally, complex global value chains when the factor content crosses multiple borders. The decomposition formula is as follows:

$$\hat{V}B\hat{Y} = \hat{V}L\hat{Y}^L + \hat{V}L\hat{Y}^E + \hat{V}LA^E L\hat{Y}^L + \hat{V}LA^E(B\hat{Y} - L\hat{Y}^L) \quad (1)$$

Where B is the global Leontief inverse, reflecting the industrial linkages among all countries; $L = (I - A^L)^{-1}$, is the local Leontief inverse, reflecting linkages among various industries within each individual country. $\hat{Y}^L$ and A^L are diagonal sub-matrices of $\hat{Y}$ and A, and $\hat{Y}^E$ and A^E are off-diagonal sub-matrices of $\hat{Y}$ and A, respectively.

The four terms on the right hand of equation (1) are pure domestic value chains, classic trade, simple and complex GVCs respectively. Each term is an GN×GN matrix. Summing along the row provides a decomposition of GDP production (based on forward linkages). Summing along the columns provides a decomposition of final goods and services production (based on backward linkages). This is the beauty of equation (1) in matrix form which expresses the two decompositions of either forward or backward linkages in one unified formula.

Keeping track of both value-added created and final products produced by each type firm, we can split the value-added coefficient vector $\hat{V}$ and final product output vector $\hat{Y}$ as follows:

$$\hat{V} = \hat{V}_D + \hat{V}_F, \quad \hat{Y} = \hat{Y}_D + \hat{Y}_F, \quad \hat{Y}^L = \hat{Y}_D^L + \hat{Y}_F^L, \hat{Y}^E = \hat{Y}_D^E + \hat{Y}_F^E \quad (2)$$

where $V_D = \begin{bmatrix} V_D^1 & 0 & \cdots & V_D^g & 0 \end{bmatrix}$ and $V_F = \begin{bmatrix} 0 & V_F^1 & \cdots & 0 & V_F^g \end{bmatrix}$ are direct value-added coefficient vectors of DOEs and FIEs, respectively, in various country-sectors; $\mathrm{Y}_D = \begin{bmatrix} Y_D^1 & 0 & \cdots & Y_D^g & 0 \end{bmatrix}'$ and $\mathrm{Y}_F = \begin{bmatrix} 0 & Y_F^1 & \cdots & 0 & Y_F^g \end{bmatrix}'$ are final production outputs of DOEs and FIEs in various industries within each country respectively[8]; $Y_D^L = \begin{bmatrix} Y_D^{11} & 0 & \cdots & Y_D^{gg} & 0 \end{bmatrix}'$ and $Y_F^L = \begin{bmatrix} 0 & Y_F^{11} & \cdots & 0 & Y_F^{gg} \end{bmatrix}'$ represent final production of DOEs and FIEs in various industries that satisfies host country's domestic final demand respectively; $Y_D^E = \mathrm{Y}_D - Y_D^L$ and $Y_F^E = \mathrm{Y}_F - Y_F^L$ are exports of final goods and services of DOEs and FIEs for various country/industry pairs respectively.

[8] Where the superscript ′ denotes a transpose operation.

Inserting these coefficient vectors （$\hat{V}_D$ and $\hat{V}_F$） and （$\hat{Y}_D$, $\hat{Y}_F$, $\hat{Y}_D^L$, $\hat{Y}_F^L$, $\hat{Y}_D^E$ and $\hat{Y}_F^E$） in equation (2) into equation (1), we have

$$\hat{V}B\hat{Y} = \left(\hat{V}_D + \hat{V}_F\right)L(\hat{Y}_D^L + \hat{Y}_F^L) + \left(\hat{V}_D + \hat{V}_F\right)L(\hat{Y}_D^E + \hat{Y}_F^E) + \left(\hat{V}_D + \hat{V}_F\right)LA^E L(\hat{Y}_D^L + \hat{Y}_F^L)$$
$$+\left(\hat{V}_D + \hat{V}_F\right)LA^E[B(\hat{Y}_D + \hat{Y}_F) - L(\hat{Y}_D^L + \hat{Y}_F^L)] \quad (3)$$

Expending (3), we can obtain following equation

$$\hat{V}B\hat{Y} = \hat{V}_D L\hat{Y}_D^L + \hat{V}_D L\hat{Y}_F^L + \hat{V}_F L\hat{Y}_D^L + \hat{V}_F L\hat{Y}_F^L + \hat{V}_D L\hat{Y}_D^E + \hat{V}_D L\hat{Y}_F^E + \hat{V}_F L\hat{Y}_D^E + \hat{V}_F L\hat{Y}_F^E$$
$$+\hat{V}_D LA^E L\hat{Y}_D^L + \hat{V}_D LA^E L\hat{Y}_F^L + \hat{V}_F LA^E L\hat{Y}_D^L + \hat{V}_F LA^E L\hat{Y}_F^L + \hat{V}_D LA^E\left(B\hat{Y}_D - L\hat{Y}_D^L\right) \quad (4)$$
$$+\hat{V}_D LA^E(B\hat{Y}_F - L\hat{Y}_F^L) + \hat{V}_F LA^E(B\hat{Y}_D - L\hat{Y}_D^L) + \hat{V}_F LA^E(B\hat{Y}_F - L\hat{Y}_F^L)$$

Rearranging terms in (4) according to the source of value-added and their use in final production by firm types, we obtain a 16-term decomposition equation that distinguishes between DOEs and FIEs as follows:

$$\begin{aligned}\hat{V}B\hat{Y} = {} & \hat{V}_D L\hat{Y}_D^L + \hat{V}_D L\hat{Y}_D^E + \hat{V}_D LA^E L\hat{Y}_D^L + \hat{V}_D LA^E(B\hat{Y}_D - L\hat{Y}_D^L) \\ & +\hat{V}_D L\hat{Y}_F^L + \hat{V}_D L\hat{Y}_F^E + \hat{V}_D LA^E L\hat{Y}_F^L + \hat{V}_D LA^E(B\hat{Y}_F - L\hat{Y}_F^L) \\ & +\hat{V}_F L\hat{Y}_D^L + \hat{V}_F L\hat{Y}_D^E + \hat{V}_F LA^E L\hat{Y}_D^L + \hat{V}_F LA^E(B\hat{Y}_D - L\hat{Y}_D^L) \\ & +\hat{V}_F L\hat{Y}_F^L + \hat{V}_F L\hat{Y}_F^E + \hat{V}_F LA^E L\hat{Y}_F^L + \hat{V}_F LA^E(B\hat{Y}_F - L\hat{Y}_F^L)\end{aligned} \quad (5)$$

The sixteen terms on the right hand side of Equation (5) are organized into four rows and four columns. For ease of discussion, we use Home to refer to the country whose value added will be tracked in the following discussion. We first look at the decomposition by rows. The first row traces how the value added generated by the DOEs is used in the final production activities by the DOEs. The second row traces how the value added generated by the DOEs is used by the FIEs in the latter's final production activities. The third row traces how the value added generated by the FIEs in Home is used in final production activities by the DOEs. Finally, the fourth row traces how the value added generated by the FIEs in Home is used in the final production activities by the FIEs in both Home and direct importing countries. A more detailed explanation for each of the 16 terms can be found in Appendix A.

We then look at the decompositions by columns. The first column decomposes final production activities in Home that satisfy its domestic final demand. The second column decomposes final production activities in Home that satisfies the final demand of foreign countries. The third column decomposes the production in Home of intermediate exports that satisfies the final demand in the direct importing countries. The fourth column decomposes the production in

Home of the intermediate exports that are in turn used in the production for exports by the direct importing countries to satisfy the demand in the world market. Our framework can also be summarized by the following table:

Table 3 Value-added and Final Production Decomposition with FIEs

Production activities / Source and destination of value-added		Domestic production in host country	Final exports production in host country	Simple intermediate exports production	Complex intermediate exports production
Value-added generated by DOEs	Used in final production by DOEs	$\hat{V}_D L \hat{Y}_D^L$	$\hat{V}_D L \hat{Y}_D^E$	$\hat{V}_D L A^E L \hat{Y}_D^L$	$\hat{V}_D L A^E (B \hat{Y}_D - L \hat{Y}_D^L)$
	Used in final production by FIEs	$\hat{V}_D L \hat{Y}_F^L$	$\hat{V}_D L \hat{Y}_F^E$	$\hat{V}_D L A^E L \hat{Y}_F^L$	$\hat{V}_D L A^E (B \hat{Y}_F - L \hat{Y}_F^L)$
Value-added generated by FIEs	Used in final production by DOEs	$\hat{V}_F L \hat{Y}_D^L$	$\hat{V}_F L \hat{Y}_D^E$	$\hat{V}_F L A^E L \hat{Y}_D^L$	$\hat{V}_F L A^E (B \hat{Y}_D - L \hat{Y}_D^L)$
	Used in final production by FIEs	$\hat{V}_F L \hat{Y}_F^L$	$\hat{V}_F L \hat{Y}_F^E$	$\hat{V}_F L A^E L \hat{Y}_F^L$	$\hat{V}_F L A^E (B \hat{Y}_F - L \hat{Y}_F^L)$

From this table we can see clearly that in the first cell of the first row (marked green) both the source of value-added and final completion of production to satisfy domestic final demand is by DOEs, the whole production process is completed within the host country, thus can be defined as pure domestic production activities. The second cell of the first row (marked blue) the source of value-added and completion of final exports production is by DOEs, which can be defined as traditional trade production activities. The first two cells are value-added produced by DOEs used in their own final production, there is no production sharing involved and defined as Non-GVC Activities. In the last two cells of the first row (marked yellow) both the source of value-added and production activities is also conducted by DOEs，but there is factor content embodied in intermediate trade flows cross national border for production, therefore can be defined as trade related GVC Activities. Cells in the rest three rows are all interreacted with FIEs in the host country，thus can be defined as direct investment related GVC activities. Among them the first two cells in the second, third and fourth columns (marked grey) are missed GVC activities in WWYZ (2017). The economic interpretation of each of the 16 terms is list in the Appendix A.

Based on the GVC and non-GVC activities defined in table 3, we can combine some cells

and simplify equation (5) as follows:

$$\hat{V}B\hat{Y} = \underbrace{\underbrace{\hat{V}_D L\hat{Y}_D^L}_{\substack{Pure\ domestic\ production \\ (1)V\_D}} + \underbrace{\hat{V}_D L\hat{Y}_D^E}_{\substack{Traditional\ trade \\ (2)V\_RT}}}_{non-GVCsactivities} + \underbrace{\hat{V}_D L\mathrm{A}^E B\hat{Y}_D}_{\substack{trade-related\ GVCs \\ (3)V\_GVC\_T}}$$
$$+ \underbrace{\hat{V}_D L\hat{Y}_F^L + \hat{V}_D L\hat{Y}_F^E + \hat{V}_F L\hat{Y}_D^L + \hat{V}_F L\hat{Y}_D^E + \hat{V}_F L\hat{Y}_F^L + \hat{V}_F L\hat{Y}_F^E}_{\substack{FDI-related\ GVCs \\ (4)V\_GVC\_I}} \quad (6)$$
$$+ \underbrace{\hat{V}_D L\mathrm{A}^E B\hat{Y}_F + \hat{V}_F L\mathrm{A}^E B\hat{Y}_D + \hat{V}_F L\mathrm{A}^E B\hat{Y}_F}_{\substack{Trade\ and\ FDI\ related\ GVCs \\ (5)V\_GVC\_TI}}$$

The 12 terms in the right hand of equation (6) can be classified into 5 types of production activities, each of them has a clear economic meaning as follows: The first three items are pure domestic value production, traditional trade production and trade-related global value chain activities. Each of them can be interpreted as follows:

The first term $\hat{V}_D L\hat{Y}_D^L$ is value-added created by DOEs used by their final production to satisfy domestic final demand. In other words, DOEs are both the supplier of value-added and the final product producers, and the whole process from production to consumption takes place within the host country. There is no foreign factor content involved.

The second term $\hat{V}_D L\hat{Y}_D^E$ is value-added created by DOEs but embedded in the final goods exports to satisfy the final demand abroad. While DOEs are also both the supplier of value-added and the producers of final products, and the production takes place within one country, but the value added is consumed abroad. There is no factor content crossing border for production either.

The third term $\hat{V}_D L\mathrm{A}^E B\hat{Y}_D (= \hat{V}_D L\mathrm{A}^E L\hat{Y}_D^L + \hat{V}_D L\mathrm{A}^E \left(B\hat{Y}_D - L\hat{Y}_D^L\right)$) is value-added embodied in intermediate exports that are produced by DOEs in the host country, but is used by the direct importing country to produce final products either for domestic final demand (simple GVC activities) or for exports to third countries. DOEs in both the original country and the direct importing country participate in the production of the final good. Factor content crosses national borders at least once through intermediate input trade, so can be labeled as trade-related simple and complex GVC activities.

The fourth type is the GVC activities of FIEs in a host country, and can be further divided into six terms: The first two terms ($\hat{V}_D L\hat{Y}_F^L$ and $\hat{V}_D L\hat{Y}_F^E$) are value added originally created by DOEs

in the host country but used by FIEs in the final production to satisfy final demand in domestic (host country) and foreign markets respectively. In this case, the DOEs are the upstream value-added suppliers and the FIEs are in the downstream. Because the FIEs have used local inputs but also sell locally, they possess properties of both horizontal and vertical FDIs if we are to use the traditional terminology for FDI types. The third and fourth terms ($\hat{V}_F L\hat{Y}_D^L$ and $\hat{V}_F L\hat{Y}_D^E$) within the fourth type are value added generated by the FIEs in a host country but used in the final production of host-country DOEs to satisfy final demand in the domestic and global markets, respectively. In this case, the FIEs are located in the upstream, whereas the DOEs are in the downstream. While we can call both as part of the vertical FDI, the term would not capture the nuanced differences between them. The last two terms ($\hat{V}_F L\hat{Y}_F^L$ and $\hat{V}_F L\hat{Y}_F^E$) are value added created by one set of FIEs in a host country but is used by potentially a different set of FIEs in their final goods and service production to satisfy final demand in either domestic or foreign markets. Technically, both are a subset of vertical FDIs. However, we see that it is both useful and feasible to disaggregate the value added in FDI-related GVC activities into several different sub-categories. This would require going beyond the distinction between vertical versus horizontal FDIs.

The last type involves both cross-border investment by FIEs and cross-border trade. It includes 3 terms: The first term $\hat{V}_D L\mathrm{A}^E B\hat{Y}_F$ $(= \hat{V}_D L\mathrm{A}^E L\hat{Y}_F^L + \hat{V}_D L\mathrm{A}^E (B\hat{Y}_F - L\hat{Y}_F^L))$ is value-added created by DOEs embodied in their intermediate exports that are used by FIEs in the direct importing countries to produce final goods and services that are either consumed domestically (in the direct importing country) or exported to other countries. In this case, the DOEs in the first country are the suppliers of value-added (in upstream) and the FIEs in the direct importing country are the users for their final production. As any production by FIEs already involves factor content crossing borders (from their source country S to the current host H, and their use of imported intermediate inputs implies another border crossing, the supply chain in this production sharing relationship would involve at least two border crossing of factor content. This type of complex GVC activities involve both FDI and trade.

The second term (of the last type) $\hat{V}_F L\mathrm{A}^E B\hat{Y}_D (= \hat{V}_F L\mathrm{A}^E L\hat{Y}_D^L + \hat{V}_F L\mathrm{A}^E \left(B\hat{Y}_D - L\hat{Y}_D^L\right))$ is value-added embedded in the exports of intermediate inputs that is created by the FIEs in the host country and used by the DOEs in the direct importing country in final production for both local and global markets. The FIEs in the first country are the suppliers of value-added located in the

upstream, and the DOEs in the direct importing country are the users in final production located in downstream. Since the presence of the FIEs in the first country is already a consequence of foreign capital crossing national borders, the intermediate exports by the FIEs in the first country to DOEs in the second country involves factor content crossing national borders at least twice. This is another form of complex GVC activities involving both trade and FDI.

The third term (of the last type) $\hat{V}_F LA^E B\hat{Y}_F$ $(= \hat{V}_F LA^E L\hat{Y}_F^L + \hat{V}_F LA^E (B\hat{Y}_F - L\hat{Y}_F^L)$ is value-added embedded in the exports of intermediate inputs that is created by the FIEs in the first country and used by the FIEs in the second country (the direct importing country) for final production that are either consumed locally (in the direct importing country) or exported to other countries. The FIEs in the first country are the suppliers of value-added located in the upstream, and the FIEs in the second country (the direct importing country) are the users in downstream. This is the third form of complex GVC activities involving both trade and FDI.

To summarize, production activities are not GVCs if they are performed only by DOEs within a country with no imported factor content used in the production. Otherwise, production would be GVC activities as it involves factor content from more than one country. Among the GVC activities, some involve jus trade, labeled by GVC-T, some involve just FDI, labeled as GVC-I, and some involve both FDI and trade, labeled as GVC_TI. Note that the GVC_I component has not be identified by the previous literature on GVC measurement. We will show in the next section that this missing component is quantitatively large. In addition, the sum of type 3 and 5 yields the GVC activities related to intermediate exports, and equals to the measure of GVC activities defined in Wang et al (2017).

Similar to equation (1), each of the five types in the right hand of equation (6) is a G×N×2 by G×N×2 matrix. Since summing along a row yields the country/sector GDP, this provides a GDP decomposition based on forward linkages as depicted in Figure 2. On the other hand, since summing along the columns gives the value of the final goods and services, this provides a decomposition of the final goods and services production based on backward linkages as depicted in Figure 3 (with more details in Appendix B).

Figure 2: A Map of Value Added in a Country in Relation to GVC Participation

(by firm ownership, sector, and country)

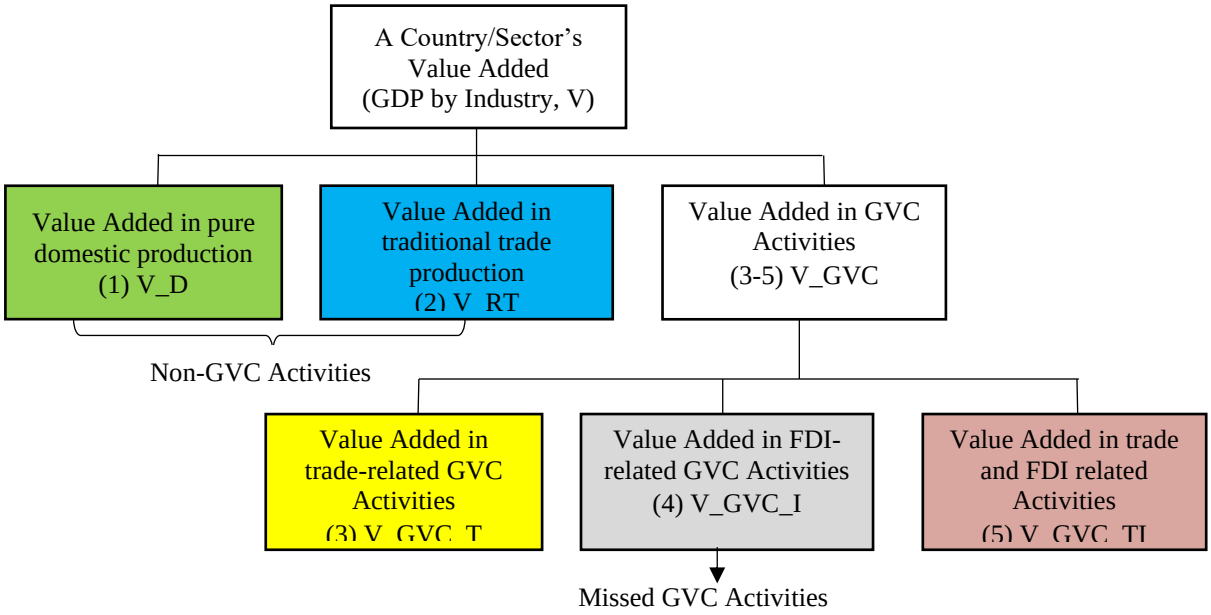
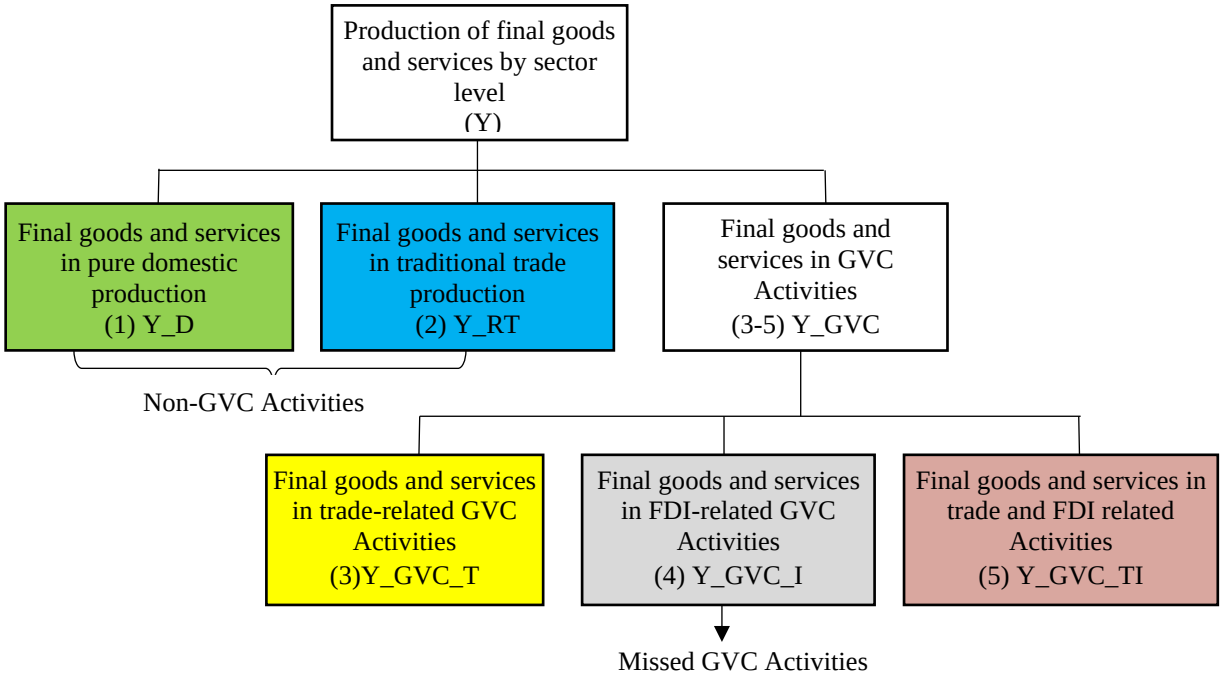


Figure 3: Production of Final Goods and Services and GVC Participation

(by Firm Ownership, Sector, and Country)



This extended accounting framework identifies components that are previously unidentified or misidentified in the existing literature. In particular, "V_GVC_I/Y_GVC_I" is the

"missed" or uncounted GVC activities by the affiliates of foreign MNEs in the host country market, while the earlier work treats all firms' domestic sales and final goods exports, including the sales in the host country by FIEs either as "Pure Domestic Production" or as "Traditional Trade" activities. The decomposition frameworks in the existing literature do not recognize an important feature of the real world that production by FIEs always involves some foreign factor (foreign capital, or other "intangible" assets)[9].

Applying the accounting framework, we also generalize the GVC participation indexes proposed in Wang et el. (2017) by taking FDI-related GVC activities into account. In particular, the GVC participation measure based on forward industrial linkages is

$$GVCP\_f = \frac{V\_GVC}{Va'} = \frac{V\_GVC\_T}{Va'} + \frac{V\_GVC\_I}{Va'} + \frac{V\_GVC\_TI}{Va'} \quad (7)$$

Similarly, the GVC participation measure based on backward industrial linkages is

$$GVCP\_b = \frac{Y\_GVC}{Y'} = \frac{Y\_GVC\_T}{Y'} + \frac{Y\_GVC\_I}{Y'} + \frac{Y\_GVC\_TI}{Y'} \quad (8)$$

3.2 Ownership-based value added under the extended GVC accounting framework

As an economy-wide value-added measure, GDP is "territory-based," it differs from total income of a country generated (GNI) by their worldwide investment and trade activities. An important part of the difference between the two is bilateral transfer of investment income between the host country of FIEs and their source countries [10]. Categories 4-5 of equation 6 measure the value added created by MNEs production and trade activities from different perspectives. In other words, sub-terms 3, 4, 5 and 6 of category 4 ($\hat{V}_F L\hat{Y}_D^L$, $\hat{V}_F L\hat{Y}_D^E$, $\hat{V}_F L\hat{Y}_F^L$ and $\hat{V}_F L\hat{Y}_F^E$), and sub-terms 2 and 3 of category5 ($\hat{V}_F LA^E B\hat{Y}_D$, $\hat{V}_F LA^E B\hat{Y}_F$) in Equation (6) are part of GDP of the host country

[9] The "simple GVCs" defined in our earlier work (Wang et al, 2017) do not distinguish between arms-length transactions and transactions organized by subsidiaries of MNEs in the host countries. By tracking ownership status, export sales by FIEs in a country are more likely to be a part of an international production network.

[10] As pointed out by Bohn, Brakman and Dietzenbacher (2021) "value added generated within a country does not necessarily result in income for that country. Although a large share of the value added is absorbed by the host country's residents in the form of wages, reinvested earnings, and profits, a substantial share of MNEs' earnings is repatriated as income to owners in the home country of the MNEs."

based on the territory rule of national accounts, but a large portion of the value-added is actually returns to FDI that will be attributed to the source countries (parent companies of the FIEs).[11]

The OECD AMNE database also includes the estimates of gross outputs of MNEs at the source-host pair and sector level, which can be represented by the following matrix:

$$\mathrm{X}_M = \begin{bmatrix} X_F^{ss} & X_F^{sr} & X_F^{st} \\ X_F^{rs} & X_F^{rr} & X_F^{rt} \\ X_F^{ts} & X_F^{tr} & X_F^{tt} \end{bmatrix}$$

Every cell in the matrix is a bilateral gross output vector (1 by N)， with the two letters in its superscript representing the source and host countries of FIE, respectively. For instance， X_F^{sr} represents the gross outputs of foreign invested enterprises from source country s in host country r. Different elements of the vector represents different sectors. This means that X_M is a G by GN matrix， with its rows representing source countries of FIEs, and its columns representing gross outputs of foreign affiliates in different sectors. The sum of the elements in matrix X_M over the columns yields the total output of all FIEs from different source country in the host country. Computing the ratio of each element to its column sum, one can obtain a weight matrix W_M as follows:

$$W_M = \begin{bmatrix} W_F^{ss} & W_F^{sr} & W_F^{st} \\ W_F^{rs} & W_F^{rr} & W_F^{rt} \\ W_F^{ts} & W_F^{tr} & W_F^{tt} \end{bmatrix}$$

where $W_F^{sr} = X_F^{sr}(\hat{X}_F^{r})^{-1}$ is the proportion of the gross outputs of the FIEs from source s in host r in the total gross output of all FIEs located in host country r.

In practice, while a vast majority of the labor compensation in the value-added created by FIEs goes to the local labor force in the host country[12], the capital returns belong mostly to the source country. Under the assumption that the labor income of FIEs belongs to the host country,

[11] The first term in type 5 and the first two terms in type 4 ($\hat{V}_D L \mathrm{A}^E B \hat{Y}_F$; $\hat{V}_D L \hat{Y}_F^L$, $\hat{V}_D L \hat{Y}_F^E$) in equation 6 measures value-added generated by domestic firms that used as input in the final production of FIEs. They are both GDP and GNI of the host country.

[12] While some employees of FIEs may be expatriates, existing data does not allow one to partition labor income to those belonging to the source versus host countries. The balance of payments statistics from IMF suggests that laborer compensation is small relative to investment income in the international transfer of income.

and the capital income belongs to the source country, we can decompose the value added of the FIEs in a given host country into individual components belonging to different source countries. In particular, assuming homogeneity in the production technology in a given country/sector, the weight matrix W_M is used to distribute capital returns of foreign affiliates in each host country (the last four sub-items in term 4 and the last two sub-terms in term 5 in equation 6) back to their home country as shown in equation 9.

$$\widehat{W_M K V a_F} = W_M \hat{K} diag[\hat{V}_F L(Y_D^L + Y_D^E)] + W_M \hat{K} diag[\hat{V}_F L(\hat{Y}_F^L + \hat{Y}_F^E)]$$
$$+ W_M \hat{K} diag[\hat{V}_F L \mathrm{A}^E B \mathrm{Y}_D] + W_M \hat{K} diag[\hat{V}_F L \mathrm{A}^E B \mathrm{Y}_F] \quad (9)$$

where K represents the vector of the ratio of capital returns to total value-added of various sectors in each host country. Thus, through equation 9, FIEs' territory-based value-added vector (GN by 1, part of the GDP by industries of the host country) in the production decomposition result of equation 6 is transferred into an income distribution matrix (G by GN) reflecting the income of the home country from its MNEs. The first G represents the number of home countries, and the latter GN represents the numbers of host-country and sector pairs. The sum over the rows equals the value added (income) of the FIEs attributed to their source countries.

Each term of Equation 9 is a G by GN matrix, and the column sum is the value chain activities of FIE in the host country, which belongs to the GDP of the host country; the row sum is the value chain activities of the home country, which belongs to the GNI of the home country. Terms 1-2 of Equation 9 are the investment returns of FIEs created by FDI-related GVC activities in the host country, and terms 3-4 are investment returns of GVC activities related to both trade and FDI.

GVC participation rate (and its breakdown) can be defined either from GDP perspective based on the share of value added created through GVC activities in the GDP of the host country as equation (7) and (8), or or from GNI (income) perspective according to how much of a country's GNI is generated by GVC activities based on equation (9). .

4. Decomposition Results: FIEs and GVCs around the World

A new OECD database by linking the Analytical Database on Multinational Enterprises (AMNE) with the Inter-Country Input Output (ICIO) tables (2019 version) allows for a distinction

between domestic firms and FIEs in each country-sector.[13] It covers 34 sectors in 59 individual countries plus a composite "rest of the world" from 2005-2016. With our accounting framework, we compute the extent of production sharing and GVC activities in both GDP and final goods production with separate roles of foreign invested enterprises (FIEs) and DOEs (domestically owned enterprises).

We first report in Section 4.1 the results on five main production activity groups based on equation (6), i.e., pure domestic production activities, labeled as D (corresponding to the green cell in Table 3); traditional trade related production activities, labeled as RT (the blue cell); trade related GVC activities, labeled as GVC_T (the terms marked yellow); FDI related GVC activities, labeled as GVC_I (the terms marked grey); and both trade and FDI related GVC activities, labeled as GVC_TI (the terms marked red), respectively. Then in section 4.2, we further decompose the FDI-related production activities (GVC_I and GVC_TI) into 9 detailed sub-terms, with attention to their economic significance.

4.1 Production Decomposition that Takes into Account the FIEs

4.1.1 Global Patterns

We summarize the decomposition results (value added creation by type in GDP) for the world economy during 2005-2016 in Figure 4. A few patterns are especially noteworthy. First, purely domestic activities (use of domestic factors to produce for domestic final demand) still account for the lion's share of the global GDP, and its relative importance appears counter-cyclical. In particular, it decreases during the growth phase and expands during the Great Recession of 2008-2009. Second, the value added associated with FDI-related GVC activities (GVC-I) is consistently greater than that of either trade-related GVC activities (GVC-T) or non-GVC trade (RT). While the value added creation in the GVC activities involving trade (both GVC-T and GVC-TI) shrank during the global financial crisis, the value added creation in the FDI related GVC activities that do not involving cross border trade (GVC-I) stay relatively stable as a share of global GDP. As these measurements are new, such accounting may help with future research that needs a way to quantify the aggregate roles of trade and MNE affiliates in GVCs and to see their evolution over business cycles.

[13] For details, see *https://www.oecd.org/sti/ind/analytical-AMNE-database.htm*

<Insert Figure 4 here>

We plot the annual growth rates of the value added creation from different types of production activities (Figure 5). During 2005-2008, there had been a dramatic expansion of the GVC activities. The Global Financial Crisis and the subsequent recessions in Europe appear to have impacted the trade related value added creation much more than the FDI-related value creation.

<Insert Figure 5 here>

4.1.2 Country Patterns

Individual country experiences regarding to the relative sizes of different GVC activities may vary by country characteristics. For example, small open economies may involve in both more regular trade and more GVC activities than large economies. As small economies likely both receive more inward FDI and do more trade as a share of their economic size than larger economies, it may not be clear *ex ante* whether they do more FIE-related or trade related value creation.

As an illustration, Table 4 reports the GDP decomposition results for three small open economies, namely, Singapore, Hong Kong, Netherlands, and two large economies, namely, the United States, and China, in 2005, 2008 and 2016, respectively. Both Singapore and Hong Kong are small in terms of territorial size although not necessarily so in terms of population. Importantly, both are known to pursue more open trade and FDI policies than either China, the United States, or the European Union.

<Insert Table 4 here>

For Singapore, the value added purely from and for the domestic market is about 20% in 2005, rising to about 30% by 2016, based on either the forward linkages or the backward linkages. The value added involved in global value chains or classic trade accounts for 80% of the GDP in 2005, and declined to about 70% in 2016. Because of the presence of many foreign invested firms in the country, the two types of FDI-related value added, those that do not involve trade (GVC_I) and those involve both trade and FDI (GVC_TI) account for approximately 30%of the GDP each. This shows the very open nature of the Singaporean economy and its high degree of embeddedness in global value chains. These numbers suggest that describing GVC activities without taking into account FIEs in the country would have missed a significant portion of GVC activities.

Hong Kong has a slightly bigger economy than Singapore but equally open to trade and foreign investment. In shares of GDP, its GVC_I and GVC_TI components are also higher than the counterparts of the larger economies in our sample. Nonetheless, these shares are still noticeably lower than that of Singapore. Hong Kong may be special in some ways. Many firms, while with significant foreign factor content, may be classified in the OECD database as local firms. For example, Jardine Matheson, a large and diversified conglomerate founded by British and still run by people with foreign passports, may be classified as a local conglomerate as it is headquartered in Hong Kong. Even HSBC, founded in Hong Kong and has twice declared Hong Kong as its home base or co-home base, might be classified as a local firm too. While such examples may be present in many other economies, the economic significance of such quasi-foreign firms may be especially big in Hong Kong given its history.

The third case is Netherlands, which is well-integrated in the world economy, especially with other European countries. Based on forward linkages in GDP decomposition (the left column of Table 4), its value added that is from domestic factor and absorbed in the local market accounts for 61% of its GDP in 2005, which is almost 20 percentage points below the world average in that year, declining further to about 56% in 2016. A noteworthy feature of the Netherlands is that its GVC_I component, the share of the value added that is linked to FIEs, is bigger than most countries in the sample, rising from 14% of its GDP in 2005 to 17% by 2016. In comparison, its value added component involving final goods trade but no FIEs is much lower at between 6-7%. The value added component involving GVC trade (those with imported or exported intermediate goods but no FDI) is about 10% of GDP, approximately the same as that involving in both trade and FIEs (GVC_TI), but lower than that involving FIEs without trade (GVC_I). This example also shows the inaccuracies in describing value added in GVC activities without considering FIEs.

The fourth case is the United States. As the world's largest economy, it is perhaps unsurprising that more than 80% of its value added created by the local factor content is absorbed in the country. Still, for the value added components related to US participation in global value chains, the part related to the FIEs (the sum of GVC_I and GVC_TI) is greater than the part involving just trade (the sum of GVC_T and GVC_TI).

The fifth case, China, is the largest developing country, the largest exporter in the world and one of the largest importers, and the largest developing country host of inward FDI. Its value added related to FIEs as a share of GDP (measured by GVC_I +GVC_TI) is slightly lower than that

involving trade (the sum of GVC_T and GVC_TI) in 2005, but has evolved to surpass the latter by 2016. The Chinese estimates also confirm our point that a country's participation in GVCs would have been substantially underestimated based on the ICIO tables that do not account for the presence of FIEs.

For the world as a whole (the last panel in Table 4), the value added creation related to global value chains is about 20% of global GDP. Out of this, more than half are related to FIEs, including about 10% of global GDP by GVC_I, and another 4% by GVC_TI. In other words, recognizing the role of FIEs is crucial for an accurate account of the extent of GVC activities.

Table 5 lists the top and bottom five economies in terms of GVC_I as a share of GDP based on either forward or backward linkages, respectively. In terms of the forward linkages, Hong Kong, Czech Republic, Singapore, Romania, and Hungary have the highest shares (from 29-36%), whereas Korea, Russia, Japan, Saudi Arabia, and Israel have the lowest shares (0.9-4.2%). It might be somewhat surprising to see Japan and Korea on the list of lowest GVC_I share, but both have relatively high barriers on inward FDI and consequently a relatively small amount of FIEs.

<Insert Table 5 here>

Based on the backward linkages, the top five economies in terms of GVC_I share are Singapore, Hong Kong, Czech Republic, Romania, and Ireland (between 27-35%), whereas the bottom five economies are India, Korea, Japan, Saudi Arabia, and Israel (between 0.7-4.0%).

4.1.3 Sector Patterns (with Different R&D Intensities)

The relative importance of FDI-related GVC participation may also vary across sectors within a country. Based a sector's R&D intensity, the OECD classifies manufacturing sectors into "high tech", "medium tech" and "medium-low tech" categories. We compare the different degrees and forms of GVC participation between high-tech and other sectors and compare them across country groups based on their incomes.

Table 6 shows the share of GVC activities and the FDI-related share in GVC activities by country income groups and sector-level R&D intensities. We observe the following patterns for both the forward and backward-linkage decomposition results. First, for a given country group, the higher the R&D intensity of a sector, the higher the GVC participation of that sector. In other

words, the high-tech sector is most involved in \ GVC activities, and this pattern is true for each of the three income groups.

<Insert Table 6 here>

Second, in terms of the share of the FDI-related share in the GVC activities, the ratio is generally very high, on the order of 60% in all income groups and in almost all years. Such ratio is generally higher in high-tech sectors than in medium or low-tech sectors.

Third, the relative importance of FIEs exhibits some differences across country groups. For high-income countries, the FIEs are also important in the medium or medium/low-tech sectors. In comparison, for the middle-income group, the FIEs are not as prominent in the medium and medium/low-tech sectors. These patterns suggest that any policy attempts to decouple, or reshoring manufacture production need to consider a tremendous amount of reorganization of the global production network, especially in the high-tech sectors.

We contrast the GVC participation patterns across the manufacturing sectors with High, Medium, Medium-Low R&D intensities for China and the United States, respectively. Our key findings are summarized in Figures 6 and 7. Similar to Table 6, the share of FDI-related GVC activities in the high-tech sector in both countries is higher than those in sectors with a medium R&D intensity. On the other hand, as shown in Figure 6, the share of FDI-related GVCs (the sum of GVC-I+GVC-TI) in Total GVC activities is always higher in the United States than in China for all sectors.

<Insert Figure 6 and 7 here>

The scatterplots in Figures 8 and 9 summarize the trade and FDI-related GVC participation rates in the manufacturing sectors in 2016, grouped by R&D intensities. A dot above the 45-degree line indicates a higher participation rate in FIE related than trade related GVC activities. For most countries, the FIE-related GVC share is higher than trade-related GVC share in high R&D intensity manufacturing sectors. This pattern does not exist in medium-low tech sectors.

<Insert Figure 8 and 9 here>

4.1.4 The "Missing" GVC Activities

The six terms in grey in the 16-term GDP decomposition formula in Table 3 are FDI-related GVC activities that do not show up in international trade statistics. They are collectively

represented by the GVC_I term in the computations reported so far. They may be regarded as "missing GVC activities" in previous trade focused GVC measures in the literature.

The "missing GVC activities" are roughly 10% of the global GDP (see Figure 4). The omission is more serious for high tech sectors than for medium-tech sectors, and more serious for high-income economies than middle-income economies (Table 6). They are also more serious for small open economies than for large economies (Tables 4-5).

The FIE- related GVC activities (GVC-I) in share of GDP varies significantly among the 60 economies in our sample. In highly open economies such as Hong Kong, Czech Republic, Singapore, Romania, Hungary and Ireland, the GVC-I participation rate reached 30-40 percent, while in Korea, Russia, Japan, Saudi Arabia and Israel, it is much lower.

Our measurement can be used to study the cyclical properties of global supply chains. For example, the FDI-related component of the GVC activities appears more stable than the trade-related GVC component. This suggests that the missing component of the GVC activities are less volatile than those parts already measured by the existing literature. This is especially true during the global financial crisis of 2008-2009. In other words, the cyclical feature of the GVC activities may be exaggerated by the existing method that does not consider the FIEs. Of course, a more formal analysis would be needed to make precise these relationships.

In Figure 10, we plot the time series of GVC activities as a share of global GDP both with FDI-related GVC activities - represented by the pink bars by the current method) and without (represented by the blue bars by the existing method). Without considering foreign invested firms and FDI-related GVCs, the GVC activities appear to be around 10% of the global GDP. However, once we consider FIEs and their role in GVCs, the GVC share in the global GDP is almost doubled to about 20%.

<Insert Figure 10 here>

In Figure 11, we present the "missed" GVC activities for high, upper-middle-income, and lower-middle income countries, respectively (in shares of their GDPs). The underestimation of the GVC activities is most severe for advanced countries, from about 10% to 30% of their GDP, because they host more FDIs and therefore have more FDI-related GVC participation. Lower-middle income countries exhibit the least amount of missed GVC activities due to the smallest presence of FDI as a share of world FDIs.

<Insert Figure 11 here>

In Figure 12, we see that the missing GVC activities are most serious for the manufacturing sector (accounting for about 14% of its value added), followed by services (about 6%), and agriculture and mining sectors (about 3%). This is consistent with a greater presence of FIEs in the manufacturing sector than in the other sectors. Based on sector average data, many modern investment and commercial banks, business consulting firms, and IT service firms appear to operate in more countries than their counterparts in the mining and agriculture industries.

<Insert Figure 12 here>

As examples, we plot the estimated size of the missing GVC activities in the motor vehicles and computer sectors in China, respectively, in Figure 13. In the motor vehicle industry, the missing part grows over time from about 17% of the industry's value added in 2005 to about 25% in 2016. This comes as a result of the increased foreign investment in the Chinese auto industry. Foreign owned auto companies buy inputs from local firms, which is an important part of GVC_I. The growing importance of these activities yields a growing value of GVC_I. In comparison, in the computer, electronics, and optical equipment industry, the GVC activities not accounted for by the existing method is about 10% throughout the sample period. While there is also increased foreign investment in this industry, the increased competitiveness of the local firms in this industry, including Huawei and Xiaomi, may have offset the market share gains by foreign firms both in and outside China.

<Insert Figure 13 here>

4.2 Portrait of FDI Structure: Further Disaggregation

Based on the types of production linkages between firms, and the way value added is used, GVC activities related to MNEs (GVC_I and GVC_TI, the fourth and fifth categories in equation (6)) in our decomposition framework are divided into nine more detailed types.

First, from the perspective of "inter-firm production sharing", the production activities of MNEs can be divided into the following three types:

(1) D-F: Domestic Firms in the Upstream, MNEs in the downstream;

(2) F-D: MNEs in the Upstream, Domestic Firms in the downstream;

(3) F-F: Production sharing between MNEs.

Second, from the perspective of "Value Added Use", the production activities of MNEs can also be divided into three types:

(1) GVC_I_D: Value-added to satisfy host country's domestic final demand;

(2) GVC_I_E: Value-added embodied in final goods and service exports to satisfy final demand abroad;

(3) GVC_TI: Value-added embodied in intermediate goods exports, which is to serve the demands of GVC production taking place in other countries.

By performing a 3x3 classification, our framework can provide a new portrait of FDI production in terms of relative significance of the activities in 9 sub-categories. In this section, we will analyze the structural differences across countries, industries, and years in these nine dimensions. That is, the so-called "Portrait" of FDI production structure.

We note that in principle we can perform a 16-term decomposition, more finely disaggregated than even the 12-term formula in equation (6). The mapping between the 16-term and the 12-term decomposition is described in Table 7 below.

Table 7 The relationship between the 16-term and 9-term decompositions

<table>
<tr><th colspan="2">Production activities
Source and destination of value-added</th><th>Domestic production in host country</th><th>Final exports production in host country</th><th>Simple intermediate exports production</th><th>Complex intermediate exports production</th></tr>
<tr><td rowspan="2">Value-added generated by Domestic firms</td><td>Used in final production by domestic firms</td><td colspan="4">Production activities done by DOEs only
$\hat{V}_D L \hat{Y}_D^L$</td></tr>
<tr><td>Used in final production by foreign affiliates</td><td>$\hat{V}_D L \hat{Y}_F^L$
1. (D-F, GVC_I_L)</td><td>$\hat{V}_D L \hat{Y}_F^E$
2. (D-F, GVC_I_E)</td><td>$\hat{V}_D L A^E L \hat{Y}_F^L$
3. (D-F, GVC_TI)</td><td>$\hat{V}_D L A^E (B \hat{Y}_F - L \hat{Y}_F^L)$</td></tr>
<tr><td rowspan="2">Value-added generated by FIEs</td><td>Used in final production by domestic firms</td><td>$\hat{V}_F L \hat{Y}_D^L$
4. (F-D, GVC_I_L)</td><td>$\hat{V}_F L \hat{Y}_D^E$
5. (F-D, GVC_I_E)</td><td>$\hat{V}_F L A^E L \hat{Y}_D^L$
6. (F-D, GVC_TI)</td><td>$\hat{V}_F L A^E (B \hat{Y}_D - L \hat{Y}_D^L)$</td></tr>
<tr><td>Used in final production by foreign affiliates</td><td>$\hat{V}_F L \hat{Y}_F^L$
7. (F-F, GVC_I_L)</td><td>$\hat{V}_F L \hat{Y}_F^E$
8. (F-F, GVC_I_E)</td><td>$\hat{V}_F L A^E L \hat{Y}_F^L$
9. (F-F, GVC_TI)</td><td>$\hat{V}_F L A^E (B \hat{Y}_F - L \hat{Y}_F^L)$</td></tr>
</table>

As explained before, the standard dichotomous characterization of FDI into horizontal versus vertical FDI does not fully capture the rich menu of ways by which multinational firms participate in global supply chains. For example, FIEs in a host country may combine foreign technology and capital to produce intermediate inputs in the host countries and then supply them to local firms to

produce for either local or the world market. FIEs may also buy intermediate inputs from local firms to produce for either the local market or the world market. Both are different from purely DOEs importing foreign intermediate inputs. Our framework allows us to track five different types of vertical integration.

A given multinational firm can simultaneously participate in multiple forms of FDI and GVC activities. Our framework provides a convenient and transparent way to distinguish these "compound" contributions by the FIEs to global supply chains. By incorporating ownership information in the ICIO tables, our framework can generate new value added data at the bilateral, sector, and ownership level. Such data could be used for future research on global supply chains.

4.2.1 Global Level

We begin by analyzing the structure of the production activities of MNEs at the global level.

（1）The use perspective

From the perspective of absorption, as shown in Figure 14, about half of the value added generated in FDI-related production activities serves directly the host country's local final demand (denoted by GVC_I_D), and this type of production activity is closest to the concept of "Horizontal FDI". The remaining half is closer to the concept of "Vertical FDI", with about 20 percent of the value added generated in FDI-related production activities being absorbed by final demand in other countries in the form of final goods exports (denoted by GVC_I_E), and another 30 percent being exported as intermediate inputs to serve subsequent production demand in GVCs (denoted by GVC_TI).

<Insert Figure 14 here>

The composition of FDI-related production activities fluctuates with economic ups and downs. During economic expansion, inter-country production sharing activities run smoothly, with production activities to meet GVC production demand (GVC_TI) expanding rapidly and production activities to meet local demand (GVC_I_D) contracting gradually; however, the opposite is true during recessions.

It is also worth noting that FDI-related production activities serving final demand in other countries (GVC_I_E) show a more stable trend. As this type of production activities

takes place entirely within a host country and does not involve production sharing with third countries, it suffers less from external shocks.

（2）Inter-firm production sharing

From the perspective of "inter-firm production sharing", the three types (D-F, F-D and F-F) had a similar share in 2005. Since then, there have been two noteworthy changes (Figure 15).

<Insert Figure 15 here>

First, the share of value added in D-F type production activities shrank significantly during the financial crisis. A look at individual country data shows that a large part of the decline in 2009 was driven by a decline in local production in certain countries, making it difficult to sustain the demand for intermediated inputs from downstream MNEs. Ten countries shown in Table 8 account for 65% of the decline in global D-F type value added. Besides the G7 economies, Mexico, which is closely linked to US production, and Saudi Arabia, an important energy supplier, are also on the list. China is not on the list because it avoided a recession during the GFC period.

<Insert Table 8 here>

Secondly, production sharing among MNEs within a host country (F-F type production activities) exhibits an upward trend. This suggests that some host markets have increasingly played a role of a “hub,”, providing opportunities and markets for production sharing among MNEs from various countries. Even during the financial crisis, the upward trend of F-F type production sharing activities continued.

From Figure 16, we see that the F-F type of production sharing activities (in % of host-country GDP) are higher for richer countries, indicating richer countries offering larger production and consumption markets and possibly a better business operating environment for FIEs. In emerging developing countries such as China, India, Indonesia, Philippines, Malaysia and Vietnam, changes in the structure of FDI-related production activities are driven by a rise in the D-F share. In other words, DOEs in these countries are more and more engaged in production sharing activities with MNEs as upstream intermediate goods suppliers. This would be consistent with industrial upgrading in these countries driven by integration with MNEs as a part of their global supply chains.

<Insert Figure 16 here>

（3）Further disaggregation

Finally, by combining the perspectives of "value added use" and "inter-firm production sharing", we can classify FDI-related production activities in a more disaggregated way. Table 9 shows the results in the first and last years of the sample (2005 and 2016, respectively), and the start of the financial crisis (2008). In the bottom half of Table 9, we present the relative changes between years (2008 versus 2005, and 2016 versus 2008).

<Insert Table 9 here>

There are a few notable patterns. First, inter-MNE production sharing activities (F-F) account for the largest share when the value added is directly used to meet final consumption demands, either locally (GVC_I_D) or in other countries (GVC_I_E). MNEs may use this type of cross-border investment to enter the host country, or to bypass trade barriers in third countries.

Second, when the value added created by FDI-related production activities continues to serve GVC production as intermediate inputs, there is significantly more production sharing between MNEs and DOEs in the host country (D-F, F-D) than between MNEs (F-F). This result reflects the cross-border production sharing by MNEs based on differences in comparative advantage between countries.

Furthermore, the biggest structural changes are a significant rise in the share of (D-F, GVC_I_D) type production activities during the economic growth period from 2005 to 2008. In particular, China and Korea exhibit an increase in their ability to supply intermediate goods and an increase in the size of their domestic markets, which drive the (D-F, GVC_I_D) growth.

After the financial crisis, the share of value added embodied in intermediate goods exports (DF, GVC), (FD, GVC), (FF, GVC) declined significantly, with the shares of the first two falling by more than 1 percentage point each. At the same time, market-oriented FDI activities rose, especially the production sharing among FIEs in the same host countries to meet the final demand of either the host countries (F-F, GVC_I_D) or other countries (F-F, GVC_I_E).

4.2.3 Country Level

To provide more intuition, we adopt a similar approach to the Euclidean distance to quantify the FDI structural differences.

The structural difference of FDI-related production activities between any two countries (i, j) can be calculated as:

$$DIF = \sum_{k=1}^{9} (Term_{i,k} - Term_{j,k})^2$$

For example, if we take the US as the benchmark country, the differences in FDI structure between the remaining 59 economies and the US are shown in Table 10. The higher the ranking, the greater the difference. Iceland has the largest gap in FDI structure with the US, followed by Saudi Arabia and Singapore.

<Insert Table 10 here>

For a given country i, the contribution of production activity k (k=1 to 9) to the difference in the structure of FDI between that country and the US can be calculated as:

$$\frac{(Term_{i,k} - Term_{USA,k})^2}{\sum_{k=1}^{9}(Term_{i,k} - Term_{USA,k})^2}$$

The results for six selected countries are shown in Table 11. When the share of a particular type of production activity is lower in country i than in the United States, we refer to the difference as a "negative difference", which is marked with a grey background in the table.

<Insert Table 11 here>

Saudi Arabia, as an important energy exporter, exhibits the second largest structural differences in FDI with the US. 60.5% of the structural difference comes from (D-F, GVC_TI), i.e. the share of production activities where "MNEs are in the downstream and DOEs are in the upstream, and value added is exported as intermediate goods" is significantly higher than in the US. In addition, the difference also stems from the three items in column 1, which together contribute 30.8% of the FDI structural difference between US and Saudi Arabia, indicating that FDI-related production activities that serving host country (Saudi Arabia)'s domestic final demand are significantly lower than in the US.

The main difference between Singapore and the U.S. comes from two aspects. (F-D, GVC_TI), where MNEs are in the upstream and DOEs are in the downstream, and where value added is exported as intermediate goods, which has a significantly higher share in Singapore than in the US. At the same time, similar to Saudi Arabia, the share of all three elements in the column

1 (FDI-related production activities that serve domestic final demand in Singapore) are lower than the US.

Germany, similar to the US, is a large high-income country, and may be expected to exhibit a similar pattern in global production sharing. Compared to the US, less of the value added created by FDI-related production activity in Germany serves its domestic final demand and a greater proportion is exported.

For China, a significantly lower proportion of value added generated by FDI-related production activities are used to meet its domestic final demand, while a larger proportion of value added is exported from China to directly serve the final demand of other countries or as intermediate goods for further use in GVC production. At the same time, somewhat surprisingly, a greater proportion of MNEs in China is located in the downstream of the DOEs. Korea is somewhat similar to China, with a greater proportion of FDI-related production activities serving consumption or production demand abroad.

Finally, for Ireland, a tax heaven for MNEs with very low corporate income tax to attract MNE headquarters, its domestic final demand is not a major concern for MNEs. The proportion of value added created by FDI-related production activity that is absorbed by local consumption is much lower than in the US, contributing almost half of the difference in the FDI structure between Ireland and the US. More of the value added created by FDI-related production activity is exported in the form of final or intermediate goods.

4.2.3 Sectoral Level

To illustrate sector level results, we report results for four sectors in Table 12.

<Insert Table 12 here>

First, in the Mining and Quarrying sector, consistent with MNEs desiring for "energy access," there is a high proportion of production activities (89.9%) with "DOEs in the upstream and MNEs in the downstream". At the same time, a significant proportion of the energy products obtained by MNEs, such as crude oil, metallic and non-metallic minerals, need to be returned to the MNEs' home country for subsequent production, and therefore the term (D-F, GVC_TI) accounts for a high share.

For “Textile and Textile Products”, the value added generated by FDI-related production activities is almost evenly distributed among the three types of production activities, which are used to meet the domestic final demand, foreign countries’ final demand and the further production needs of GVCs, respectively. As DOEs are more often located in the upstream (The share of “D-F” production activities is as high as 51.5%.), obtaining inputs from local firms appears to be a motivation for FDI in this sector.

For “Computer, Electronic and Optical Equipment”, which is an important high-tech sector, there is a significantly higher proportion of production sharing in the form of F-D or F-F. At the same time, a higher proportion of the value added generated by FDI-related production activities is used to serve the final demand of the host country. Companies that choose to invest abroad in this sector often have certain technological R&D advantages and are therefore located in the upstream of DOEs. In addition, choosing to enter the foreign market in the form of FDI may help MNEs to bypass potential trade barriers against final goods.

Finally, in the services sector "R&D and Other Business Activities", consistent with greater sensitivity of FDI to the final demand of host country's local market, more than half of the value added created by FDI-related production activities is absorbed by host countries’ final consumption. At the same time, production sharing between MNEs and DOEs accounts for more than 80% of FDI-related production activities, and only 20% is between MNEs. Through production linkages between MNEs and DOEs, this implies that there may be a spillover effect of MFNs on the industrial upgrading in the host country.

In addition, a significantly higher proportion of FDI-related value added is exported as intermediate goods in high-technology sectors - nearly 12 percentage points higher in technology-intensive manufacturing than in other manufacturing sectors, and about 7 percentage points higher in knowledge-intensive services than in other service sectors (Table 13).

<Insert Table 13 here>

4.2.4 Country-Sector Level

For illustration, we focus one the "Computer, Electronic and Optical Equipment" sector as an example and go deeper into the "country-sector" level to examine the structural differences in FDI-related production activities in a more disaggregated way.

Similar to the approach in Section 4.4.2, we use China's "Computer, Electronic and Optical Equipment sector" as a benchmark to calculate the FDI structural differences between the other economies and China, and the results are shown in Table 14.

<Insert Table 14 here>

In Table 15, the structural differences vis-à-vis China are reported for six countries.

<Insert Table 15 here>

The difference of the FDI structure between Japan (and Korea) and China is big, 81.5% is reflected in the term (D-F, GVC_TI), which is the production activities with DOEs in the upstream and FIEs in the downstream, and value added exported as an intermediate goods for next stage of GVC production. The share of this type of production activity is significantly higher in Japan than in China. For comparison, the difference between India and China is driven by a higher share of (F-F, GVC_I_D) type production activities in India. In other words, FIEs buy inputs from each other and serve the local market final demand in India more than in China. In the case of Singapore, MNEs are often located in the upstream of DOEs, with a greater proportion of the value added exported as intermediate goods for next stage of GVC production.

Vietnam is somewhat unique. FDI structure in that the country is similar to that of China, but with one key difference: DOEs in Vietnam are more likely to produce in the downstream of MNEs (possibly to provide assembly services).

The results for US and Germany suggest that their FDI-related production activities are more oriented towards their own final domestic demand than in China. A difference between German and the United States is that more production sharing between FIEs is seen in Germany than in the United States.

4.3 Ownership-Based Value-Added of MNEs

Using the approach outlined in section 3.2, we recompute MNEs' capital returns on cross-border investments under the ownership-based principle and compare them with those under the territory-based principle.

As shown in Table 16, for high income countries, MNE's ownership-based value added is significantly higher than territory-based value added, in other words, the net capital return on cross-border investment is positive for high income countries. For upper-middle income and

lower-middle income countries (especially the latter), the opposite is true, with net capital return on cross-border investment being negative on average, implying that outward payments of capital gains are higher than returns to capital from abroad.

<Insert Table 16 here>

China, as an important host country for foreign investment, has a negative net capital return on cross-border investment. The opposite is true for three developed countries, Germany, Japan and the US, which are top sources of outward investment. They all have positive net capital return for MNEs and therefore higher ownership-based value added than territory-based value added.

Because high-income countries account for the lion's share of outbound FDI, they are expected to account for more of the total capital gains based on ownership than on residence. Indeed, from Table 17, they account for about 72% of the global capital gains under the territory-based principle, but their share increases to 91% under the ownership-based principle, an increase by almost 20 percentage points.

<Insert Table 17 here>

Finally, we can also compute separate bilateral trade balance based on ownership versus territory principle. We report the bilateral balance between the United States and China (Figure 17) as an illustration. For example, the gross value of US trade deficit with China in 2016 was $251.5 billions. This number shrinks to $219.2 billion, a reduction by $32.3 Billion, or about 13 percentage points, when we look at the bilateral imbalance in value added term using the territory-based principle. The bilateral imbalance shrinks further to $171.7 billion under the ownership-based principle, or a reduction by about 32% of its original gross value.

<Insert Figure 17 here>

5. Conclusion

This paper develops a framework for decomposing a country's GDP and final production in the presence of foreign invested enterprises. We propose a 16-term decomposition that quantifies the different roles of FIEs by 12 of the terms. For ease of presentation, we aggregate the 16 terms

to 5 broad categories, with all FDI related terms into two categories, those related to FDIs but not trade, GVC_I, and those related to both FDIs and trade, GVC_TI.

Using a relatively recent OECD database that tracks FIEs and DOEs separately in an expanded inter-country input-output table, we compute these decomposition terms. We find that about half of the GVC activities, or about 10% of the global GDP, are missing in the existing GVC measures. This is because the previous framework treats FIEs the same as DOEs, and fail to realize that the interactions between the FIEs and DOEs within a country are still a part of GVC activities. We also find that the volume of "missing GVC activities" are bigger in high-tech sectors than in medium-tech sectors, and bigger for high-income countries than for middle-income countries.

We illustrate some basic patterns in the new data that we construct by applying our framework. While this paper does not perform formal hypothesis testing, the decomposition results provide necessary inputs for future work that do carry out such tests.

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Figures and Tables

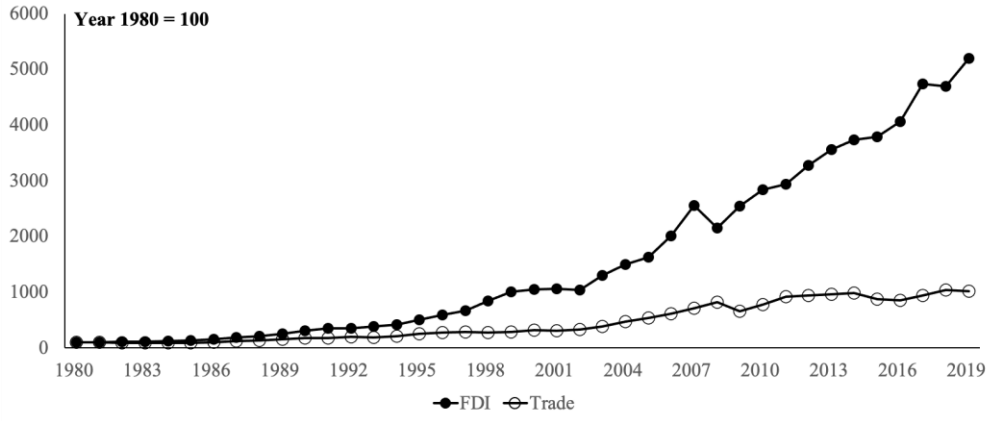


Figure 1: Global FDI Stock and Trade Volume, 1980=100

Note: Data on global FDI stock (inward direction) are obtained from UNCTAD. Data on global trade volume (import side) come from the World Bank WDI database.

[Figures 2-3 are in the main text]

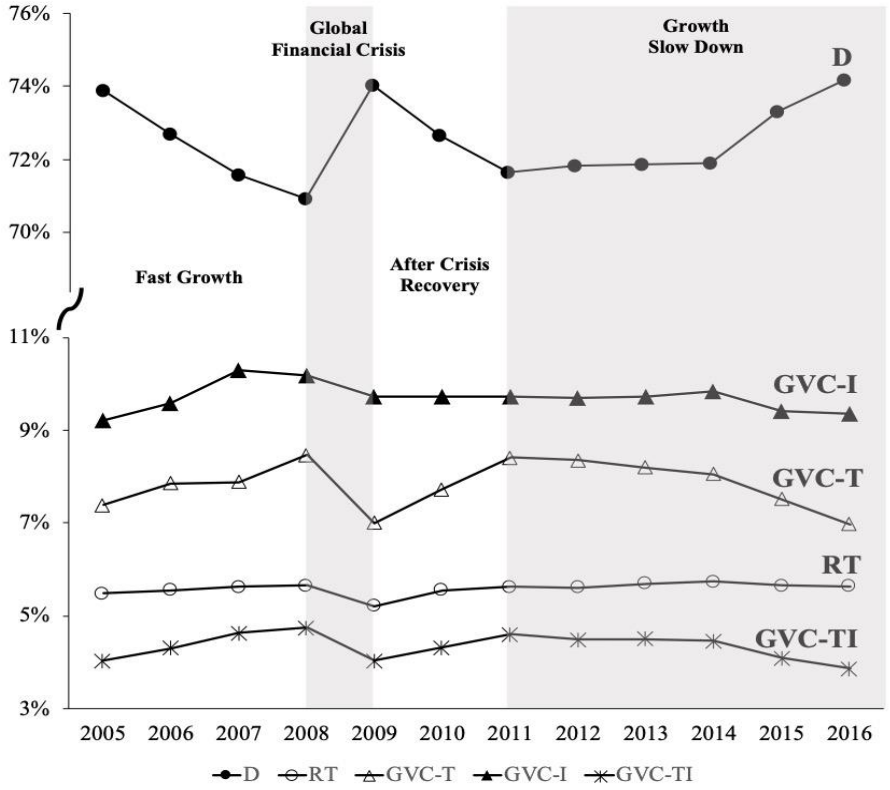


Figure 4: Different Activities of Value-added Creation in Global GDP

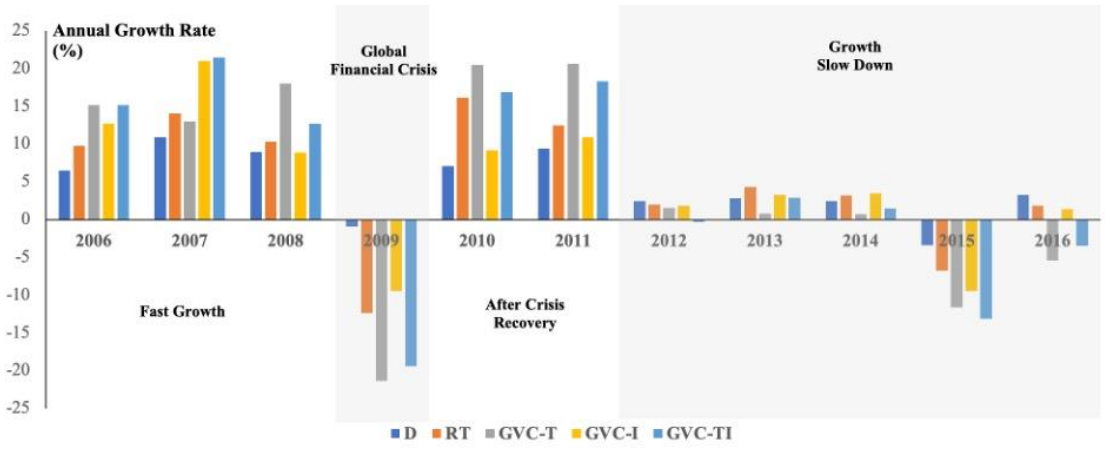


Figure 5: Annual Growth Rate of Different Value-added Creation Activities

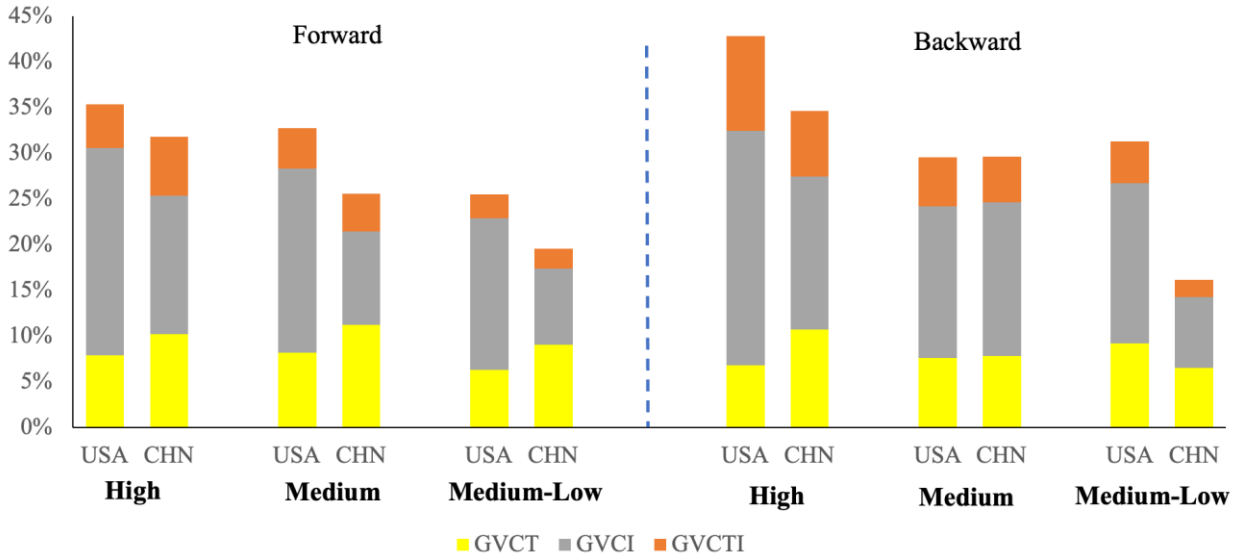


Figure 6: GVC Participation Ratio
for High, Medium, Medium & Low R&D Intensive Manufacturing Sectors, 2016

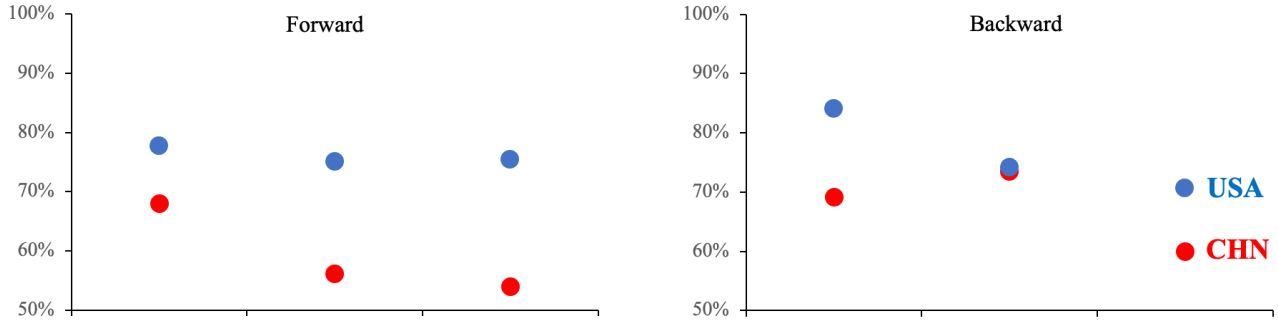


Figure 7: Share of FDI-related GVCs (GVC-I+GVC-TI) in Total GVC Production and Trade Activities
for High, Medium, Medium-Low R&D Intensive Manufacturing Industries, 2016

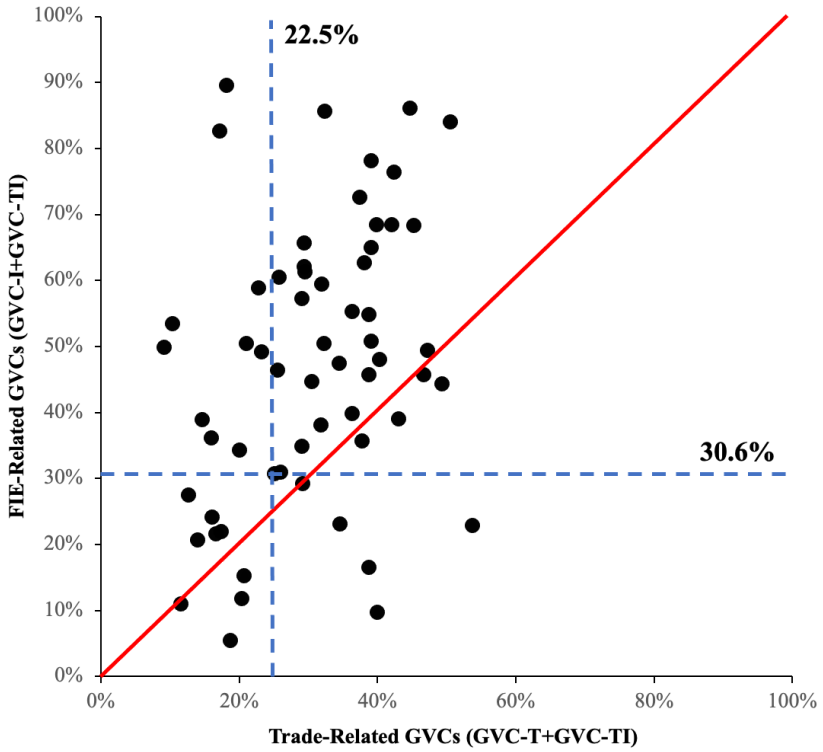


Figure 8: Trade and FAS related GVC participation rate in high R&D intensity manufacturing sectors, 2016

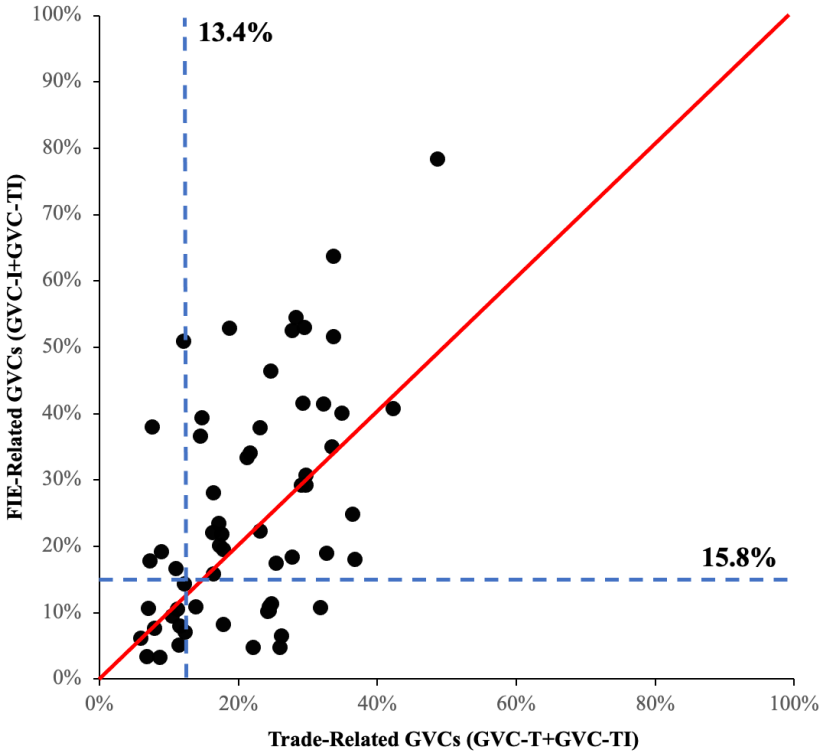


Figure 9: Trade and FIE related GVC participation rate in medium-low R&D intensity manufacturing sectors, 2016

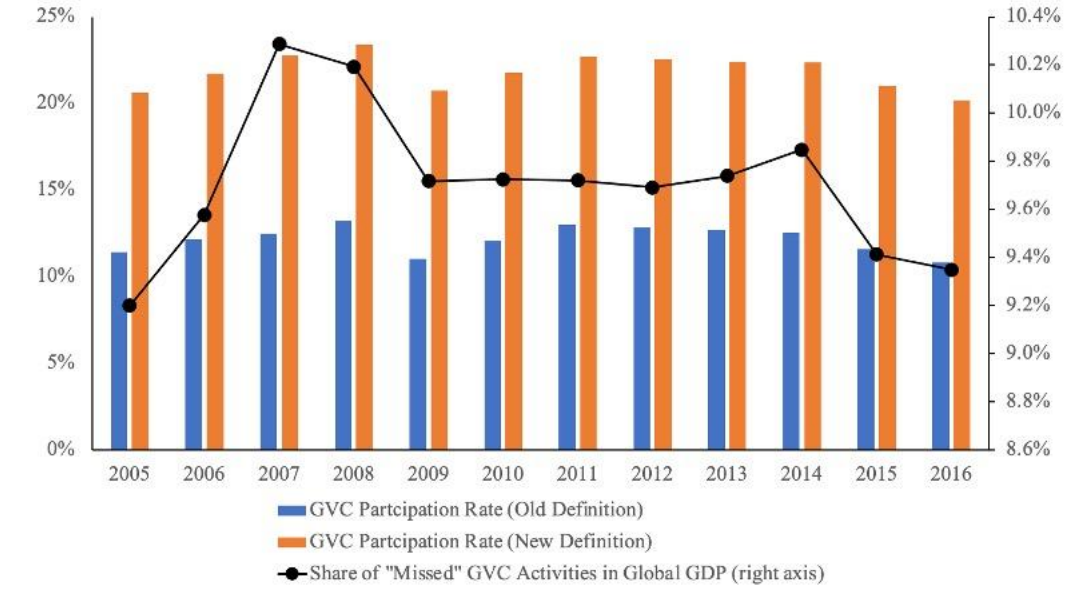


Figure 10: GVC Participation Rate under New and Old Definition

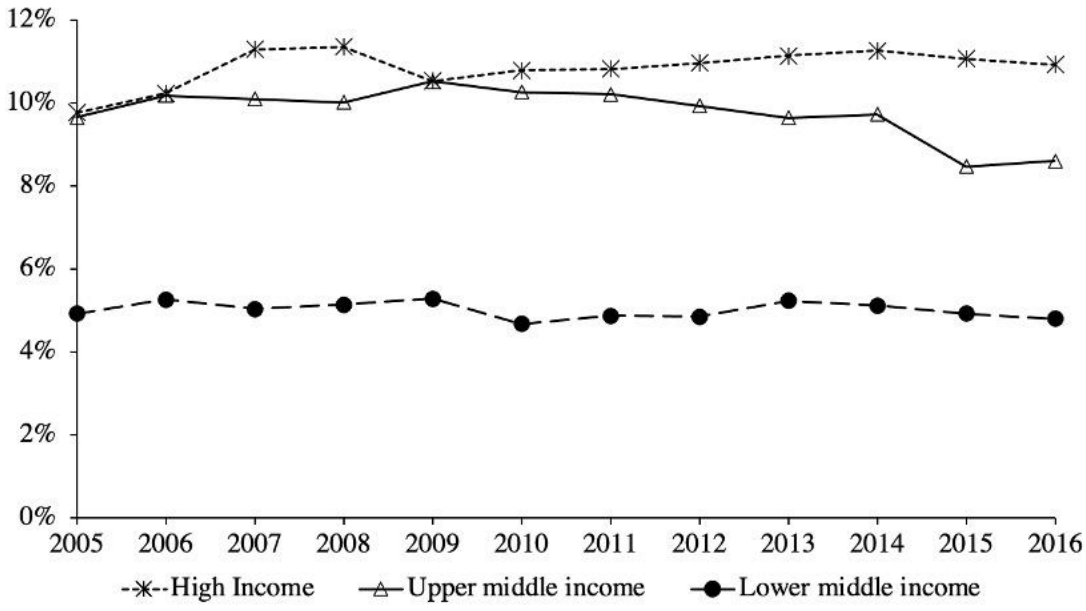


Figure 11: Share of "Missed" GVC Activities, by Income Level

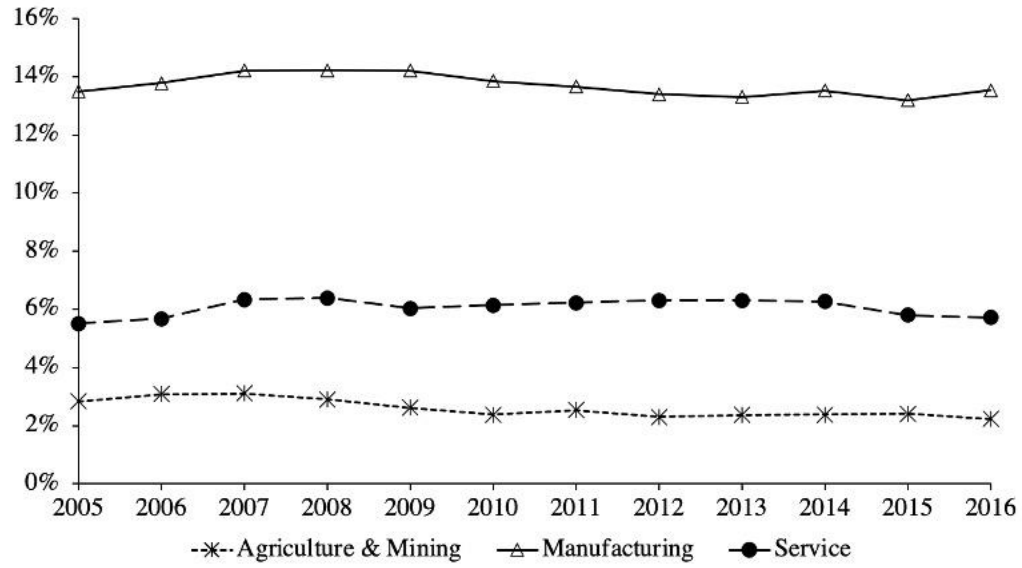


Figure 12: Share of "Missed" GVC Activities, by Sector

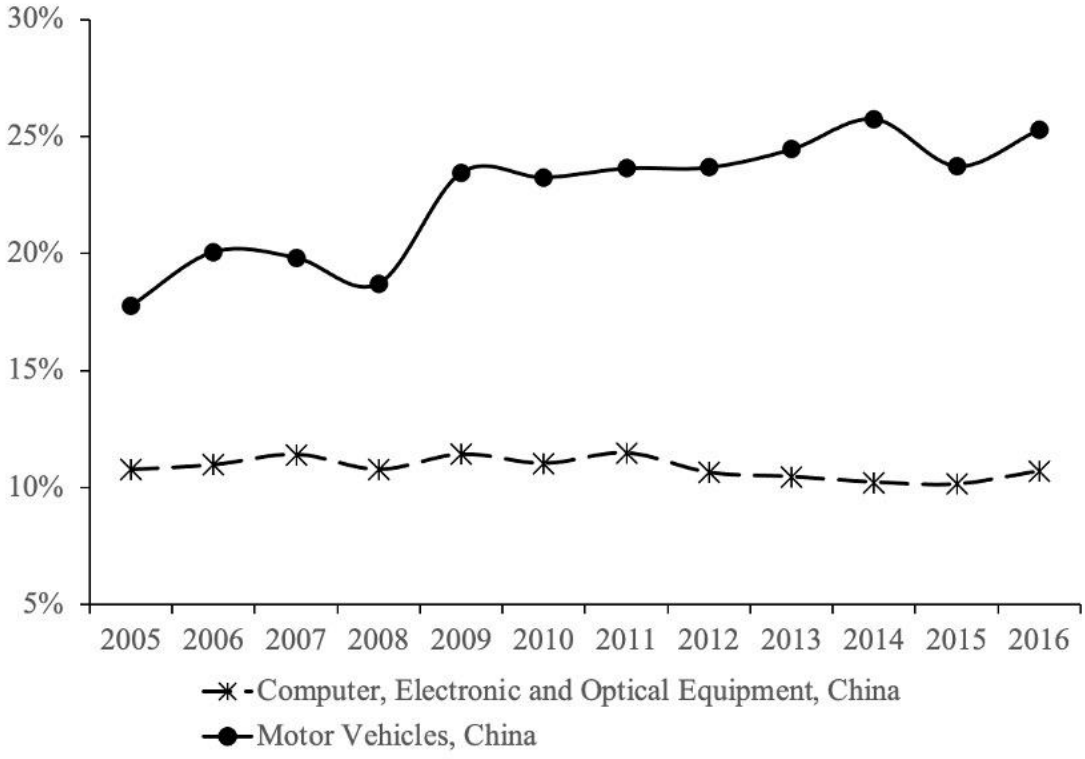


Figure 13: Share of "Missed" GVC Activities, by Country-Sector

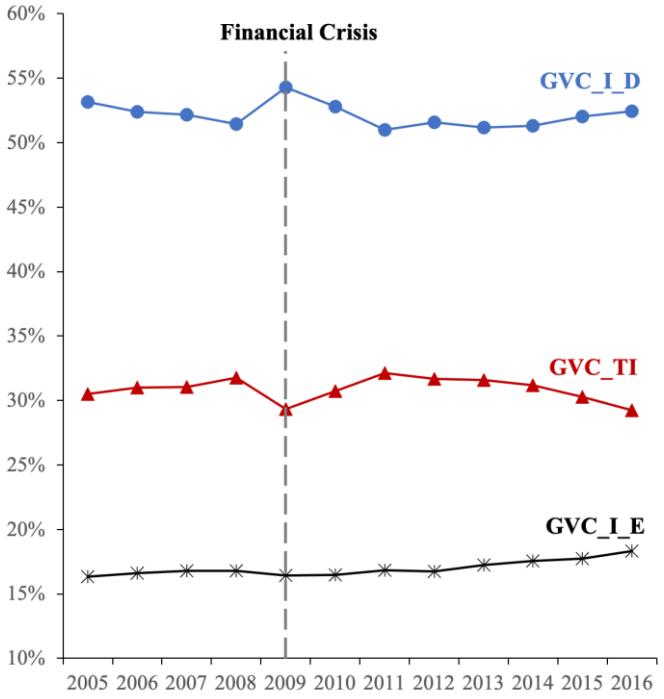


Figure 14: Decomposition of FDI-related production activities from the perspective of "Value Added Use"

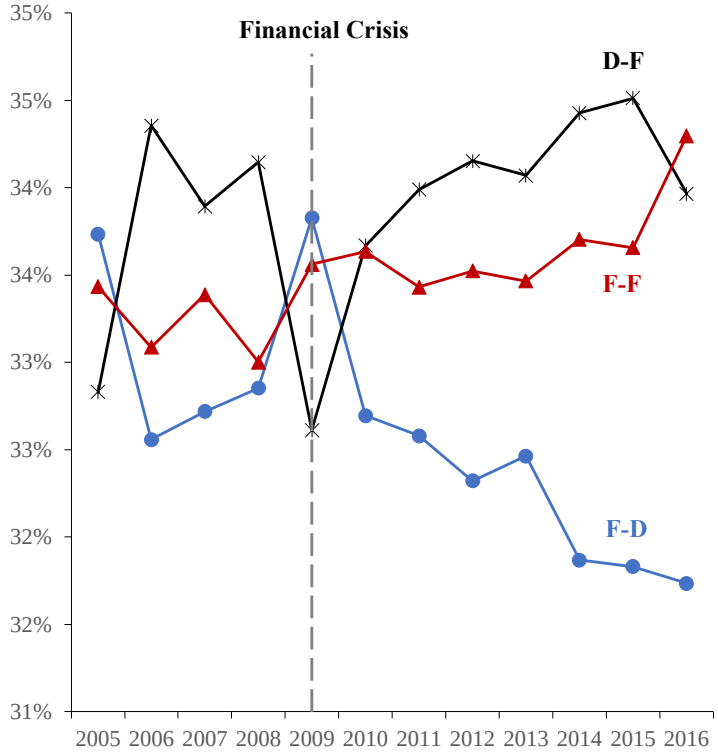


Figure 15: Decomposition of FDI-related production activities from the perspective of "inter-firm production cooperation"

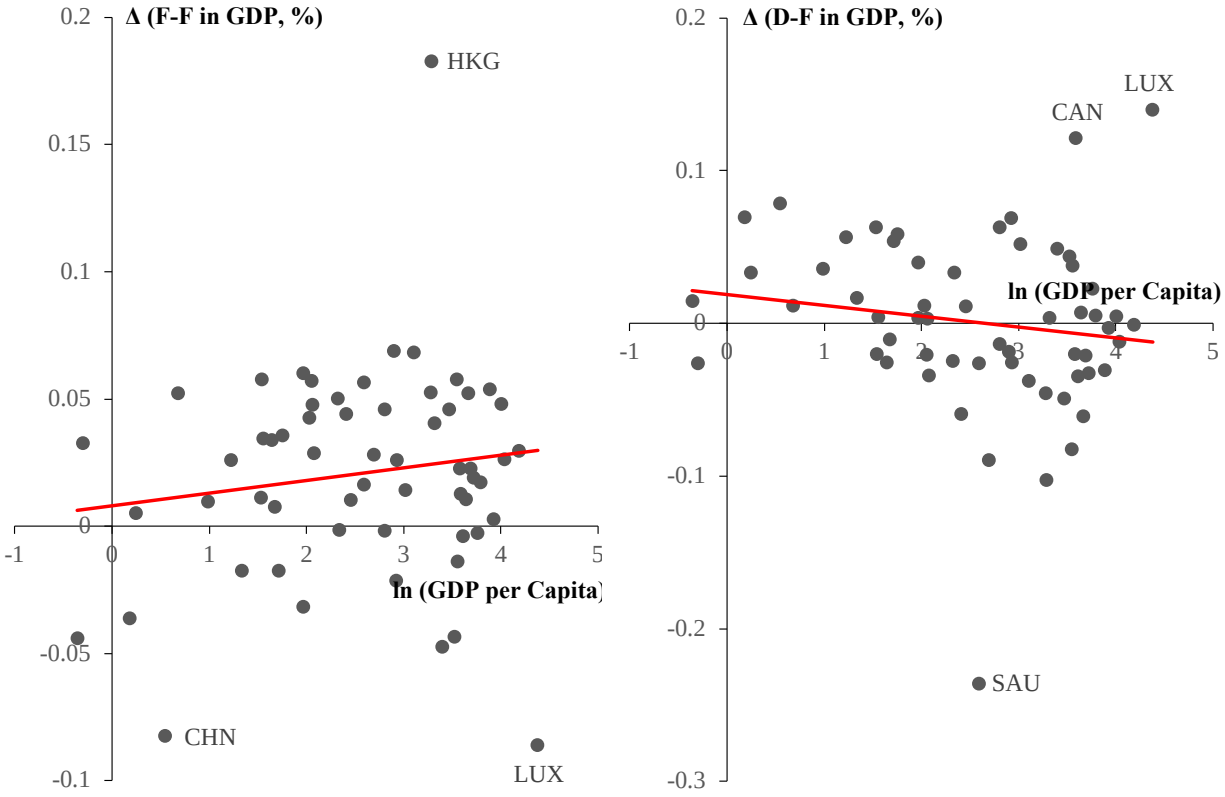


Figure 16: Level of economic development and the Structural changes in FDI-related production activities

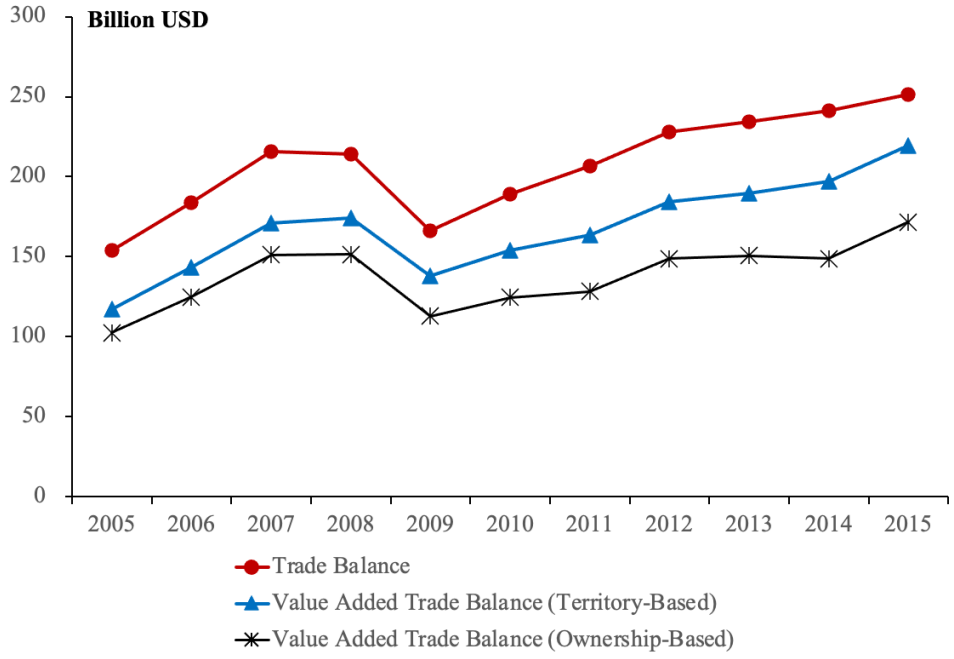


Figure 17: US-China Bilateral Trade Balance and Value Added Trade Balance

Table 1: Sales by overseas affiliates of US multinationals in 2016

(Million USD)

	CAN	CHN	MEX	DEU	JPN	KOR TWN	Rest of OECD	ROW	World Total
Goods and Services									
Total sales	531,293	343,807	224,858	339,520	193,577	102,391	2,248,418	1,578,340	**5,562,204**
Local sales	406,203	284,950	144,816	197,353	166,063	67,863	1,258,894	764,007	**3,290,149**
Local share	76.5	82.9	64.4	58.1	85.8	66.3	56.0	48.4	**59.2**
Exports									
To the US	105,096	21,001	65,015	21,496	4,939	6,995	215,630	199,493	**639,665**
To other countries	19,994	37,856	15,026	120,671	22,574	27,533	773,892	614,844	**1,632,390**
US share	19.8	6.1	28.9	6.3	2.6	6.8	9.6	12.6	**11.5**
Other share	3.8	11.0	6.7	35.5	11.7	26.9	34.4	39.0	**29.3**

Source: **BEA**
https://www.bea.gov/data/intl-trade-investment/activities-us-multinational-enterprises-mnes

[Tables 2 and 3 are in the main text]

Table 4: Production Activity Decomposition Results for CHN and the US under New Accounting Framework, 2016

	Forward Linkage Decomposition of GDP		Backward Linkage Decomposition of Final Goods Production	
SGP	**Non-GVC:** 22.2%, 23.5%, 30.5%	**D:** 19.5%, 20.0%, 26.0%	**Non-GVC:** 25.0%, 24.7%, 34.2%	**D:** 22.0%, 21.1%, 29.1%
		RT: 2.7%, 3.5%, 4.5%		**RT:** 3.0%, 3.6%, 5.1%
	GVC: 77.8%, 76.5%, 69.5%	**GVC-T:** 8.0%, 7.0%, 12.8%	**GVC:** 75.0%, 75.3%, 65.8%	**GVC-T:** 11.4%, 12.0%, 13.2%
		GVC_I: 34.6%, 35.5%, 28.8%		**GVC_I:** 38.9%, 37.4%, 32.2%
		GVC_TI: 35.2%, 34.1%, 27.9%		**GVC_TI:** 24.8%, 25.9%, 20.4%
HKG	**Non-GVC:** 54.8%, 53.3%, 45.7%	**D:** 49.4%, 47.3%, 37.9%	**Non-GVC:** 54.2%, 50.8%, 42.8%	**D:** 48.9%, 45.0%, 35.5%
		RT: 5.3%, 6.0%, 7.8%		**RT:** 5.3%, 5.7%, 7.3%
	GVC: 45.2%, 46.7%, 54.3%	**GVC-T:** 7.4%, 7.6%, 4.2%	**GVC:** 45.8%, 49.2%, 57.2%	**GVC-T:** 8.4%, 10.0%, 7.1%
		GVC_I: 27.2%, 27.9%, 40.8%		**GVC_I:** 26.9%, 26.5%, 38.2%
		GVC_TI: 10.7%, 11.2%, 9.3%		**GVC_TI:** 10.5%, 12.7%, 11.9%
NLD	**Non-GVC:** 67.1%, 65.2%, 61.4%	**D:** 60.6%, 59.5%, 55.9%	**Non-GVC:** 69.3%, 67.6%, 64.0%	**D:** 62.6%, 61.6%, 58.2%
		RT: 6.5%, 5.7%, 5.5%		**RT:** 6.8%, 5.9%, 5.8%
	GVC: 32.9%, 34.8%, 38.6%	**GVC-T:** 9.8%, 9.8%, 9.6%	**GVC:** 30.7%, 32.4%, 36.0%	**GVC-T:** 9.6%, 9.2%, 8.9%
		GVC_I: 13.9%, 15.1%, 16.8%		**GVC_I:** 14.3%, 15.7%, 17.5%
		GVC_TI: 9.2%, 9.9%, 12.1%		**GVC_TI:** 6.7%, 7.5%, 9.5%
USA	**Non-GVC:** 89.3%, 87.2%, 87.3%	**D:** 86.1%, 83.4%, 83.8%	**Non-GVC:** 86.5%, 84.3%, 86.3%	**D:** 83.5%, 80.7%, 82.8%
		RT: 3.2%, 3.8%, 3.6%		**RT:** 3.1%, 3.7%, 3.5%
	GVC: 10.7%, 12.8%, 12.7%	**GVC-T:** 3.0%, 3.8%, 3.5%	**GVC:** 13.5%, 15.7%, 13.7%	**GVC-T:** 5.0%, 5.6%, 4.2%
		GVC_I 6.3%, 7.4%, 7.5%		**GVC_I:** 6.1%, 7.1%, 7.4%
		GVC_TI 1.3%, 1.6%, 1.6%		**GVC_TI:** 2.4%, 2.9%, 2.1%
CHN	**Non-GVC:** 78.5%, 77.9%, 84.7%	**D:** 70.3%, 70.1%, 79.5%	**Non-GVC:** 75.7%, 76.6%, 83.5%	**D:** 67.8%, 68.9%, 78.4%
		RT: 8.2%, 7.8%, 5.2%		**RT:** 7.9%, 7.7%, 5.1%
	GVC: 21.5%, 22.1%, 15.3%	**GVC-T:** 9.5%, 9.4%, 6.1%	**GVC:** 24.3%, 23.4%, 16.5%	**GVC-T:** 11.4%, 10.0%, 6.8%
		GVC_I: 8.6%, 9.1%, 7.0%		**GVC_I:** 8.3%, 9.0%, 6.9%
		GVC_TI: 3.4%, 3.6%, 2.2%		**GVC_TI:** 4.7%, 4.4%, 2.8%
WLD	**Non-GVC:** 79.4%, 76.6%, 79.8%	**D:** 73.9%, 70.9%, 74.2%	**Non-GVC:** 79.4%, 76.6%, 79.8%	**D:** 73.9%, 70.9%, 74.2%
		RT: 5.5%, 5.6%, 5.6%		**RT:** 5.5%, 5.6%, 5.6%
	GVC: 20.6%, 23.4%, 20.2%	**GVC-T:** 7.4%, 8.5%, 7.0%	**GVC:** 20.6%, 23.4%, 20.2%	**GVC-T:** 7.4%, 8.5%, 7.0%
		GVC_I: 9.2%, 10.2%, 9.3%		**GVC_I:** 9.2%, 10.2%, 9.3%
		GVC_TI: 4.0%, 4.7%, 3.9%		**GVC_TI:** 4.0%, 4.7%, 3.9%

Table 5: Top and Bottom 5 Economies in Terms of FDI-related GVC Production Activities, 2016

	Economy	**Forward** GVC-I in GDP	**Economy**	**Backward** GVC-I in Final Goods Output
1	Hong Kong	36.1%	Singapore	35.2%
2	Czech Republic	32.2%	Hong Kong	33.7%
3	Singapore	32.1%	Czech Republic	30.0%
4	Romania	29.0%	Romania	27.7%
5	Hungary	28.9%	Ireland	27.3%
56	Korea	4.2%	India	4.0%
57	Russia	3.8%	Korea	4.0%
58	Japan	3.3%	Japan	3.2%
59	Saudi Arabia	0.9%	Saudi Arabia	1.3%
60	Israel	0.7%	Israel	0.7%

Table 6: Trade and FIE related GVC activities by country-level incomes and sector-level R&D intensities

	Income Level	Year	GVC ratio (GVC-T +GVC-I+ GVC-TI)			FDI-related Share (GVC-I+GVC-TI)		
			High	Medium	Medium-Low	High	Medium	Medium-Low
Forward	High	2005	42.7%	38.7%	28.9%	71.5%	64.1%	69.1%
		2010	44.0%	42.3%	33.1%	70.7%	63.7%	72.5%
		2016	46.7%	44.0%	33.4%	71.8%	65.0%	70.8%
	Upper middle	2005	44.7%	38.5%	27.6%	74.8%	58.6%	41.5%
		2010	40.8%	33.5%	24.9%	72.1%	54.3%	38.6%
		2016	38.3%	29.9%	21.9%	68.8%	56.3%	38.1%
	Lower middle	2005	38.4%	31.0%	20.7%	71.7%	49.6%	54.3%
		2010	35.8%	28.6%	19.3%	74.9%	55.7%	56.8%
		2016	36.9%	28.7%	17.9%	73.2%	57.0%	56.5%
Backward	High income	2005	45.0%	35.1%	38.2%	76.0%	67.8%	64.8%
		2010	47.4%	39.6%	41.4%	75.7%	69.9%	66.0%
		2016	49.0%	39.5%	39.7%	78.8%	73.5%	68.8%
	Upper middle income	2005	48.1%	42.0%	20.9%	64.7%	61.9%	38.0%
		2010	48.1%	44.9%	21.4%	58.0%	60.3%	36.9%
		2016	44.6%	42.8%	19.6%	64.2%	64.2%	36.3%
	Lower middle income	2005	51.0%	36.8%	25.8%	68.9%	64.5%	59.6%
		2010	46.0%	34.6%	23.8%	70.8%	66.7%	60.9%
		2016	41.3%	32.9%	20.7%	73.9%	71.4%	61.4%

[Tables 7 are in the main text]

Table 8: Top 10 Economies with largest decline in D-F term during the global financial crisis

	Country	Contribution in Global D-F Decline
1	USA	17.2%
2	DEU	16.0%
3	GBR	6.8%
4	JPN	4.4%
5	RUS	4.1%
6	CAN	4.1%
7	ITA	3.7%
8	SAU	3.5%
9	FRA	2.8%
10	MEX	2.3%

Table 9: Structural decomposition of FDI-related production activities: Global Level

2005				**2008**				**2016**			
	GVC_I_D	GVC_I_E	GVC_TI		GVC_I_D	GVC_I_E	GVC_TI		GVC_I_D	GVC_I_E	GVC_TI
D-F	14.7%	5.5%	12.6%	D-F	14.7%	6.0%	13.5%	D-F	15.2%	6.4%	12.4%
F-D	17.3%	2.0%	14.5%	F-D	16.1%	2.0%	14.7%	F-D	16.1%	2.0%	13.6%
F-F	21.2%	8.8%	3.4%	F-F	20.6%	8.8%	3.6%	F-F	21.2%	9.9%	3.3%
				2008 versus 2005				**2016 versus 2008**			
					GVC_I_D	GVC_I_E	GVC_TI		GVC_I_D	GVC_I_E	GVC_TI
				D-F	0.0%	0.4%	0.9%	D-F	0.5%	0.4%	-1.1%
				F-D	-1.1%	0.0%	0.3%	F-D	0.0%	0.1%	-1.2%
				F-F	-0.6%	0.0%	0.1%	F-F	0.5%	1.1%	-0.3%

Table 10: Differences in FDI structures with the US

Ranking of the Difference	Economy	Ranking of the Difference	Economy
1	ISL	31	HRV
2	SAU	32	LVA
3	**SGP**	33	SWE
4	**IRL**	34	ROU
5	LUX	35	MAR
6	MLT	36	JPN
7	CYP	37	FIN
8	**KOR**	38	ZAF
9	HUN	39	CHL
10	ROW	40	NOR
11	BEL	**41**	**MEX**
12	TWN	**42**	**DEU**
13	HKG	43	PRT
14	NLD	44	GRC
15	CHE	45	POL
16	THA	46	GBR
17	VNM	47	NZL
18	ISR	48	COL
19	SVN	49	CRI
20	SVK	50	AUS
21	EST	**51**	**CHN**
22	MYS	52	ESP
23	RUS	53	FRA
24	CZE	54	IND
25	LTU	55	ITA
26	DNK	56	CAN
27	PHL	57	ARG
28	BGR	58	TUR
29	IDN	59	BRA
30	AUT		

Table 11: Structural decomposition of FDI-related production activities: Country Level

SAU	GVC_I_D	GVC_I_E	GVC_TI	Total
D-F	18.6%	0.5%	60.5%	**79.6%**
F-D	4.4%	0.0%	7.6%	**12.0%**
F-F	7.8%	0.5%	0.1%	**8.4%**
Total	**30.8%**	**1.0%**	**68.2%**	**100.0%**

SGP	GVC_I_D	GVC_I_E	GVC_TI	Total
D-F	29.5%	0.1%	1.4%	**31.0%**
F-D	5.4%	0.0%	46.2%	**51.6%**
F-F	2.2%	6.6%	8.8%	**2.0%**
Total	**37.2%**	**6.7%**	**56.4%**	**84.6%**

KOR	GVC_I_D	GVC_I_E	GVC_TI	Total
D-F	27.4%	0.3%	55.0%	**82.7%**
F-D	3.0%	0.1%	2.4%	**5.5%**
F-F	11.7%	0.0%	0.1%	**11.8%**
Total	**42.0%**	**0.5%**	**57.5%**	**100.0%**

IRL	GVC_I_D	GVC_I_E	GVC_TI	Total
D-F	34.5%	0.2%	0.2%	**34.8%**
F-D	10.8%	0.8%	23.7%	**35.3%**
F-F	3.9%	24.6%	1.5%	**29.9%**
Total	**49.1%**	**25.5%**	**25.4%**	**100.0%**

DEU	GVC_I_D	GVC_I_E	GVC_TI	Total
D-F	69.3%	0.0%	1.5%	**70.8%**
F-D	3.9%	1.6%	15.7%	**21.2%**
F-F	0.0%	6.1%	1.9%	**8.0%**
Total	**73.2%**	**7.7%**	**19.1%**	**100.0%**

CHN	GVC_I_D	GVC_I_E	GVC_TI	Total
D-F	17.5%	36.5%	6.1%	**60.1%**
F-D	0.0%	0.2%	0.7%	**0.9%**
F-F	38.4%	0.5%	0.0%	**39.0%**
Total	**56.0%**	**37.2%**	**6.8%**	**100.0%**

Table 12: Structural decomposition of FDI-related production activities: Sectoral Level

Mining and Quarrying					Textiles				
	GVC_I_D	GVC_I_E	GVC_TI	**Total**		GVC_I_D	GVC_I_E	GVC_TI	**Total**
D-F	11.5%	0.1%	78.3%	**89.9%**	D-F	13.7%	12.6%	25.2%	**51.5%**
F-D	3.9%	0.0%	0.1%	**4.0%**	F-D	6.7%	1.9%	10.4%	**19.0%**
F-F	6.0%	0.1%	0.0%	**6.1%**	F-F	10.9%	16.6%	2.0%	**29.5%**
Total	**21.4%**	**0.2%**	**78.4%**	**100.0%**	**Total**	**31.3%**	**31.1%**	**37.7%**	**100.0%**
Computer, Electronic and Optical Equipment					**R&D and Other Business Activities**				
	GVC_I_D	GVC_I_E	GVC_TI	**Total**		GVC_I_D	GVC_I_E	GVC_TI	**Total**
D-F	6.7%	5.2%	15.2%	**27.1%**	D-F	21.8%	8.1%	14.5%	**44.5%**
F-D	13.6%	1.9%	19.1%	**34.6%**	F-D	21.9%	2.3%	12.0%	**36.1%**
F-F	15.5%	17.4%	5.4%	**38.3%**	F-F	11.7%	4.9%	2.8%	**19.4%**
Total	**35.7%**	**24.6%**	**39.7%**	**100.0%**	**Total**	**55.4%**	**15.2%**	**29.3%**	**100.0%**

Table 13: Structural decomposition of FDI-related production activities: Skill-intensive Manufacturing and Knowledge-intensive Service

Skill-intensive Manufacturing					Other Manufacturing				
	GVC_I_D	GVC_I_E	GVC_TI	**Total**		GVC_I_D	GVC_I_E	GVC_TI	**Total**
D-F	5.8%	3.7%	11.5%	**21.0%**	D-F	19.4%	6.3%	10.2%	**35.9%**
F-D	12.3%	2.1%	17.4%	**31.8%**	F-D	22.3%	2.3%	9.8%	**34.4%**
F-F	21.6%	20.4%	5.2%	**47.2%**	F-F	22.9%	4.4%	2.3%	**29.7%**
Total	**39.6%**	**26.2%**	**34.2%**	**100.0%**	**Total**	**64.6%**	**13.0%**	**22.4%**	**100.0%**
Knowledge-intensive Service					**Other Service**				
	GVC_I_D	GVC_I_E	GVC_TI	**Total**		GVC_I_D	GVC_I_E	GVC_TI	**Total**
D-F	12.1%	6.9%	14.1%	**33.1%**	D-F	17.2%	7.6%	11.6%	**36.4%**
F-D	18.3%	2.4%	14.3%	**35.0%**	F-D	13.8%	1.9%	10.7%	**26.4%**
F-F	18.6%	9.9%	3.4%	**32.0%**	F-F	24.3%	10.4%	2.5%	**37.2%**
Total	**49.1%**	**19.2%**	**31.8%**	**100.0%**	**Total**	**55.3%**	**20.0%**	**24.7%**	**100.0%**

Table 14: Differences in FDI structures with China:
(Computer, Electronic and Optical Equipment Sector)

Ranking of the Difference	Economy	Ranking of the Difference	Economy
1	CYP	31	GRC
2	SAU	32	PRT
3	JPN	33	SWE
4	CHL	34	BGR
5	AUS	35	AUT
6	BRA	36	MLT
7	ARG	37	NZL
8	KOR	38	LVA
9	IND	39	MEX
10	SGP	40	CZE
11	LUX	41	FIN
12	HUN	42	SVN
13	CAN	43	POL
14	USA	44	ZAF
15	COL	45	HKG
16	RUS	46	HRV
17	ROW	47	ESP
18	ISR	48	THA
19	ISL	49	CRI
20	MAR	50	DEU
21	NOR	51	MYS
22	LTU	52	GBR
23	TUR	53	ITA
24	EST	54	DNK
25	IRL	55	PHL
26	FRA	56	TWN
27	BEL	57	CHE
28	ROU	58	VNM
29	IDN	59	NLD
30	SVK		

Table 15: Structural decomposition of FDI-related production activities: Country-Sector Level
(Computer, Electronic and Optical Equipment Sector)

JPN	GVC_I_D	GVC_I_E	GVC_TI	Total	IND	GVC_I_D	GVC_I_E	GVC_TI	Total
D-F	0.1%	1.3%	81.5%	**82.9%**	**D-F**	0.4%	5.6%	3.7%	**9.7%**
F-D	0.9%	0.0%	8.3%	**9.2%**	**F-D**	0.4%	0.0%	5.8%	**6.2%**
F-F	0.1%	7.4%	0.4%	**7.9%**	**F-F**	80.7%	3.2%	0.3%	**84.1%**
Total	**1.1%**	**8.7%**	**90.2%**	**100.0%**	**Total**	**81.5%**	**8.8%**	**9.8%**	**100.0%**
SGP	**GVC_I_D**	**GVC_I_E**	**GVC_TI**	**Total**	**USA**	**GVC_I_D**	**GVC_I_E**	**GVC_TI**	**Total**
D-F	6.1%	10.1%	19.5%	**35.7%**	**D-F**	0.0%	9.3%	7.7%	**17.1%**
F-D	2.8%	0.0%	49.2%	**52.1%**	**F-D**	51.2%	0.1%	7.3%	**58.6%**
F-F	0.0%	9.3%	2.9%	**12.2%**	**F-F**	15.8%	8.4%	0.1%	**24.4%**
Total	**9.0%**	**19.5%**	**71.6%**	**100.0%**	**Total**	**67.1%**	**17.9%**	**15.1%**	**100.0%**
DEU	**GVC_I_D**	**GVC_I_E**	**GVC_TI**	**Total**	**VNM**	**GVC_I_D**	**GVC_I_E**	**GVC_TI**	**Total**
D-F	5.8%	25.0%	0.1%	**30.9%**	**D-F**	26.9%	26.1%	15.0%	**68.0%**
F-D	3.2%	2.6%	4.6%	**10.5%**	**F-D**	12.1%	10.0%	5.6%	**27.7%**
F-F	53.3%	4.8%	0.5%	**58.6%**	**F-F**	0.8%	3.5%	0.0%	**4.3%**
Total	**62.3%**	**32.4%**	**5.3%**	**100.0%**	**Total**	**39.9%**	**39.6%**	**20.6%**	**100.0%**

Table 16: Balance of Capital Return for Cross Border Investment, 2016
(Territory-Based / Ownership-Based)

Country Group / Country	Territory-Based (1)	Ownership-Based (2)	Balance of Capital Return for Cross Border Investment (3)=(2)-(1)
High income	2378.2	3013.4	635.3
Upper-middle income	706.9	204.7	-502.2
Lower-middle income	231.6	98.5	-133.1
CHN	294.1	64.2	-229.9
DEU	267.4	351.8	84.3
JPN	75.0	299.0	224.0
USA	450.8	816.9	366.1

Table 17: Allocation of Capital Return for Cross Border Investment, 2016

Income Level of Host Country	Income Level of Home Country			**Total Income (Territory-Based)**
	High	Upper Middle	Lower middle	
High income	2200.0	125.0	86.9	**2411.9**
Upper middle income	631.5	64.7	10.8	**706.9**
Lower middle income	215.7	15.1	0.7	**231.6**
Total income (Ownership-Based)	**3047.1**	**204.7**	**98.5**	**3350.4**

Appendix A: Economic Interpretation of the 16 Terms in Equation (2)

For ease of discussion, we use Home to refer to the country in question whose GDP or final production are being dissected. All firms in a country are placed into two mutually exclusive groups: domestically owned enterprises (DOEs) and foreign invested enterprises (FIEs). The FIEs are local affiliates of foreign multinational firms. Any production activities that combine factor content from two or more countries in the production are called global-value-chains- (GVCs) related activities. Any GVC activities that involve factor content crossing national borders twice or more are labeled as complex GVC activities.

All terms in Equation (2) are grouped into four blocks. The first block - the first four terms in the first row of Equation (2) - traces how the value added generated by the DOEs in Home is used in the final production activities by the same set of firms:

1. **Pure domestic production activities** ($\hat{V}_D L \hat{Y}_D^L$): the value-added created by DOEs used in their final production to satisfy domestic final demand. The DOEs are both the supplier of the value added and the producers of the final products. This means that the whole production is completed within Home, and is related neither to the production of FIEs, nor international trade. There is no foreign factor content involved. (Labeled as "D" in section 3)

2. **Production activities for "classic trade"** ($\hat{V}_D L \hat{Y}_D^E$): the value-added created by DOEs used in their production of the final goods and service exports to satisfy final demand abroad. While the DOEs are both the supplier of value-added and the final product producers, the final products are consumed abroad. Similar to the first term, the production process is entirely within the national borders, and involves no cross-country production sharing（The result is denoted by VD_RTD. (Labeled as "RT" in section 3)

3. **Simple GVC activities by the DOEs** ($\hat{V}_D L A^E L \hat{Y}_D^L$): the value-added embodied in intermediate exports by the DOEs that are used by the direct importing country to satisfy its own final demand. The DOEs in Home are the suppliers of the value-added, and the DOEs in the direct importing country are the final product producers. As the DOEs in both countries participate in production sharing, but the factor content from Home crosses the national border once, such activities are labeled as "simple GVC activities" by the DOEs（VD_GVCD_S and labeled as GVC_T in section 3）.

4. **Complex GVC activities by the DOEs** $\hat{V}_D LA^E\left(B\hat{Y}_D - L\hat{Y}_D^L\right)$: the value-added embodied in intermediate exports produced by the DOEs in Home and used by the direct importing country to produce its own exports. In this case, as the DOEs in Home are the suppliers of value-added, and the DOEs in the direct importing country are producers of the next stage production, both sets of the firms participate in production sharing. Importantly, the factor content from Home crosses national borders at least twice, which is a defining feature in our definition of "complex GVC activities"（VD_GVCD_C and belong to GVC_T in section 3）.

The next block - the four terms in the second row of Equation (2) - traces how value added originally generated by the DOEs in Home is used in the final production activities by the FIEs in Home. While the DOEs in Home are the upstream suppliers, the FIEs in either Home or the direct importing country are the final goods producers in the downstream.

5. **Production Activities by the FIEs for the Host Country Market** ($\hat{V}_D L\hat{Y}_F^L$): the value added created by the DOEs in Home that is used by the FIEs in Home in the final production to satisfy the final demand in Home (VD_RF, foreign capital as FDI cross national border only once, this is a type simple GVC activities and belong to GVC_I in section 3).

6. **Simple GVC Activities by the FIEs for Final Goods Exports** ($\hat{V}_D L\hat{Y}_F^E$): The value added created by the DOEs in Home that is used in the production of final exports by the FIEs (VD_RTF and belong to GVC-I in section 3).

7. **Complex GVC Activities by the FIEs for Intermediate Goods Exports for Locally Consumed Final Production in the Direct Importing Country**. ($\hat{V}_D LA^E L\hat{Y}_F^L$): the value added created by the DOEs in Home that is used by the FIEs in Home for their intermediate goods exports that are in turn used by the direct importing country to produce final goods and services to satisfy their own final demand (VD_GVCF_S, foreign factor content cross national twice for production, first in FDI, second in FIE's intermediate exports and belong to GVC_TI in section 3).

8. **Complex GVC Activities by the FIEs for Intermediate Goods Exports Used by the Direct Importing Country in the Production for Final Goods Exports**. ($\hat{V}_D LA^E(B\hat{Y}_F - L\hat{Y}_F^L)$): the value added created by the DOEs in Home that is used by the FIEs in Home in their exports of intermediate goods that are in turn used by the direct importing country to produce exports of final goods and services (VD_GVCF_C, belong to GVC_TI in section 3).

The third block – the four terms in the third row in Equation (2) – traces the value added

originally generated by the FIEs in Home and used in the final production activities by the DOEs in Home. The FIEs in Home are the upstream suppliers of the value added, while the DOEs in Home and the firms in the direct importing countries are the downstream users in final production.

9. **Simple GVC Activities by the FIEs to Support Production by the DOEs for Local Final Demand**($\hat{V}_F L \hat{Y}_D^L$): the value-added originally created by the FIEs in Home that is used by the DOEs in Home in the final production to satisfy the final demand in Home (VF_RD, belong to GVC_I in section 3).

10. **Simple GVC Activities by the FIEs to Support Production by the DOEs for Final Goods Exports** $\left(\hat{V}_F L \hat{Y}_D^E\right)$: the value-added created by FIEs in Home that is used by the DOEs in Home in the production of final goods exports (VF_RTD, belong to GVC_I in section 3).

11. **Complex GVC activities related to both FIEs and trade serving the final demand of the direct importing countries** ($\hat{V}_F L A^E L \hat{Y}_D^L$): the value added originally created by the FIEs in Home that is embedded in their intermediate exports and used by the DOEs in the direct importing country in their final production to satisfy their local final demand (VF_GVCD, factor content cross national border twice for production, first in FDI, second in FIE's intermediate exports, belong to GVC_TI in section 3).

12. **Complex GVC activities related to both FIEs and trade serving the global market** $\widehat{(V_F L A^E \left(B \hat{Y}_D - L \hat{Y}_D^L\right))}$: the value added created by the FIEs in Home that is embedded in their intermediate exports and used by the DOEs in the direct importing countries in the production for their final goods exports (VF_GVCD_C, belong to GVC_TI in section 3).

The fourth block – the four terms on the fourth row of Equation (2) – traces value added generated by the FIEs in Home that is used in the final production activities by the FIEs in both Home and the direct importing countries. In the first two terms, the FIEs in Home are both the suppliers and users. In the last two terms, the FIEs in Home are the upstream suppliers, and the FIEs in the directing importing countries are the downstream users.

13**. Local Sale of Final Goods and Services by the FIEs （Simple GVC activities）** ($\hat{V}_F L \hat{Y}_F^L$): the value-added created originally by the FIEs in Home that is used in their final goods and service production to satisfy domestic final demand (VF_RF, belong to GVC_I in section 3).

14: **Final-Goods Exports Platform by the FIEs' Simple GVC activities** ($\hat{V}_F L \hat{Y}_F^E$): the value-added created by the FIEs in Home that is used in their production of final goods exports to

serve the global market (VF_RTF, belong to GVC_I in section 3).

15. **Complex GVC Activities Related to Both FIEs and Trade That Serve the Market of Direct Importing Countries** ($\hat{V}_F LA^E L\hat{Y}_F^L$): the value added created by the FIEs in Home that is embedded in their exports of intermediate inputs and used by the FIEs in the direct importing countries in the latter's final production to satisfy its local final demand (VF_GVCF_S, belong to GVC_TI in section 3).

16. **Complex GVC Activities related to Both FIEs and Trade That Serve the Global Market** ($\hat{V}_F LA^E (B\hat{Y}_F - L\hat{Y}_F^L)$): the value added originally created by the FIEs in Home that is embedded in their exports of intermediate inputs and used by the FIEs in the direct importing countries in their production of exports to serve the global market (VF_GVCF_C, belong to GVC_TI in section 3).

Appendix B: The forward and backward decomposition framework of Equation 6

Each of the nine terms on the right hand side of equation (6) is a G×N×2 by G×N×2 matrix. On the one hand, summing along the row decomposes the GDP production based on forward linkages as depicted in Figure B2. On the other hand, summing along the columns decomposes the final goods and services production based on backward linkages as depicted in Figure B3.

Figure B2: A Map of Value Added in a Country in Relation to GVC Participation (by firm ownership, sector, and country)

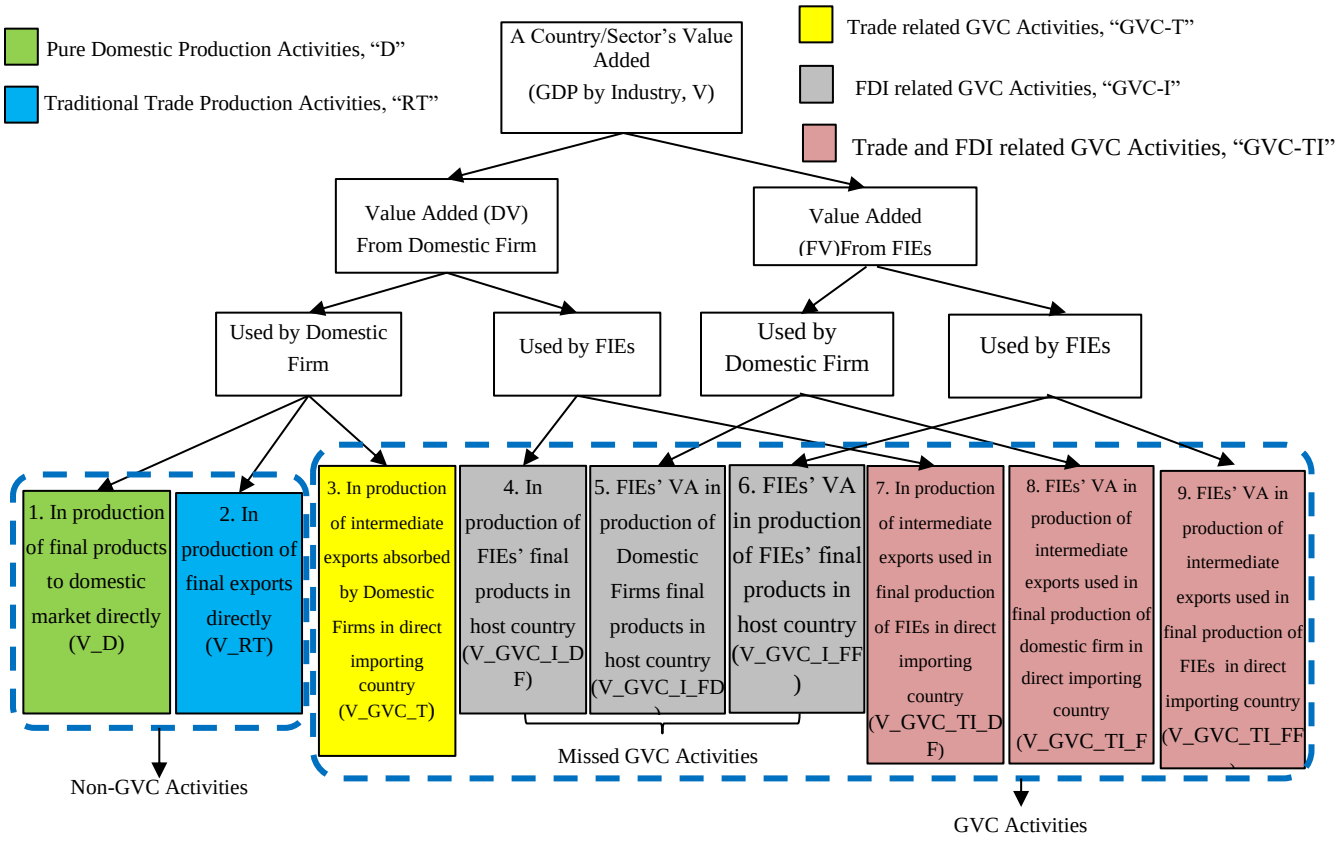
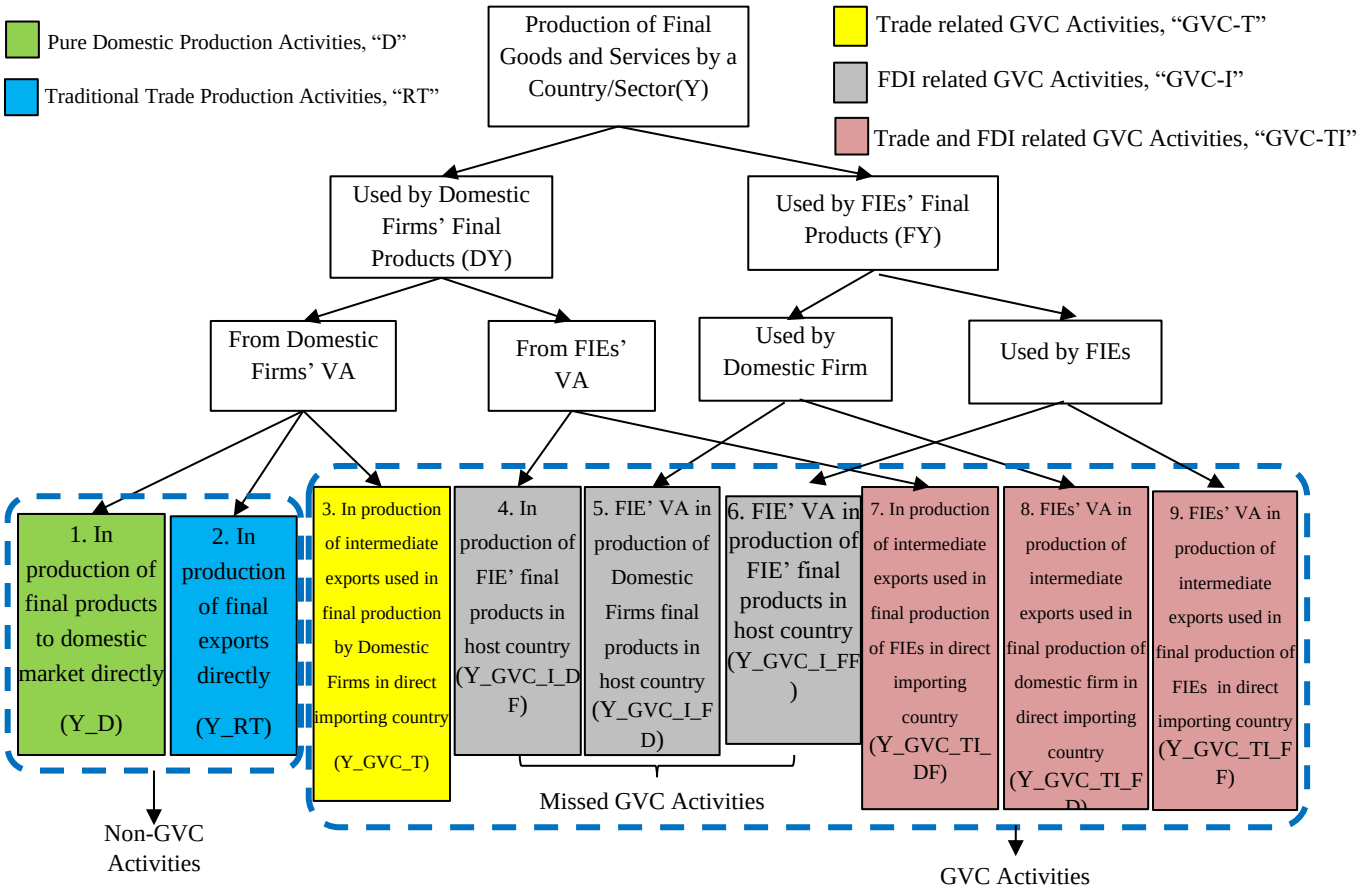


Figure B3: Production of Final Goods and Services and GVC Participation

(by Firm Ownership, Sector, and Country)



Appendix C: Tracing Value Added and Double Counting in Bilateral Gross Trade Flows That Incorporates a Role of Foreign Invested Enterprise

Gross exports at the different aggregation levels can be decomposed into domestic value-added in exports (DVA) and the well-known measure of Vertical Specialization (VS)[14] (Koopman, Wang, and Wei, 2014; Borin and Mancini, 2019, Antràs and Chor 2021). The decomposition can be expressed in matrix notation:

$$\hat{E} = \mathrm{V}B\hat{E} = \mathrm{V}L\hat{E} + \mathrm{V}B\mathrm{A}^{E}L\hat{E} = \mathrm{V}L\hat{E} + \mathrm{A}^{E}L\hat{E} \quad \text{(C1)}$$

Where $\mathrm{V}B$ = I, the identity matrix. To bypass the debate on how to define and measure Foreign Value Added (FVA) and pure double counting (PDC) terms, we present a simplified gross exports decomposition that takes into account the presence of FIEs.

Depending on whether the domestic value-added (GDP) in exports is produced by DOEs or FIEs，and which firm types use the intermediate imports, the gross exports decomposition formula equation (A1) can be extended to equation (A2) based on backward industrial linkage:

$$\mathrm{V}B\hat{E} = \mathrm{V}_{D}L\hat{E} + \mathrm{V}_{F}L\hat{E} + \mathrm{V}_{D}B\mathrm{A}^{E}L\hat{E} + \mathrm{V}_{F}B\mathrm{A}^{E}L\hat{E} \quad \text{(C2)}$$

In the existing gross export decomposition without FIEs，$\mathrm{V}L\hat{E}$ is defined as domestic value-added (DVA)（equation (37) in KWW，2014），and $\mathrm{A}^{E}L\hat{E}$（$\mathrm{A}^{M}L\hat{E}$ in single country case） is defined as VS（HIY，2001 and equation (38) and (39) in KWW, 2014）. However, a part of the DVA in exports（$\mathrm{V}_{F}L\hat{E}$） performed by FIEs comes from foreign production factors such as physical and intangible capitals employed by the FIEs. This should be recognized as a part of vertical specialization in production. Consequently, the pure domestic value-added in exports is only the portion created by the DOEs ($\mathrm{V}_{D}L\hat{E}$). The economic interpretation of the four terms on the right hand of equation (A2) is listed in flowing tables:

[14] To more accurately such equivalence at bilateral level only exists for the source (backward linkage) based decomposition. See appendix C of Borin and Mancini (2019) for details.

Economic interpretation	Value-added from DOEs	Value-added from affiliates of foreign MNEs	VS of DOEs	VS of affiliates of foreign MNEs
Math formula	$V_D L\hat{E}$	$V_F L\hat{E}$	$V_D BA^E L\hat{E}$	$V_F BA^E L\hat{E}$
DVA or VS	DVA in exports	FDI related VS (missed in standard ICIO tables)	Trade related VS	FDI and trade related VS

A country's gross exports equals the sum of the final products and intermediate exports from both DOEs and FIEs, i.e. $E = Y_D^E + A^E BY_D + Y_F^E + A^E BY_F$. Inserting into equation A(2) and combining terms, we decompose the first two terms on the right hand of equation (A2) as follows：

$$\begin{aligned} VBE &= V_D LY_D^E + V_D LA^E BY_D \\ &+ V_D LY_F^E + V_D LA^E BY_F + V_F LY^E + V_F LA^E BY \\ &+ V_D BA^E LE + V_F BA^E LE \end{aligned} \tag{C3}$$

Among the eight terms on the right hand of equation (A3), only the first term $V_D LY_D^E$ is pure domestic production activities. This is the "classic" trade term in our production activity decomposition. The remaining seven terms are all GVC related trade activities. The second term $V_D LA^E BY_D$ are arm length trade，the third term $V_D LY_F^E$ are FDI related，the fourth to sixth terms are related to both FDI and trade, and the seventh and eighth term are VS of the DOEs and FIEs, respectively.

Consider gross exports from country s to country r, the four terms on the right hand side of equation (A2) can be written as：

$$\begin{aligned} E^{sr} &= [V^s L^{ss}] \# E^{sr} + [\textstyle\sum_t^G V^t \sum_{u \neq s}^G B^{tu} A^{us} L^{ss}] \# E^{sr} \\ &= [V_D^s L^{ss}] \# E^{sr} + [V_F^s L^{ss}] \# E^{sr} + [\textstyle\sum_{t \neq s}^G V_D^t \sum_{u \neq s}^G B^{tu} A^{us} L^{ss}] \# E^{sr} \\ &+ [\textstyle\sum_{t \neq s}^G V_F^t \sum_{u \neq s}^G B^{tu} A^{us} L^{ss}] \# E^{sr} \end{aligned} \tag{C4}$$

For $t = s$， $\sum_{u \neq s}^G B^{tu} A^{us} L^{ss} = B^{ss} - L^{ss}$； For $t \neq s$， $\sum_{u \neq s}^G B^{tu} A^{us} L^{ss} = B^{ts}$

Summing up equation (A3) over all G countries，we decompose the gross exports from

country s as follows：

$$
\begin{aligned}
E^s &= \mathrm{V}_D^s \sum_{r\neq s}^{G} B^{sr} \sum_{t\neq s}^{G} Y^{rt} + \mathrm{V}_F^s \sum_{r\neq s}^{G} B^{sr} \sum_{t\neq s}^{G} Y^{rt} \\
&+\mathrm{V}_D^s(\sum_{r}^{G} B^{sr} Y^{rs} - L^{ss}Y^{ss}) + \mathrm{V}_F^s(\sum_{r}^{G} B^{sr} Y^{rs} - L^{ss}Y^{ss}) \qquad \text{(C5)} \\
&+\sum_{t\neq s}^{G} \mathrm{V}_D^t B^{ts} \sum_{r\neq s}^{G}(Y^{sr} + A^{sr}L^{rr}Y^{rr}) + \sum_{t\neq s}^{G} \mathrm{V}_F^t B^{ts} \sum_{r\neq s}^{G}(Y^{sr} + A^{sr}L^{rr}Y^{rr}) \\
&+[\mathrm{V}_D^s(B^{ss} - L^{ss})E^s + \sum_{t\neq s}^{G} \mathrm{V}_D^t B^{ts} \sum_{r\neq s}^{G} A^{sr} L^{rr}Y^{rr}] + [\mathrm{V}_F^s(B^{ss}L^{ss})E^s \sum_{t\neq s}^{G} \mathrm{V}_F^t B^{ts} \sum_{r\neq s}^{G} A^{sr} L^{rr}Y^{rr}]
\end{aligned}
$$

The eight terms on the right hand of equation (A5) are arranged in four rows. The two terms in the first row are value added exports by the DOEs and FIEs, respectively, i.e. value-added produced in the host country s but consumed abroad (VAX). The two terms in the second row are value-added produced by the DOEs and FIEs, respectively, that is embodied in Home's exports but eventually returned to and consumed in Home (RDV). The two terms in the third row are value added created in other countries (by their DOEs and FIEs) that is embodied in Home's exports (FVA). Finally, the two terms in the last row are double counted terms originally coming from either DOEs or FIEs in both Home and abroad (PDC). This decomposition is an extension of equation (36) in KWW 2014.

How to properly measure the PDC is a subject of debate in the literature. As their values are part of Home's export value from the partner country's viewpoint, they can be seen as a part of the imported content embodied in Home's exports (Borin and Mancini, 2019). However, it is important to note that some of them can originate from Home country s, ($\mathrm{V}_D^s(B^{ss} - L^{ss})E^s$ and $\mathrm{V}_F^s(B^{ss} - L^{ss})E^s$). For this reason, the distinction between Home and Foreign is not clear-cut. In any case, it is still economically meaningful to recognize the PDC block (and other double counted value added) as part of the VS measure. Furthermore, as the factor content embodied in PDC has to cross national borders at least three times, it represents a higher level of GVC activities than other components of gross exports, indicating a sophisticated form of production sharing arrangement.

Appendix Table A1: Sector Classification

Sector No.	ISIC rev.3	Sector Name	R&D Intensity
1	C15T16	Food products, beverages and tobacco	Medium-low
2	C17T19	Textiles, textile products, leather and footwear	Medium-low
3	C20	Wood and products of wood and cork	Medium-low
4	C21T22	Pulp, paper, paper products, printing and publishing	Medium-low
5	C23	Coke, refined petroleum products and nuclear fuel	Medium-low
6	C24	Chemicals and chemical products	High
7	C25	Rubber and plastics products	Medium
8	C26	Other non-metallic mineral products	Medium
9	C27	Basic metals	Medium
10	C28	Fabricated metal products	Medium
11	C29	Machinery and equipment, nec	High
12	C30.32.33	Computer, Electronic and optical equipment	High
13	C31	Electrical machinery and apparatus, nec	High
14	C34	Motor vehicles, trailers and semi-trailers	High
15	C35	Other transport equipment	High
16	C36T37	Manufacturing nec; recycling	Medium

Appendix Table A2: Country Code and Classification

Country Code	Country Name	Income Group	Country Code	Country Name	Income Group
ARG	Argentina	Upper middle	JPN	Japan	High
AUS	Australia	High	KHM	Cambodia	Lower middle
AUT	Austria	High	KOR	Korea, Rep.	High
BEL	Belgium	High	LTU	Lithuania	High
BGR	Bulgaria	Upper middle	LUX	Luxembourg	High
BRA	Brazil	Upper middle	LVA	Latvia	High
BRN	Brunei Darussalam	High	MAR	Morocco	Lower middle
CAN	Canada	High	MEX	Mexico	Upper middle
CHE	Switzerland	High	MLT	Malta	High
CHL	Chile	High	MYS	Malaysia	Upper middle
CHN	China	Upper middle	NLD	Netherlands	High
COL	Colombia	Upper middle	NOR	Norway	High
CRI	Costa Rica	Upper middle	NZL	New Zealand	High
CYP	Cyprus	High	PER	Peru	Upper middle
CZE	Czech Republic	High	PHL	Philippines	Lower middle
DEU	Germany	High	POL	Poland	High
DNK	Denmark	High	PRT	Portugal	High
ESP	Spain	High	ROU	Romania	Upper middle
EST	Estonia	High	RUS	Russian	Upper middle
FIN	Finland	High	SAU	Saudi Arabia	High
FRA	France	High	SGP	Singapore	High

Country Code	Country Name	Income Group	Country Code	Country Name	Income Group
GBR	United Kingdom	High	SVK	Slovak Republic	High
GRC	Greece	High	SVN	Slovenia	High
HKG	Hong Kong SAR, China	High	SWE	Sweden	High
HRV	Croatia	High	THA	Thailand	Upper middle
HUN	Hungary	High	TUN	Tunisia	Lower middle
IDN	Indonesia	Lower middle	TUR	Turkey	Upper middle
IND	India	Lower middle	TWN	Chinese Taipei	High
IRL	Ireland	High	USA	United States	High
ISL	Iceland	High	VNM	Vietnam	Lower middle
ISR	Israel	High	ZAF	South Africa	Upper middle
ITA	Italy	High	ROW	Rest of World	-