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# Economic Consequences of Trade and Global Value Chain Integration

## A Measurement Perspective

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## Abstract

This paper introduces a new approach to measuring Global Value Chains (GVC), crucial for informed policy-making. It features a tripartite classification (backward, forward, and two-sided) covering trade and production data. The findings indicate that traditional trade-based GVC metrics significantly underestimate global GVC activity, especially in sectors like services and upstream manufacturing, and overstate risks in early trade liberalization stages.

Additionally, conventional backward-forward classifications over-estimate backward linkages. The paper further applies these measures empirically to assess how GVC participation mediates the impact of demand shocks on domestic output, highlighting both the exposure and stabilizing potential of GVC integration. These new measures are comprehensively available on the World Bank's WITS Platform, providing a key resource for GVC analysis.

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# Economic Consequences of Trade and Global Value Chain Integration: A Measurement Perspective

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**JEL Codes:** *E16, F1, F14, F15*

**Online Appendix:** *The Online Appendix is available [here](#)*

# 1 Introduction

Securing market access and promoting exports are since long considered as primary drivers of economic growth and prosperity. The emergence of Global Value Chains (GVCs), which encompass production processes whose stages are spread across different countries, industries, and firms, complicate policy-making decisions. Global Value Chains introduce new opportunities and risks compared to traditional trade. On the one hand, GVC-led growth strategies feature additional gains from specializing in specific tasks or components and securing better access to inputs, technology, and skills through repeated firm-to-firm interactions (World Bank, 2019 and Antràs, 2020). On the other hand, GVC participation presents countries with greater challenges, including more income inequality and heightened exposure to imported shocks and risks (due for example to dependencies on foreign partners, sourcing challenges, market concentration of critical inputs or stages of production, and new types of technology and intellectual property vulnerabilities).

Understanding how countries and sectors participate in global production networks is essential for analyzing the drivers of economic development, resilience to shocks, and the welfare implications of globalization. While trade in value-added and related GVC metrics have become mainstream in policy and academic circles, most rely on trade-based measures constructed from Inter-Country Input-Output (ICIO) tables, and bi-partite backward-forward classifications of linkages. These conventional measures, while insightful, fall short in some key respects: they often blur distinctions between participation modes, overlook indirect contributions of non-exporting sectors, and distort the true scale and nature of GVC integration.

This paper addresses these gaps by advancing both the methodology and interpretation of GVC participation metrics. It targets two fundamental questions: how much do countries and industries participate to traditional trade and to GVCs? And in what different ways? It argues that answering these questions requires a decomposition into three components: pure backward participation, pure forward participation, and a two-sided engagement strategically positioned between the extremes, involving elements of both backward and forward participation. Furthermore, the paper also advocates for extending the assessment of GVC participation to include both trade-based and output-based metrics. This approach deviates significantly from conventional metrics that decompose participation in backward and forward linkages and focus exclusively on trade measures. These two improvements allow to capture indirect and non-exporting contributions to global production and align measures more closely with real-world production structures.

Applying this methodology to major ICIO datasets (EORA, ADB MRIOT, OECD TiVA, and WIOD), we construct a comprehensive set of indicators covering nearly 190 countries and up to 56 industries starting in 1990, and updated to the most recent year of available data, which at the time of writing (March 2025) goes to 2023. The new metrics show that previous approaches systematically underestimate the extent and complexity of GVC participation, especially for services, upstream manufacturing, and countries with low export-to-output ratios. They also reveal distinct patterns of engagement that matter for resilience, risk exposure, and by extension for economic development.

By bridging conceptual gaps in existing GVC measures, this paper equips policymakers and researchers with more accurate and actionable tools for understanding globalization's evolving landscape and their implications for economic growth, exposure to shocks, and development. For example, the paper shows that the risks associated with a country's involvement in GVCs

during the initial phases of trade liberalization can often be exaggerated. This occurs when a country's exports are heavily dependent on GVCs while forming only a minor portion of its total domestic output. Such a scenario was seen in early liberalizing China, for example. Measuring GVC participation against domestic output, in addition to trade, reveals that economies at such junctures are more shielded from international disturbances than previously thought. Moreover, the measures also allow to empirically show that GVC integration mediates the impact of demand shocks on domestic output in opposing directions, leading both to higher exposure and greater stabilizing potential for the domestic economy.

The rest of the paper is structured as follows: Section 2 provides a short literature review. Section 3 describes the tri-partite decomposition of GVC trade and it applies these concepts to GVC-related output. Section 4 applies these measures to multiple ICIO databases, highlighting how different countries and sectors participate in GVCs and comparing trade- and output-based metrics. Section 5 provides an empirical application of the new measures by examining how different types of GVC participation mediate the transmission of external demand shocks to domestic output. Section 6 concludes by summarizing key insights and outlining implications for research and policy. The full methodology describing the accounting framework and additional results are available in the [supplementary online appendix](#), while the full set of new measures, provisioned from all major ICIO databases is available on the World Bank's [WITS Platform](#) and described in Section S1 of the [supplementary online appendix](#).

## 2 Related Literature

Rigorous measures of GVC participation are needed to inform questions relevant to economic growth and development. Among these questions, there are two of primary importance: firstly, the extent of GVC involvement by different countries and industries; and secondly, the nature of their participation. In essence, good measures of GVC participation are needed to discern the importance of a given country's involvement for the domestic economy, and whether it primarily manifests itself as input supply to downstream nations and industries, as utilization of foreign inputs, or as a combination of both.

Assessing the extent to which the production and exchange of goods and services is interconnected globally is, however, a complex task. The most accurate and thorough approach requires data at the individual company level from numerous countries, especially when aiming for a global perspective. Obtaining such extensive and specific data poses a major hurdle, since very few countries generate the required data (Bems & Kikkawa, 2021). Owing to the shortage of such data, researchers have dedicated significant effort over the past twenty-five years to methodically combine transaction data from customs with national aggregate production data. They have developed accounting measures at the country-sector level based on global databases of inter-country input-output (ICIO) relationships. This approach ensures a scientific rigor in their analysis, despite well-known limitations due to assumptions in terms of homogeneity, proportionality and aggregation that such data require, as discussed by de Gortari (2019), Antràs (2021) and Bems and Kikkawa (2021) among others. The resulting country-sector level measures have allowed to quantify the extent to which production processes have become global in the past decades, and how countries and sectors participate in GVCs, together with other features of participation, such as direct and indirect supply and demand inter-linkages. The study by Antràs (2020) calls this body of work "the broad view of GVC participation" while Antràs and Chor (2022) define it as the "macro-approach" to GVC

measurement.

A number of studies have laid the groundwork in understanding and quantifying production sharing and trade in value added following such “macro-approach”. Key contributions include Hummels et al. (2001), Johnson and Noguera (2012), Koopman et al. (2014), and Borin and Mancini (2015). These have been instrumental in conceptualizing this field and in developing sound measurement methodologies, that are now accepted as standard in the literature. In particular, Hummels et al. (2001) introduced a fundamental idea, suggesting that a minimal condition for trade to be considered GVC-related, is that it must cross at least two country borders.<sup>1</sup>

Early measures have tended to concentrate on specific aspects of the trade-GVC relationship, providing foundational estimates of participation, which have been refined in later research for greater comprehensiveness, accuracy and statistical rigor. The ‘vertical specialization’ index by Hummels et al. (2001), which gauges the import content of a country’s exports, was widely popular. However, as noted by the authors, it measures participation only partially, accounting for backward but not forward linkages. Koopman et al. (2014) introduced an accounting method to decompose a country’s gross exports by the source and final destination of their embedded value added. This approach, which is highly used in the literature, quantifies the extent of a country’s production included in other nations’ exports. It however does not trace whether exports undergo further processing in the importing or downstream countries, nor it aligns fully with theory (see Section S2 in the [supplementary online appendix](#) for further details). Another notable contribution is Johnson and Noguera (2012), which defined the value-added exports to gross exports ratio (VAX). The complement of this measure ( $1 - VAX$ ) has been interpreted in some cases as a measure of the share of trade involved in GVCs. While changes in this indicator align closely with variations in international production fragmentation, especially globally (Johnson and Noguera, 2017), the indicator in levels tends to underestimate the significance of GVCs in trade, a point elaborated in Antràs and Chor (2022).<sup>2</sup>

Building on the definition by Hummels et al. (2001), Borin and Mancini (2015) showed how to calculate GVC-related trade using global input-output tables in a way that aligns with the original concept established by Hummels and co-authors in 2001. The accounting framework proposed by Borin and Mancini was the first to provide a quantitative assessment of trade crossing at least two borders. The method ensured that the measure of GVC-trade corresponds to the sum of two established metrics of cross-border GVC linkages: forward GVC participation (producing and exporting inputs for further re-export by the trading partner) and backward GVC participation (utilizing imported inputs for goods exported abroad). More recently, Borin and Mancini (2023) proposed a comprehensive methodology for value-added accounting of trade flows at the aggregate, bilateral, and sectoral levels, aligning different accounting perspectives to the economic questions they address best.

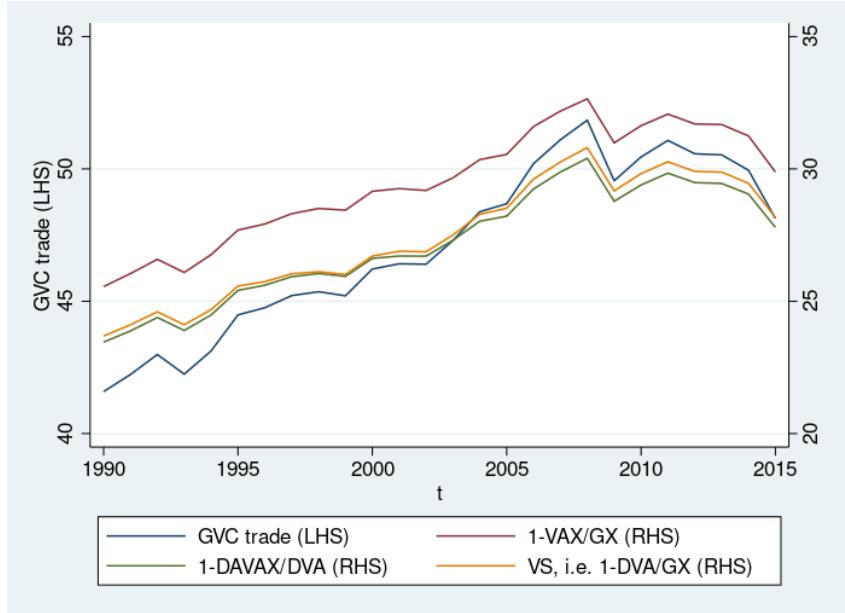
All the above-mentioned concepts and measures are now commonly accepted in academic

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<sup>1</sup>In theory, value-added generated in the final stages of an internationally fragmented production process should be regarded as related to Global Value Chains (GVC), even if it only crosses one border. However, in practical terms, this segment cannot be distinguished from conventional trade using standard inter-country input-output (ICIO) tables. Due to this empirical constraint, the study Hummels et al. (2001) and all other macro-level measures (that is, at the country-sector level) of GVC-related trade in the wider literature concentrate on the “minimal” criterion for GVC trade, namely, crossing at least two borders.

<sup>2</sup>This comes from the fact that only a sub-portion of **VAX** is not GVC-related - see Section S2 in the [supplementary online appendix](#) for further details.

**Figure 1:** Comparison among different GVC measures.



Source: Antràs and Chor, 2022

and policy research. The study by Antràs and Chor (2022), part of the *Handbook of International Economics*, surveys these methods, offering a critical evaluation of the differences between them. These are summarized in Figure 1, which reproduces Figure 3 of Antràs and Chor (2022). The line “GVC trade” in the figure corresponds to the measure proposed by Borin and Mancini (2015) and further discussed in Borin and Mancini (2023). It shows that GVC trade accounted for about 42% of gross trade globally in 1990, reaching a peak of 52% in 2008, and retrenching to about 48% by 2015. All other measures also show that cross-border GVC activity rose steadily from the mid-1990s until the late 2000s, slightly ebbing after the Global Financial Crisis. The line “1 – VAX/GX” corresponds to the complement of the “VAX” measure proposed by Johnson and Noguera (2012), while the line “VS”, i.e. “1 – DVA/GX”, corresponds to the measure of vertical specialization proposed by Hummels et al. (2001).<sup>3</sup> Both measures underestimate the degree of GVC participation by around 20 percentage points, as they do not account for forward linkages.<sup>4</sup> Lastly, “1 – DAVAX/DVA” is a close counterpart to “GVC trade”, assessing the importance of domestic value-added that crosses more than one border.

We argue that all the above measurement approaches suffer from three limitations, that the methodology discussed in this paper (Section 3) allows to overcome. First, they do not provide a formulation for forward linkages consistent with the original definition in Hummels et al. (2001). Second, they do not separate pure backward participation from two-sided engagement in GVCs, leading to a systematic exaggeration of the backward component compared to the forward component, and to the oversight of the role of two-sided participation in understanding GVCs. Third, they focus exclusively on trade flows. This practice leads simultaneously to problems of underestimation and overestimation: it tends to underestimate the *absolute* levels

<sup>3</sup>Note that Antràs and Chor (2022) do not separately plot the ratio of domestic value added in gross exports “DVA/GX”, which Koopman et al. (2014) have emphasized in their work, since the vertical specialization measure by Hummels et al. (2001) is exactly equal to “1 – DVA/GX” at the country level.

<sup>4</sup>See Section S2 in the [supplementary online appendix](#) for further details.

of GVC participation through the systematic exclusion of the contribution by industries not directly engaged in exporting activities despite being important suppliers of GVC-oriented industries; and it exaggerates the *relative* exposure for countries whose traded sector is mostly GVC-related, but it constitutes a small share of overall domestic output.

When one applies the methodology proposed by this paper to the data (Section 4), it is possible to quantify more precisely the extent and modalities of countries' and sectors' engagement in trade and GVC activities. By improving the measurement of GVC exposure, the measures proposed in this paper are also well suited for discussions about GVC riskiness and resilience, two themes very current in discussions, and for exploring the relationship between trade and countries' growth and development.

### 3 Methodology

This section presents an accounting framework that allows for a tri-partite decomposition and the use of output-based measures of GVC participation - in addition to trade-related ones. The tri-partite decomposition allows to develop a precise and intuitive measure of how countries and industries participate in traditional trade and GVC-related activities. The application of these metrics to both trade and output data allows to capture more comprehensively the extent of participation, as mentioned shortly in the Introduction and at the end of Section 2. The discussion of this Section is streamlined for ease of understanding, and the main concepts are illustrated through diagrams. These latter have a direct correspondence with the underlying algebraic forms, whose full exposition, inclusive of definitions, adopted conventions, and mathematical derivations, is available in Section S2 in the [supplementary online appendix](#).

#### 3.1 Tripartite decomposition of GVC-related trade

Characterizing linkages as either forward or backward fails to capture an important empirical regularity: GVC participation encompasses many activities that are linked simultaneously backward and forward to entities abroad. In Section 4 we will show that activities interlinked with both upstream suppliers and downstream buyers internationally could represent as much as two-thirds of all production related to GVCs, highlighting their substantial role. These activities may be critical drivers of economic growth and development, as suggested in Baldwin and Lopez-Gonzalez (2015), under the concept of I2E (import to export), underscoring their significance in the literature on international trade and development.

To more accurately represent international interdependencies, this paper introduces a nuanced accounting framework that identifies three separate modes of participation: *pure forward participation* to describe activities that occur at the start of the value chain, where primary inputs are converted in intermediate goods; *pure backward participation* to characterize activities at the end of the chain, which pertains to the final transformation of these goods into final products; and *two-sided or mixed participation* for activities that are positioned in the intermediary stages of the chain.

Taking the perspective of the exporting sector, in this section we demonstrate the method for identifying the proportion of any trade flow that can be linked to global value chains and how to operate the above-mentioned tri-partite decomposition. In the next section (Section 3.2) we show how these concepts can be applied to output data too.

### 3.1.1 Definition of GVC-trade

Consider a standard Inter-Country Input-Output (ICIO) model with  $G$  countries and  $N$  sectors. Given the  $N \times 1$  vector of gross exports from country  $s$  to country  $r$ , which we call  $\mathbf{E}_{sr}$ , the level of GVC-trade at the sectoral level is:

$$\mathbf{GVC}_{sr} = \mathbf{E}_{sr} - \mathbf{DAVAX}_{sr} = \mathbf{E}_{sr} - (\widehat{\mathbf{V}_s \mathbf{L}_{ss}} \mathbf{Y}_{sr} + \widehat{\mathbf{V}_s \mathbf{L}_{ss}} \mathbf{A}_{sr} \mathbf{L}_{rr} \mathbf{Y}_{rr}), \quad (1)$$

where  $\mathbf{V}_s$  is the  $1 \times N$  vector that incorporates the value-added shares embedded in each unit of gross output produced by country  $s$ ,  $\mathbf{L}_{ss}$  is the  $N \times N$  *local* Leontief inverse matrix taking into account only the domestic chains, i.e.  $(\mathbf{I} - \mathbf{A}_{ss})^{-1}$ , with  $\mathbf{A}_{ss}$  being the direct requirements matrix of country  $s$  inputs in its own productions,  $\mathbf{Y}_{sr}$  is the  $N \times 1$  vector of final goods and services produced by country  $s$  and absorbed in country  $r$ .<sup>5</sup>

The term in equation (1) we subtract from gross exports  $E_{sr}$  corresponds to the  $\mathbf{DAVAX}_{sr}$  – directly absorbed value-added in exports – which identifies, for each country  $s$  and sector  $n \in N$  of exports, the ‘traditional’ type of exports to country  $r$ , as opposed to the international shipments that take place under the global sharing of production (‘GVC-related trade’). Traditional trade  $\mathbf{DAVAX}_{sr}$  is the simplest form of trade between countries. In alignment with the concept established by Hummels et al. (2001), it traces the amount of value that crosses just one border, that is the one between the exporter and the importer. It consists of two types of flows: (i) the value of final goods produced entirely at home and consumed abroad ( $\widehat{\mathbf{V}_s \mathbf{L}_{ss}} \mathbf{Y}_{sr}$ ); and (ii) the value of intermediate inputs (entirely) produced at home and used by the importing country to produce final goods for its internal market ( $\widehat{\mathbf{V}_s \mathbf{L}_{ss}} \mathbf{A}_{sr} \mathbf{L}_{rr} \mathbf{Y}_{rr}$ ).

Accordingly, the measure of ‘GVC-related trade’,  $\mathbf{GVC}_{sr}$ , includes all traded items that cross at least two international borders, i.e. that are re-exported at least once before being absorbed in final demand.<sup>6</sup>

Characterizing  $\mathbf{GVC}_{sr}$  as in Equation (1) presents two desirable features: *i*) once divided by gross exports, i.e.  $\mathbf{GVC}_{sr} / \mathbf{E}_{sr}$ , the indicator is bound between 0 and 1, since it traces the share of a trade flow value related to GVC activity; *ii*) the indicator  $\mathbf{GVC}_{sr}$  is also additive along all dimensions and levels of aggregation (or disaggregation) of trade flows.<sup>7</sup> It should be noted that the broad definition in Equation (1) aligns with a definition initially presented in Borin and Mancini (2015) and discussed in Borin and Mancini (2023). The innovation of this paper is to divide it into the three distinct modes of participation discussed above, i.e. ‘pure forward’, ‘two-sided’, and ‘pure backward’.<sup>8</sup>

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<sup>5</sup>The hat notation is a standard way to transform a generic  $1 \times N$  vector into its diagonal  $N \times N$  form. Further details are reported in Section S2 in the [supplementary online appendix](#).

<sup>6</sup>In principle, also value-added produced in completion stages of the production process, even if it crosses only one border, should be labeled as GVC trade. However, it cannot be singled out using standard ICIO tables. Due to this empirical limitation, it is not considered as part of GVC trade, neither in this paper nor in any macro (country-sector level) measure of GVC trade discussed in the broader literature. Such convention is in line with the initial conceptualization and definition by Hummels et al. (2001).

<sup>7</sup>This means that the indicator can be aggregate in multiple ways and at different levels of aggregation in order to obtain the desired GVC participation measure i.e. exports and its portions (traditional trade, GVC trade, components of GVC trade) at world-level, and at country, country-pair, country-group level, for all industries, for groups of industries, and for individual sectors) by simple summation of the relevant elements

<sup>8</sup>The mapping of these measures with previous ones is as follows: “pure forward participation”, corresponds one-to-one to what Belotti et al. (2021) and Borin and Mancini (2017) label as “forward participation”. Instead, the sum of “pure backward” and “two-sided” participation corresponds to backward participation in those papers. See Section S2 in the [supplementary online appendix](#) for further discussion.

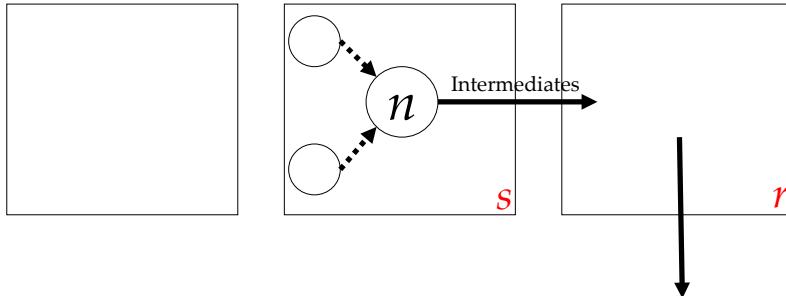
### 3.1.2 Pure forward GVC-trade participation

'Pure forward' is close to the origin of the chain. It comprises the exports of sector  $n$  of value-added generated within the domestic chains, which are then re-exported by the partner.

$$GVC_{\text{PureForw}}{}_{sr} = \widehat{V_s L_{ss} E}_{sr} - DAVAX_{sr}. \quad (2)$$

The pure forward participation is simply the difference between the entire domestic value-added that is exported ( $\widehat{V_s L_{ss} E}_{sr}$ ) and the one that is directly absorbed by the importer ( $DAVAX_{sr}$ ). Schematically one can represent this as in Diagram 1

**Diagram 1: Pure-forward GVC-trade - Origin of the chain: first exporting sector**



Notes: letters denote either countries (red) or sectors (black) traced by our accounting framework. Boxes represent countries while sectors are identified by circles. Arrows indicate sales, direct ones (solid arrows), or direct and indirect ones (dashed arrows).

The rest of GVC-related trade is given by the sum of the *pure* backward participation and the *two-sided* participation. This is what Hummels et al. (2001) call vertical specialization, i.e. the import content of exports. We discuss it, as well as its two components, in the next paragraphs.

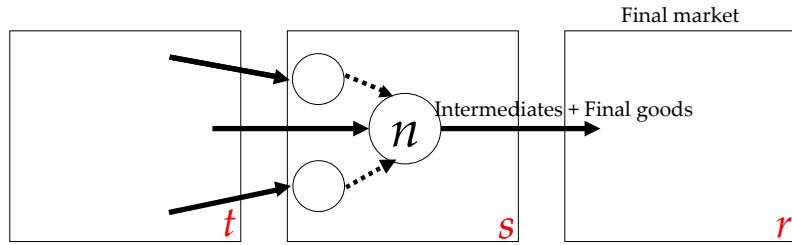
### 3.1.3 Pure backward GVC-trade participation

'Pure backward' is the portion of the import content of exports closer to the end of the chain:

$$GVC_{\text{PureBack}}{}_{sr} = \sum_{t \neq s}^G \widehat{\mathbf{u}_N \mathbf{A}_{ts} \mathbf{L}_{ss}} (\mathbf{Y}_{sr} + \mathbf{A}_{sr} \mathbf{L}_{rr} \mathbf{Y}_{rr}), \quad (3)$$

where  $\mathbf{u}_N$  is the  $1 \times N$  unit row vector whose purpose is to reduce the dimension of the matrices. Pure backward GVC-trade consists of imported inputs bought by sector  $n$  in country  $s$  directly from the foreign country  $t$  or indirectly through domestic chains and exported by the same sector to the final market  $r$ , as final products  $\left( \sum_{t \neq s}^G \widehat{\mathbf{u}_N \mathbf{A}_{ts} \mathbf{L}_{ss}} \mathbf{Y}_{sr} \right)$  or intermediates  $\left( \sum_{t \neq s}^G \widehat{\mathbf{u}_N \mathbf{A}_{ts} \mathbf{L}_{ss}} \mathbf{A}_{sr} \mathbf{L}_{rr} \mathbf{Y}_{rr} \right)$ , as shown schematically in Diagram 2.

**Diagram 2: Pure-backward GVC-trade - End of the chain: last exporting sector**



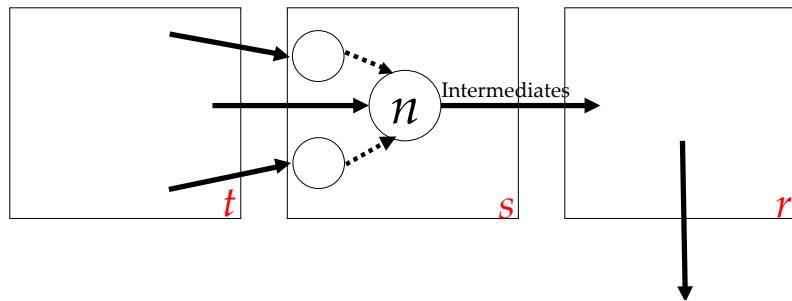
Notes: letters denote either countries (red) or sectors (black) traced by our accounting framework. Boxes represent countries while sectors are identified by circles. Arrows indicate sales, direct ones (solid arrows), or direct and indirect ones (dashed arrows).

### 3.1.4 Two-sided GVC-trade participation

Finally, the two-sided participation is given by all imported inputs embedded in the re-export of the bilateral partner. The measure represents a measure of both backward and forward participation. It consists of imported inputs in a country's exports that are further re-exported by the bilateral partner (Diagram 3). It clearly excludes the value added captured by pure backward participation – i.e. imported inputs for a country's exports to final markets – and the one captured by pure forward participation – i.e. exports of inputs produced with domestic value added and then re-exported by the bilateral partner.

$$\text{GVCTwoSided}_{sr} = \sum_{t \neq s}^G \widehat{\mathbf{u}_N \mathbf{A}_{ts} \mathbf{L}_{ss}} \left( \mathbf{A}_{sr} \mathbf{L}_{rr} \sum_{j \neq r}^G \mathbf{E}_{rj} \right) \quad (4)$$

**Diagram 3: Two-sided or intermediate position: other sectors have already exported the item, others will re-export it**



Notes: letters denote either countries (red) or sectors (black) traced by our accounting framework. Boxes represent countries while sectors are identified by circles. Arrows indicate sales, direct ones (solid arrows), or direct and indirect ones (dashed arrows).

## 3.2 GVC Concepts and Measures Applied to Output

Traded activities represent the most visible manifestation of cross-country production linkages. However, global production networks extend beyond import-export dynamics and encompass both international and domestic production relationships.

### 3.2.1 Definition of GVC-related output

The approach to measure GVC-related output mirrors the method used for GVC-related trade in Section 3.1. Also in this case, we focus on the three key moments that define a sector's role in the supply chain: its contributions at the initial stage, its role in the intermediary phases, and its impact at the end of the production process. Here the emphasis is on the sector of production, not on the sector of exports, as in Section 3.1. Accordingly, we identify as “pure forward participation” the very first link of a chain, i.e. the activities related to the creation of value-added that will be exported by any sector and then re-exported by a direct trade partner. Activities related to the assembly of the final goods or services will instead fall in the “pure backward participation”, as they represent the last link of a chain. Final goods that are not exported will fall into this category too, if they are assembled using inputs that have previously crossed at least two borders. Everything in between, i.e. all the activities that encompass both buying and selling of inputs, will be categorized as two-sided participation.

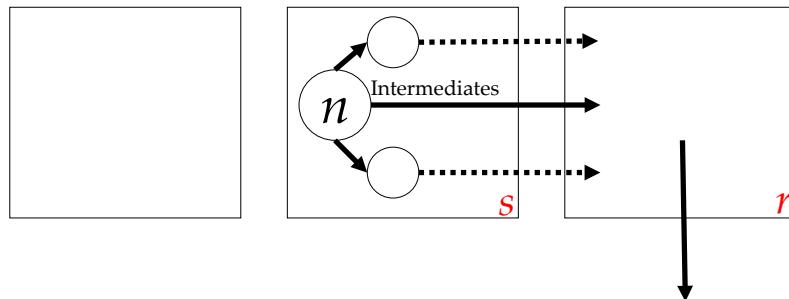
### 3.2.2 Pure forward GVC participation in output

Pure forward GVC output consists of value-added produced by sector  $n$  that is sold abroad – directly by  $n$ , or indirectly through other sectors that are part of the same domestic value chains – and subsequently re-exported by the partner country  $r$ , hence crossing two borders or more. Formally,

$$\text{GVCPureFor}w_s^X = \widehat{\mathbf{V}}_s \sum_{r \neq s}^G (\mathbf{A}_{sr} \mathbf{X}_r^{exp} + \mathbf{A}_{ss} \mathbf{L}_{ss} \mathbf{A}_{sr} \mathbf{X}_r^{exp}), \quad (5)$$

where  $\mathbf{X}_r^{exp}$  is the output of country  $r$  further re-exported. The first term ( $\mathbf{A}_{sr} \mathbf{X}_r^{exp}$ ) represents direct sales to foreign country  $r$  by sector  $n$ , while the second term ( $\mathbf{A}_{ss} \mathbf{L}_{ss} \mathbf{A}_{sr} \mathbf{X}_r^{exp}$ ) indirect sales through domestic chains. Pure-forward participation is illustrated in Diagram 4.<sup>9</sup> Therefore, GVC pure forward participation in output corresponds to value-added crossing at least two borders traced in the sector of its origin.<sup>10</sup>

**Diagram 4: Pure-forward GVC-Output - Origin of the chain: sector where the value-added originates**



Notes: letters denote either countries (red) or sectors (black) traced by our accounting framework. Boxes represent countries while sectors are identified by circles. Arrows indicate sales, direct ones (solid arrows), or direct and indirect ones (dashed arrows).

<sup>9</sup>Pure forward GVC participation in output can also be obtained by subtracting the portion of value added that is never exported and the one that crosses only one border from the total value added of a sector, as discussed in Borin and Mancini (2015).

<sup>10</sup>See Section S2 in the [supplementary online appendix](#) for a broader discussion.

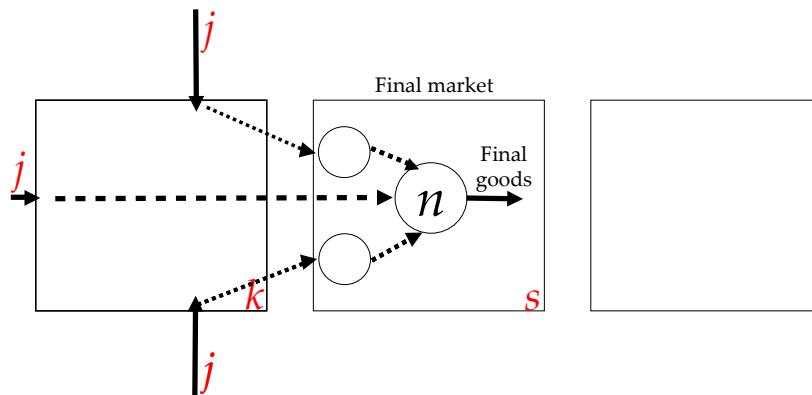
### 3.2.3 Pure backward GVC participation in output

Pure backward GVC output is defined as imported inputs bought by a sector  $n$  directly from abroad or indirectly through domestic chains that are embedded in sector  $n$ 's final goods production. If imported inputs cross more than one border before being used by  $n$ , they are part of pure backward GVC output even if they are sold to domestic consumers as final goods (Diagram 5). Instead, if imported inputs cross only one border before being used by  $n$ , they are part of pure backward GVC output only if they are sold abroad as final goods (Diagram 6). This distinction is a crucial one. It makes sure that overall pure backward GVC output adheres to our broad definition of GVCs, i.e. items crossing at least two borders. It is defined as:

$$\text{GVC}_{\text{PureBack}}^X_s = \sum_j^G \widehat{\mathbf{V}_j \mathbf{L}_{jj} \sum_{k \neq j}^G \mathbf{A}_{jk} \mathbf{B}_{ks}} \sum_z^G \mathbf{Y}_{sz} - \sum_{j \neq s}^G \widehat{\mathbf{V}_j \mathbf{L}_{jj} \mathbf{A}_{js} \mathbf{L}_{ss}} \mathbf{Y}_{ss}, \quad (6)$$

where  $\mathbf{B}_{ks}$  is the *global* Leontief inverse matrix. Intuitively, the first term identifies imported intermediates embedded in final goods production carried on by sector  $n$ , while the second one excludes from the first term those intermediates crossing just one border. Therefore,  $\text{GVC}_{\text{PureBack}}^X_s$  consists only of imported intermediates that are embedded in final goods and cross at least two borders.<sup>11</sup>

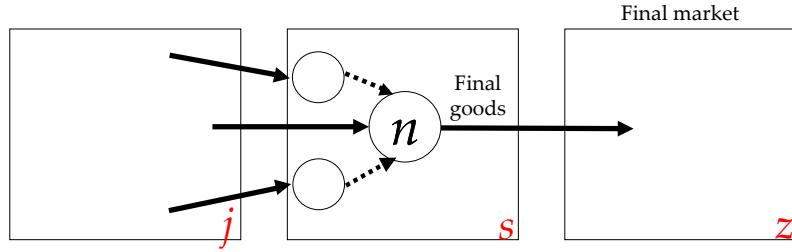
**Diagram 5: Pure-backward GVC-Output - End of the chain: case in which the good is completed and sold in the domestic market**



Notes: letters denote either countries (red) or sectors (black) traced by our accounting framework. Boxes represent countries while sectors are identified by circles. Arrows indicate sales, direct ones (solid arrows), or direct and indirect ones (dashed arrows).

<sup>11</sup>See Section S2 in the [supplementary online appendix](#) and Wang et al. (2017).

**Diagram 6: Pure-backward GVC-Output - End of the chain: case in which the good is completed and sold to foreign markets**



Notes: letters denote either countries (red) or sectors (black) traced by our accounting framework. Boxes represent countries while sectors are identified by circles. Arrows indicate sales, direct ones (solid arrows), or direct and indirect ones (dashed arrows).

### 3.2.4 Two-sided GVC participation in output

While pure forward and pure backward GVC output pertain to activities at the origin – value-added creation – or at the end – final goods production – of a value chain, two-sided GVC output is found in all the other activities in an intermediate position. Intuitively, it consists of two terms. First, intermediates bought abroad (backward) and exported as intermediates (forward). This case is illustrated in Diagram 7. Second, domestic inputs bought from other sectors in the domestic market (backward), exported as intermediates, and further re-exported by the bilateral partner (forward), as per Diagram 8. Both terms share the usual property ('crossing at least two borders') but they are computed in different ways. The first term can be computed by subtracting the inputs originating from a direct trade partner and not re-exported, and those being part of pure backward GVC output, from the total imported inputs. The second term instead follows the same rationale of GVC pure forward output in (5), but it is applied to domestic inputs instead of value-added. Formally, we write the corresponding equations as follows:

$$\text{GVCTwoSide}_s^{ImpInp} = \sum_j^G \widehat{\mathbf{V}_j \mathbf{L}_{jj} \sum_{k \neq j}^G \mathbf{A}_{jk} \mathbf{B}_{ks}} \mathbf{X}_s - \sum_{j \neq s}^G \widehat{\mathbf{V}_j \mathbf{L}_{jj} \mathbf{A}_{js} \mathbf{L}_{ss}} \mathbf{L}_{ss} \mathbf{Y}_{ss} - \text{GVCPureBack}_s^X, \quad (7)$$

where  $\mathbf{X}_s$  is the  $N \times 1$  vector of gross output produced by country  $s$ , and

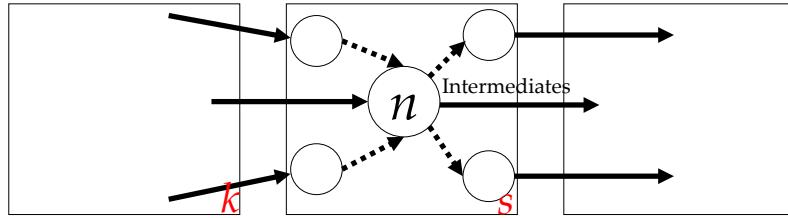
$$\text{GVCTwoSide}_s^{DomInp} = \widehat{\mathbf{V}_s \mathbf{L}_{ss} \mathbf{A}_{ss}} \sum_{r \neq s}^G (\mathbf{A}_{sr} \mathbf{X}_r^{exp} + \mathbf{A}_{ss} \mathbf{L}_{ss} \mathbf{A}_{sr} \mathbf{X}_r^{exp}). \quad (8)$$

Therefore, two-sided GVC participation in output will be equal to  $\text{GVCTwoSide}_s^X = \text{GVCTwoSide}_s^{ImpInp} + \text{GVCTwoSide}_s^{DomInp}$ .

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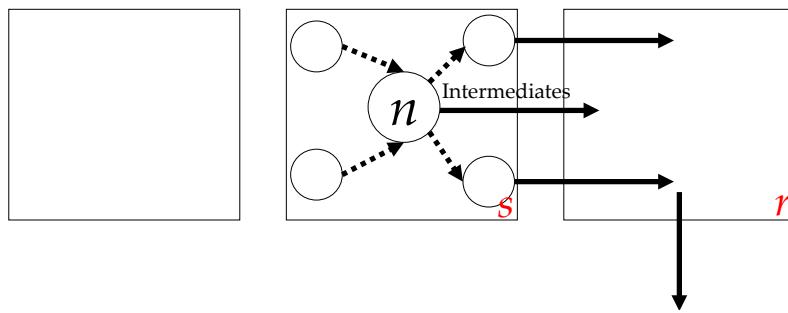
<sup>12</sup>More technical details can be found in Section S2 in the [supplementary online appendix](#).

**Diagram 7: Two-sided GVC-Output - sector buying foreign inputs and selling intermediates**



Notes: letters denote either countries (red) or sectors (black) traced by our accounting framework. Boxes represent countries while sectors are identified by circles. Arrows indicate sales, direct ones (solid arrows), or direct and indirect ones (dashed arrows).

**Diagram 8: Two-sided GVC-Output - sector buying domestic inputs and selling intermediates**



Notes: letters denote either countries (red) or sectors (black) traced by our accounting framework. Boxes represent countries while sectors are identified by circles. Arrows indicate sales, direct ones (solid arrows), or direct and indirect ones (dashed arrows).

### 3.3 Derived Measures: Aggregations, Complements of GVC Activity, and Forwardness Indices

The above accounting decompositions for trade and output can be manipulated in three useful ways: they can be aggregated to allow different empirical applications; they can be used to look at the complement of GVC-related trade and output, i.e. domestic production and traditional trade; and they can be used to compute an index of relative participation in GVC-trade and GVC-output centered at zero, that we call *forwardness*.

#### 3.3.1 Aggregation across industries, countries and modes of participation

Depending on the empirical application, it could be useful to consider broad measures of participation instead of pure ones. The accounting framework allows to aggregate by simple summation across all dimensions of the indicators, i.e. participation modes, industries, countries. More specifically:

- Broad measures of participation can be computed by simply summing up the three modes of participation into an overall measure of GVC-related trade or GVC-related output, respectively:

- $\mathbf{GVC}_{sr} = \mathbf{GVCPureForw}_{sr} + \mathbf{GVCPureBack}_{sr} + \mathbf{GVCTwoSided}_{sr}$
- $\mathbf{GVC}_s^X = \mathbf{GVCPureForw}_s^X + \mathbf{GVCPureBack}_s^X + \mathbf{GVCTwoSided}_s^X$
- The overall indicators of GVC-related trade and GVC-related output, and their forward, backward and two-sided components can be computed by summation at any level of country-sector aggregation.
- At the aggregate world level, i.e. summing across exporters  $s$ , importers  $r$  and sectors  $n$ , the ‘GVC pure backward-related trade’ is equal to the ‘GVC pure forward-related trade’, i.e.  $\sum_{s,r \neq s}^G \mathbf{u}_N \mathbf{GVCPureBack}_{sr} = \sum_{s,r \neq s}^G \mathbf{u}_N \mathbf{GVCPureForw}_{sr}$ . The same property holds for GVC-related output, i.e.  $\sum_s^G \mathbf{GVCPureForw}_s^X = \sum_s^G \mathbf{GVCPureBack}_s^X$ .

### 3.3.2 Regional GVC trade

The GVC-related trade measures presented above can also be computed so to distinguish between intra-regional and extra-regional value chain participation. The same holds for its sub-components, i.e. pure forward, pure backward and two-sided participation presented in equations (2), (3) and (4).

More specifically, given a country  $s$ , member of a region  $K$ , for each exporting sector  $n$ , intra-regional value-chain participation is defined as the sum of : *i*) domestic value-added of sector  $n$  re-exported by a regional member (pure forward); *ii*) import content of inputs sourced directly from a regional member  $t \in K$  and exported by sector  $n$  to final markets (pure backward); *iii*) import content of inputs sourced directly from a regional member  $t \in K$  and exported by sector  $n$  to partners that re-export them (two-sided).<sup>13</sup> Extra-regional value-chain participation is then computed as the difference between the total GVC participation and the intra-regional one. In Section S2.2.2 of the [supplementary online appendix](#) we provide a detailed derivation of these terms.

### 3.3.3 Measures of Domestic and Traditional Trade Output

The framework developed to single out GVC-related output allows also to compute the share of output that never crosses a border, i.e. purely domestic, as the sum of the domestic inputs and value-added that are not exported at all,  $\mathbf{Dom}_s^X = \widehat{\mathbf{V}_s \mathbf{L}_{ss} \mathbf{A}_{ss} \mathbf{L}_{ss}} \mathbf{Y}_{ss} + \widehat{\mathbf{V}_s \mathbf{L}_{ss}} \mathbf{Y}_{ss}$ , as well as output related to traditional trade, i.e. crossing only one border before being absorbed by final demand,  $\mathbf{Trad}_s^X = \mathbf{X}_s - \mathbf{Dom}_s^X - \mathbf{GVC}_s^X$ . In this way, we have obtained a full decomposition of the output produced by a country, i.e.  $\mathbf{X}_s = \mathbf{Trad}_s^X + \mathbf{Dom}_s^X + \mathbf{GVC}_s^X$ .

### 3.3.4 Forwardness Index

Finally, to fully assess the extent and nature of involvement in GVCs, it's possible to compute a relative measure of participation that we will label as “Forwardness Index”. This index ranges from  $-1$  to  $+1$ , and takes a value equal to zero at the global level. It is calculated by first subtracting the measure of “Pure Backward Participation” from that of “Pure Forward

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<sup>13</sup>See Section S2 in the [supplementary online appendix](#) for detailed formulas.

Participation”, and then dividing this difference by overall GVC participation. This measure, when applied to individual country-pair-industries and GVC-trade, can be written as follows:

$$\mathbf{P}_{sr} = (\mathbf{GVCPureFor}w_{sr} - \mathbf{GVCPureBack}_{sr}) \oslash \mathbf{GVC}_{sr}. \quad (9)$$

where the vector  $\mathbf{P}_{sr}$  measures the “forwardness” of country  $s$  exports to country  $r$ , for each sector  $n$ , and each of its elements is bounded between -1 and 1. Forwardness at the country level can be obtained simply by summing across sectors and bilateral partners both the numerator and the denominator.<sup>14</sup> In the same way, a natural measure of the type of participation in output of countries and sectors in GVC can be straightforwardly obtained as

$$\mathbf{P}_s^X = (\mathbf{GVCPureFor}w_s^X - \mathbf{GVCPureBack}_s^X) \oslash \mathbf{GVC}_s^X. \quad (10)$$

At the global level,  $P$  is equal to zero both for trade and output, given pure backward and pure forward participation are equal at that level of aggregation,  $\sum_s^G P_s = 0$ . Thus, any index different from zero at any level of aggregation might be interpreted as a deviation from the world aggregate average.

The forwardness index offers a synthetic means of evaluating the primary mode through which a country or a sector engages in GVCs. Previously, a separate strand of the literature has developed specific indicators, such as “upstreamness”, “downstreamness” and “positioning”, to characterize more accurately the participation mode (Antràs and Chor, 2019 and Wang et al., 2017; see Mancini et al., 2024 for a comprehensive database of such measures based on the most popular Inter-Country Input-Output tables). It is reassuring to see that the forwardness index proposed above shows a strong positive correlation with those measures of positioning.<sup>15</sup>

Incorporating both the dimensions of the extent of GVC participation and the primary participation mode within a unified framework provides a coherent and easily comprehensible method for a thorough evaluation of a country’s or a sector’s engagement in GVCs. Additionally, the fact that the forwardness index is bounded between -1 and 1 and neutral at the world level streamlines assessments when moving from a global perspective to specific country-sector interactions. Collectively, the set of indicators we present constitutes a straightforward and comprehensive toolbox of GVC descriptive statistics, readily applicable for policy analysis.

## 4 Results: Assessing GVC Participation Through the New Measures

We used the GVC participation measures from Section 3 on four popular Inter-Country Input-Output (ICIO) datasets: EORA, the Asian Development Bank MRIOT, OECD TiVA, and WIOD. This helped us create a detailed and up-to-date set of indicators for 189 countries and 26 to 56 industries (depending on the dataset) from 1990. The industry classification and time coverage vary based on the raw data available in each dataset. These measures are available in the World Bank’s [WITS](#) Platform, which also provides details on industry classification and time coverage. Using these measures, we can answer two main questions: First, how much

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<sup>14</sup>See Section S2 in the [supplementary online appendix](#) for more details.

<sup>15</sup>See Section S3.4 in the [supplementary online appendix](#).

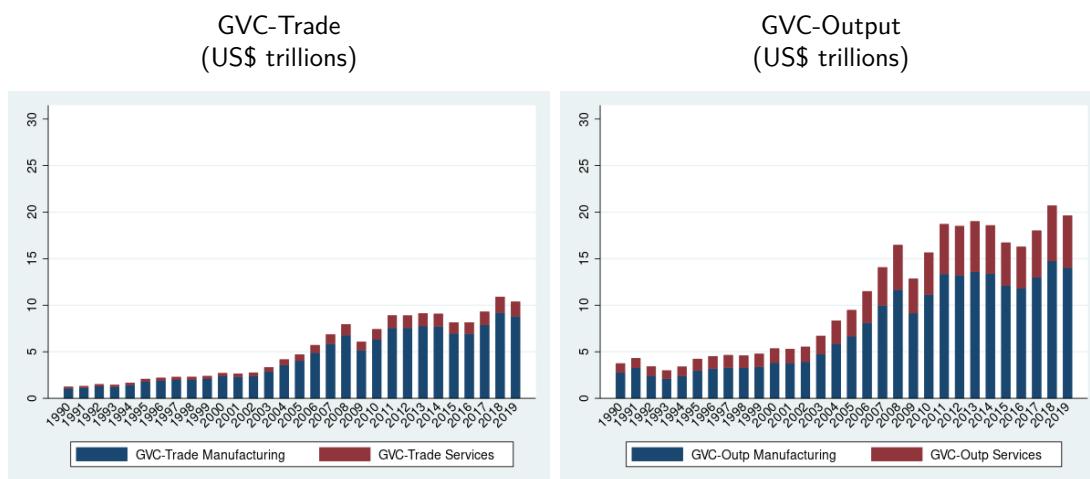
do countries and sectors participate in GVCs? This looks at the share of trade and economic output linked to GVCs. Second, how do countries and sectors participate in GVCs? This identifies if they are mainly suppliers of intermediate inputs or users of GVC-related products. Additional evidence related to these aspects is reported in Section S3 of the [supplementary online appendix](#).

## 4.1 What Part of a Country's Trade and Output are Involved in GVCs?

The main purpose of this section is to prove that a comprehensive perspective incorporating both trade-based and output-based measures of GVC participation is essential for accurately assessing the scale of global value chains. Relying solely on trade-based measures underestimates the true extent of GVC activity and overestimates the relative importance of participation for certain countries and sectors.

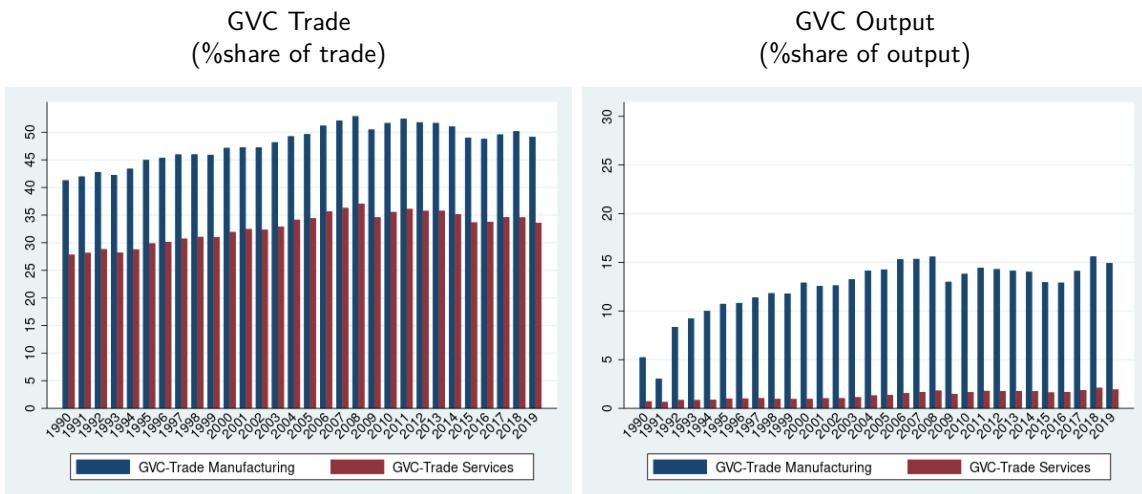
- *Underestimation, absolute terms:* Trade-based measures underestimate participation by about 10 trillion USD—since GVC trade amounts to approximately 10 trillion USD globally, while GVC output reaches nearly 20 trillion USD, as reported in Figure 2.
- *Overestimation, relative terms:* Trade-based indicators, in relative terms, tend to overstate the true scale of GVC involvement, particularly in sectors like services, highlighting the need for jointly considering trade-based and output-based metrics. Figure 3 illustrates this point. While nearly 50% of manufacturing trade is GVC-related, only about 15% of manufacturing output is. Similarly, GVC participation in services amounts to about 30% when judged by trade-based measures alone, but it masks the fact that services are far less export-intensive than goods. Complementing the trade-based metrics with output-based GVC measures allows to account for this lower export propensity and provide a more grounded view of actual participation, as shown in the right-hand panel of Figure 3.

**Figure 2:** Exporter versus producer perspective in measuring GVC participation, *absolute terms*



Source: Own elaboration based on EORA and ADB MRIO

**Figure 3:** Exporter versus producer perspective in measuring GVC participation, *relative terms*



Source: Own elaboration based on EORA and ADB MRIO

Differences between trade-based and output-based measures are especially large when sectors and countries participate in GVCs indirectly—by supplying inputs to other domestic sectors that then export.

- *Sectors:* Trade-based indicators often misattribute upstream sectors' contributions to downstream exporting sectors, overlooking the role of upstream producers. This is particularly evident in the case of services: while trade-based measures estimate GVC participation in services at approximately 1 trillion USD, output-based measures place it closer to 5 trillion USD (Figure 2). A similar pattern is observed in certain goods sectors, such as upstream manufacturing and agriculture.
- *Countries:* These measurement biases also distort how we assess countries' participation in GVCs. When exports make up a small share of a country's total output, trade-based GVC indicators exaggerate the country's actual exposure to global production. A good example is China in the late 1980s and early 1990s. While its export sector, mostly located in Special Economic Zones, was deeply embedded in GVCs, the rest of the economy remained largely domestic. An output-based measure would have shown that China's economy as a whole was still relatively insulated from global shocks, whereas trade-based measures would have overstated its vulnerability.
- *Rankings:* Incorporating both export and production perspectives significantly reshapes GVC participation rankings too, even when trade- and output-based measures are correlated. As shown in Section S3.2 of the [supplementary online appendix](#), many countries and sectors shift substantially in rank—sometimes by over 25 positions—underscoring one more risk of underestimating indirect contributions and misguiding policy priorities when relying on trade-based metrics alone. For example, Germany ranks much higher in GVC output than in GVC trade, reflecting its deep integration through domestic supply chains, while sectors like agriculture appear far more embedded in GVCs when measured by output rather than exports.

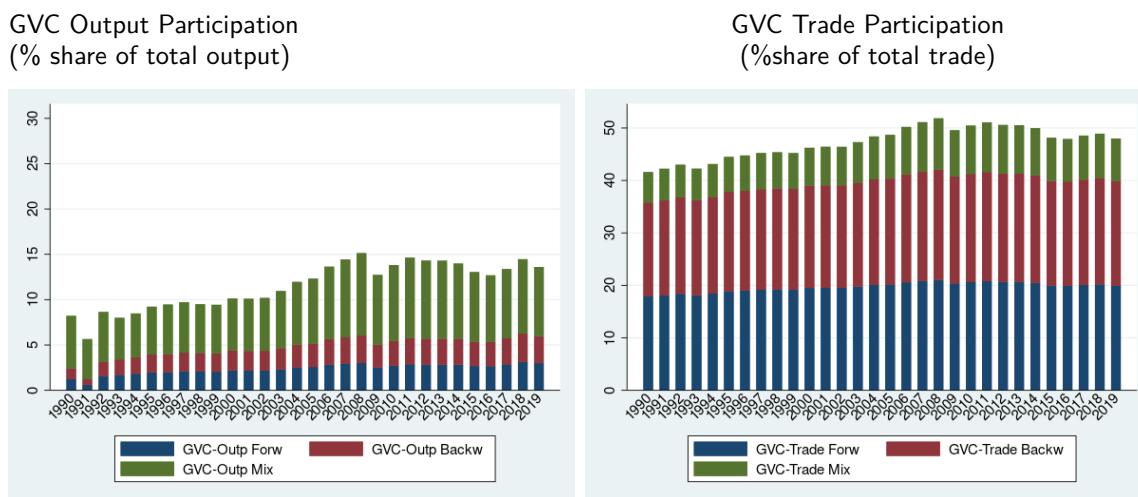
## 4.2 How do Countries and Sectors Participate?

This section highlights the second key innovation of the paper: a tripartite classification of GVC participation that distinguishes two-sided participation from pure backward and pure forward linkages. This approach, associated with the joint assessment through trade-based and output-based measures discussed in the previous section, improves the understanding of how sectors and countries engage in global value chains.

Two-sided participation—where a sector both imports inputs for export (backward) and exports inputs for other countries' production (forward)—is often overlooked but quantitatively significant. In output-based terms, it is the dominant mode of GVC engagement, accounting for over 60% of total GVC output participation ([Figure 4](#), left panel). This reflects the fact that GVC producers are frequently situated in the middle of the chain, both sourcing and supplying across borders.

By contrast, in trade-based measures, two-sided participation appears much less prominent ([Figure 4](#), right panel). This is because most exporting sectors and firms engage at the end or at the beginning of the chains. Instead, most producing sectors (GVC-output) are characterized by two-sided exposure, i.e. they engage in import to export or sourcing to sell activities. As a result, relying solely on trade-based views masks the true complexity of countries' and sectors' roles in GVCs. This result is not driven by specific sectors or countries with a high degree of two-sided participation. Instead, it is a widespread feature across countries and sectors: in nearly 70% of all country-sector pairs, GVC participation is predominantly two-sided (see Section S3.2 in the [supplementary online appendix](#)).

**Figure 4:** GVC Output and Trade Participation

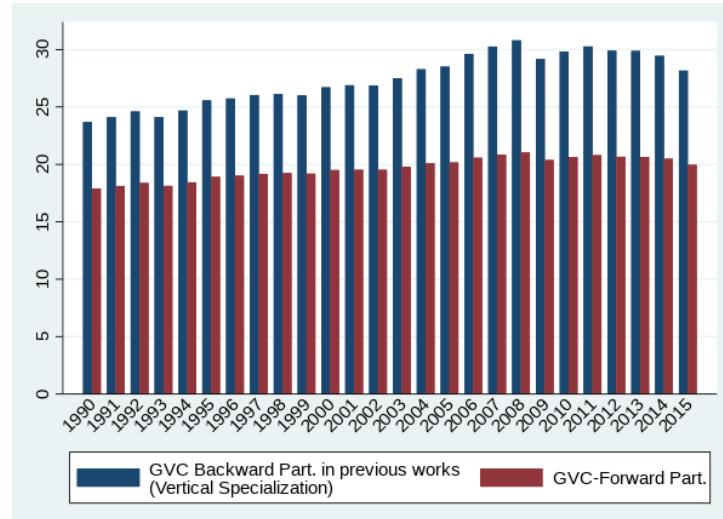


Source: Own elaboration based on EORA and ADB MRIO

Ignoring two-sided participation distorts the true structure of GVC integration, as it artificially inflates the significance of backward participation, leading to misguided policy decisions. [Figure 5](#) illustrates this issue by plotting participation as measured by the standard bipartite decomposition—such as the one reported in the OECD TiVA database—into backward (which conflates our measures of pure backward and two-sided participation) and forward linkages for the global economy. This approach erroneously suggests that backward participation is always greater than forward participation, creating the false impression of a systematic imbalance at the global level. However, this discrepancy is both theoretically unfounded and empirically

puzzling. There is no economic rationale suggesting that one mode of GVC integration should inherently dominate the other. Empirically, one would expect backward and forward linkages to balance out globally, just as world imports and exports must, by definition, be equal.

**Figure 5:** Overstating Global Backward GVC Participation: The Cost of Ignoring Two-Sided Linkages



Source: Own elaboration based on EORA.

Note: GVC Backward Participation and Forward Participation are measured at the global level as share of total trade

## 5 Empirical Application of the New Measures - Role of Global Value Chain (GVC) Participation in Mediating the Impact of Demand Fluctuations on Output

In the final part of the paper, we use the new output-based GVC participation measures and the tripartite decomposition to examine a timely policy question on macroeconomic resilience: how GVC integration mediates the transmission of external demand shocks to domestic output. By introducing the tripartite decomposition of GVC involvement we are able to capture the middle layers of global production networks and the fact that they exhibit distinct patterns of shock transmission. In addition, since output-based measures indicate the share of total output that is tied to global linkages, we are able to capture the exposure of a sector's entire production process to external shocks.

The exercise and the new metrics reveal the dual role of GVCs in providing both exposure and stability. While GVC participation increases sensitivity to certain external demand shocks, it simultaneously offers greater market diversification, risk mitigation, and resilience. For developing countries, where output volatility tends to be higher, strategic participation in GVCs can serve as a stabilizing force — provided global markets are more stable than the domestic economy.

Section S4 of the [supplementary online appendix](#) extends the analysis to additional aspects of the relationship between GVC participation and economic performance. Section S4.1 uses

a standard multi-country, multi-sector model to show that the new GVC measures better predict the impact of trade shocks on output than traditional openness indicators. Section S4.2 documents a positive correlation between GVC participation and per capita income growth, with the new measures containing more informational content than existing ones.

## Methodology and Empirical Estimation Details

Our objective is to quantify how different dimensions of GVC participation affect the output response to demand-side fluctuations. The empirical deliberately builds on well-established empirical frameworks. It comprises three steps.

**Step 1: Estimating Exogenous Demand Innovations.** We estimate innovations in country-level demand using global Input-Output (I-O) data via a fixed effects model adapted from Alfaro et al. (2021) and Kramarz et al. (2020). Specifically we estimate:

$$\Delta y_{ij,t}^r = \eta_{j,t} + \gamma_{i,t}^r + \nu_{ij,t}^r \quad i \neq j. \quad (11)$$

Here,  $\Delta y_{ij,t}^r$  indicate the change in final sales from country  $i$  to country  $j$  in sector  $r$ , expressed in percentage terms. The term  $\eta_{j,t}$  captures the demand innovations in the importing country  $j$  at time  $t$ , while  $\gamma_{i,t}^r$  accounts for exporting country-sector-time effects.<sup>16</sup>

We interpret  $\eta_{j,t}$  as a residual innovation in final demand that reflects both unexpected fluctuations and persistent shifts. Although our terminology refers to "shocks," these innovations may also include trend-like movements. Our interest lies in understanding the implications of exposure to such changes—regardless of whether they are transitory or structural—for output volatility.

**Step 2: Constructing Direct and Indirect Demand Shocks.** Using a shift-share instrument approach that builds on Ferrari (2023), we aggregate  $\eta_{j,t}$  into sector- and country-specific shocks based on observed trade patterns:

- The *direct foreign demand shock* for country  $i$ , sector  $r$ , at time  $t$ , is:

$$DirectForeignDemandShock_{i,t}^r = \sum_j^G \phi_{ij,t-1}^r \cdot \eta_{j,t}. \quad (12)$$

where  $\phi_{ij,t-1}^r$  is the lagged share of final sales from  $i$  to  $j$  in sector  $r$ .<sup>17</sup>

- The *direct domestic demand shock* for country  $j$  is simply the demand innovation  $\eta_{j,t}$ , applied when  $i = j$ .
- The *direct demand shock* variable used in Table 1, Column (5), is the sum of the foreign and domestic components, interacted with the share of output not related to GVCs.
- The *indirect demand shock* aggregates demand changes  $\eta_{j,t}$  through downstream linkages based on IO structures (captured by weights  $\psi_{ij}^r$  that measure the exposure of

<sup>16</sup>Results throughout the paper are robust to the inclusion of different sets of fixed effects in the estimation of demand innovations. The estimation is carried out by excluding country  $i$  from the sample when computing the  $jt$  demand innovation that might affect it, to reduce concerns of endogeneity.

<sup>17</sup> $\phi_{ij,t}^r$  is equal to  $y_{ij}^r / \sum_j^G y_{ij}^r$ ; note that  $\phi_{ii,t}^r = 0$ .

country  $j$  final demand for sales of intermediates exported by country  $i$  in sector  $r$ ).<sup>18</sup> This shock reflects second-order effects — that is, the influence of demand arising in sectors that are served by the immediate buyers of the intermediates exported by country  $i$ .

We leverage the ability of this instrument to differentiate between direct demand shocks (related to sales of final products) and indirect demand shocks (related to sales of intermediate products) for testing the hypothesis that indirect demand shocks should be exclusively associated with the variables capturing GVC participation, and in particular forward and two-way participation (see Step 3).

**Step 3: Integrating GVC Metrics into the Analysis:** We estimate the impact of demand shocks on output by interacting them with GVC participation metrics:

$$\begin{aligned} \Delta x_{i,t}^r = & \alpha + \beta_1 \text{DomesticDemandShock}_{i,t}^r + \beta_2 \text{DirectForeignDemandShock}_{i,t}^r + \\ & + \beta_3 \text{IndirectDemandShock}_{i,t}^r + \\ & + \beta_5 \mathbf{GVC} \text{PureForw}_{i,t-1}^r + \beta_6 \mathbf{GVCTwoSided}_{i,t-1}^r + \\ & + \mathbf{GVC} \text{PureForw}_{i,t-1}^r \times \text{IndirectDemandShock}_{i,t}^r + \\ & + \mathbf{GVCTwoSided}_{i,t-1}^r \times \text{IndirectDemandShock}_{i,t}^r + \\ & + \text{supply controls} + \dots + \delta_t + \gamma_i^r + \epsilon_{i,t}^r. \end{aligned} \quad (13)$$

We focus on interactions between indirect demand shocks and forward/two-sided GVC participation, reflecting propagation through downstream sectoral networks. While an alternative approach could consider propagation through country-level networks, we prioritize sectoral links as they more directly correspond to intermediate input flows.

Direct demand shocks, by contrast, are not interacted with GVC metrics, as they affect all producers regardless of production structure. Instead, we examine whether the sensitivity of non-GVC output to these shocks differs, as shown in [Table 1](#), Column (5).

We do not scale the domestic demand shock by the share of domestic sales, in contrast to foreign demand components. This maintains conceptual consistency with the estimation of  $\eta_{j,t}$  which reflects aggregate final demand innovations. Results are robust to alternative specifications with scaled domestic components (available upon request).

Despite the focus of this empirical application is on the demand side, we also control for supply-side shocks in the analysis. We compute those by using almost the same procedure described above. The key assumption employed to identify supply shocks is that variations in sales of intermediate inputs of a certain sector across all producers and country-sector of usage are related to some supply perturbation specific to that sector. Additional details on the derivation of supply-side shocks can be found in Section S5 in the [supplementary online appendix](#).

## Results

[Table 1](#) presents the main regression results. We find:

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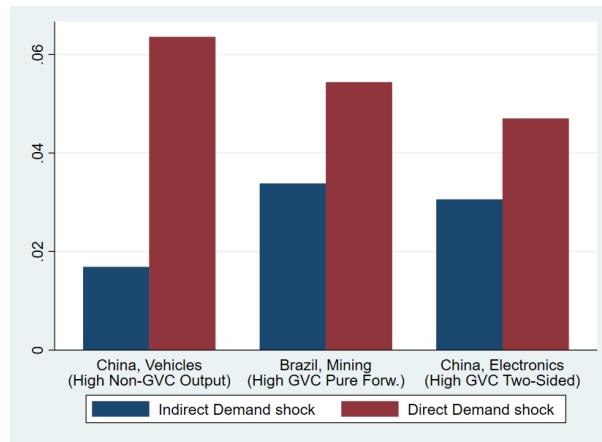
<sup>18</sup>  $\psi_{ij,t}^r$  is calculated as  $\psi_{ij,t}^r = (\sum_k^G \sum_s^N b_{ik}^{rs} y_{kj}^s - l_{ii}^{rs} y_{ij}^s) / (\sum_j^G \sum_k^G \sum_s^N b_{ik}^{rs} y_{kj}^s - l_{ii}^{rs} y_{ij}^s)$ , where  $b_{ik}^{rs}$  and  $l_{ii}^{rs} y_{ij}^s$  are the elements of the global and local Leontief inverse matrix respectively.

- Positive and significant effects of both domestic and foreign demand shocks on output, validating our construction of demand innovations.
- GVC participation increases exposure to indirect demand shocks, as seen in the positive and significant coefficients for the interactions with forward and two-sided GVC metrics.
- GVC involvement reduces sensitivity to direct demand shocks, particularly for the portion of output not linked to GVCs. This suggests a risk mitigation channel via market diversification.
- Supply-side control coefficients indicate that backward GVC participation significantly mediates supply-side shocks, and illustrate further the value of the tripartite decomposition. The symmetry between forward and backward exposure underscores the importance of distinguishing between GVC roles.

To illustrate the trade-off highlighted by the results on demand shocks, [Figure 6](#) shows output responses for three country-sector pairs, illustrative of three different types of GVC exposure: China's motor vehicles industry, which posts a high non-GVC share, Brazil's mining sector, which features high forward GVC linkages, and China's electronics, characterized by a large two-sided GVC participation. In all cases, the dominant source of volatility is the direct demand shock. However, countries and sectors with higher GVC integration exhibit smaller exposure to direct shocks, consistent with the diversification hypothesis.

[Figure 7](#) (left hand-side panel) compares the standard deviation of GVC-related vs. direct shocks across countries. GVC shocks are less volatile than direct ones for all countries except the U.S., supporting the notion that GVC participation stabilizes exposure. This is driven by the fact that GVCs serve as a channel for diversifying exposure to foreign demand shocks. Indeed, the right-hand panel of [Figure 7](#) confirms that sectors with higher GVC participation have lower market concentration, as measured by the Herfindahl-Hirschman Index (HHI).

**Figure 6:** Impact of 1 SD of GVC and non-GVC demand shocks



The above observations hold true also using trade metrics of GVC participation, and are robust to variations in data-sources and sample periods (see Section S6 in the [supplementary online appendix](#)).

Taken together, our results emphasize the stabilizing role of GVCs through diversification, particularly for countries with high domestic volatility. Even though GVCs amplify exposure to global demand fluctuations, they offer insurance against more volatile domestic or idiosyncratic shocks.

**Table 1:** WIOD GVC-Output

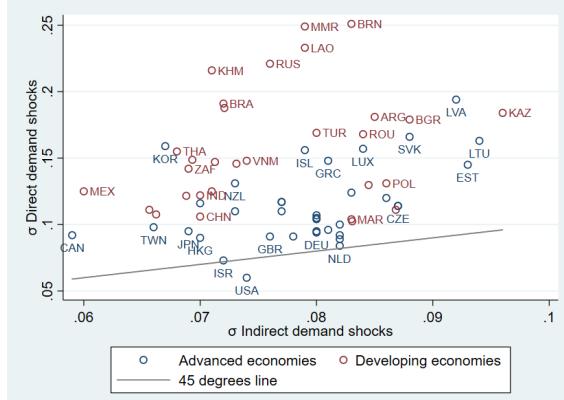
	(1) Δ Out	(2) Δ Out	(3) Δ Out	(4) Δ Out	(5) Δ Out
Domestic Demand shock	0.338*** (0.007)	0.338*** (0.007)	0.281*** (0.008)	0.281*** (0.008)	
Foreign Direct Demand shock	0.055*** (0.018)	0.035** (0.017)	0.031* (0.017)	0.026 (0.018)	
Direct Demand shock					-0.006 (0.068)
Indirect Demand shock	0.083* (0.044)	0.120*** (0.043)	0.095** (0.044)	0.146*** (0.047)	0.119*** (0.041)
Indirect Supply shock	0.258*** (0.049)	0.210*** (0.048)	0.232*** (0.048)	0.212*** (0.048)	0.190*** (0.046)
Sectoral Supply shock	0.108*** (0.007)	0.097*** (0.007)	0.095*** (0.007)	0.093*** (0.007)	0.089*** (0.007)
GVC Pure Forward <sub>t-1</sub>	0.082*** (0.029)	0.074** (0.035)	0.097*** (0.033)	0.433*** (0.091)	0.423*** (0.090)
GVC Two-Sided <sub>t-1</sub>	0.018* (0.011)	0.033** (0.015)	0.066*** (0.016)	0.132*** (0.040)	0.151*** (0.039)
GVC Pure Back <sub>t-1</sub>	-0.034* (0.019)	0.024 (0.027)	0.050** (0.026)	0.094 (0.069)	0.096 (0.069)
Indirect Demand shock × GVC Pure Forw <sub>t-1</sub>	0.634** (0.275)	0.641** (0.277)	0.741*** (0.277)	0.694** (0.295)	1.254*** (0.292)
Indirect Demand shock × GVC Two-Sided <sub>t-1</sub>	0.611** (0.239)	0.641*** (0.238)	0.626*** (0.236)	0.486* (0.257)	0.634** (0.282)
Indirect Supply shock × GVC Two-Sided <sub>t-1</sub>	0.274* (0.165)	0.269 (0.166)	0.280* (0.168)	0.439** (0.185)	0.690*** (0.193)
Indirect Supply shock × GVC Pure Back <sub>t-1</sub>	0.317*** (0.107)	0.328*** (0.108)	0.349*** (0.109)	0.387*** (0.107)	0.854*** (0.122)
Direct Demand shock × Non-GVC Output <sub>t-1</sub>					0.374*** (0.077)
Country-sector FE	No	No		Yes	Yes
Country FE	No	No	Yes		
Sector FE	No	Yes	Yes		
Year FE	Yes	Yes	Yes	Yes	Yes
R2	0.457	0.466	0.488	0.525	0.524
N	30,966	30,966	30,966	30,964	30,964

Standard errors in parentheses. Results based on WIOD data.

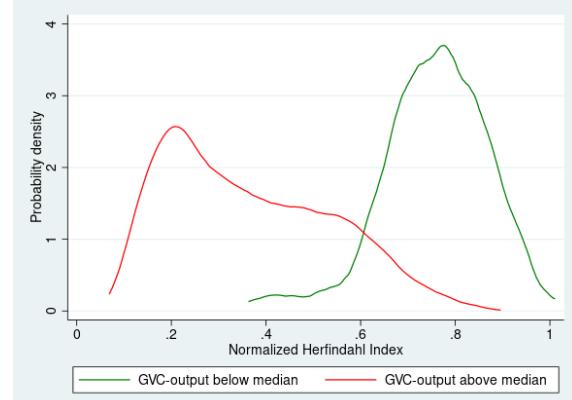
\*  $p < 0.10$ , \*\*  $p < 0.05$ , \*\*\*  $p < 0.01$

**Figure 7: Further Evidence on the Diversification Hypothesis**

Standard deviation of GVC and non-GVC shocks, by country



HHI distribution of markets of final destination, below vs. above median GVC output



Note: Herfindahl-Hirschman Index (HHI) of final market concentration are computed based on the the weights of countries' on final absorption for each country-sector pair. In particular, the red line describes the HHI concentration for manufacturing in country-sector pairs with GVC participation above the median, and the green line represents the same indicator for country-sector pairs with GVC participation below the median.

## 6 Conclusion

This paper advances the measurement of global value chain (GVC) participation by introducing a robust framework that incorporates both trade- and output-based perspectives and distinguishes between three distinct modes of GVC involvement. Other studies have quantified specific aspects of GVC participation, but with limitations in terms of scope and accuracy. Our methodology builds upon and refines existing frameworks, showing that relying solely on trade-based indicators leads to significant underestimation of GVC activity—especially in services and upstream sectors—and misclassification of countries' exposure and positioning.

Through empirical analysis using multiple ICIO datasets, we show that two-sided participation—typically overlooked—is quantitatively dominant in GVC output and central to understanding how production processes are globally interlinked. We also demonstrate the practical relevance of the new metrics by analyzing the role of GVC participation in the transmission of demand shocks. The results reveal that forward and two-sided GVC linkages amplify exposure to global demand shifts but also offer stabilization via diversification of markets—an insight particularly important for developing economies.

By offering a unified and flexible toolbox of GVC indicators, this paper provides policymakers and researchers with improved instruments to assess GVC engagement and its implications for growth, resilience, and trade policy design. Our measures are publicly available through the World Bank's [WITS Platform](#), facilitating the analysis of the structure and implications of GVC participation and the assessment of their trade, development, and macroeconomic implications.

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