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**Production Fragmentation in Manufacturing and Its
Differential Impact on High- and Low-Income
Economies**

Master's Thesis

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Abstract

This study investigates how Global Value Chain (GVC) participation affects economic development across countries at different income levels. Using a bilateral country-pair approach with data from OECD's Inter-Country Input-Output tables (1995-2020), we analyse whether GVC participation between lower-income countries generates different income convergence outcomes than participation between lower and higher-income countries. Employing Borin and Mancini's (2019, 2023) methodology for measuring GVC participation and a two-way fixed effects model, we find that GVC integration promotes income convergence across all country pairs over time, with varying magnitudes. South-South integration generates stronger convergence effects than South-North integration for lower-income exporters, with this difference becoming more pronounced over time. For higher-income exporters, the choice of trading partner matters less initially but gains significance in the long run. These findings indicate that, overall, trade integration can bring long-term, positive economic growth for most countries, especially when low-income countries integrate with high-income countries.

Keywords

Input-output analysis, global value chain, GVC Participation Index, production fragmentation, income convergence, ICIO Tables

Title

Production Fragmentation in Manufacturing and Its Differential Impact on High- and Low-Income Economies

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Introduction

Global value chains (GVC) have fundamentally transformed international trade patterns, with intermediate inputs accounting for 50%-60% or more of global trade in recent decades (Miroudot, Lanz, and Ragoussis 2009; Johnson 2014). This fragmentation of production across borders has restructured economic relationships between countries at different development stages, creating new pathways for growth and potential convergence.

The evolution of GVC participation has been remarkable. In 1995, GVC-related trade represented just 39.56% of gross trade in the manufacturing sector. This share steadily increased until 2008, when it reached near parity with traditional trade (49.82% vs. 50.18%). Though the global financial crisis temporarily reversed this trend, GVC-related trade rebounded quickly, overtaking traditional trade in 2011. Since then, both types of trades have experienced minimal ebb and flow, maintaining a difference of less than 5 percentage points on average (World Integrated Trade Solution [WITS] n.d.-a).

In absolute terms, the volume of GVC-related trade has grown substantially, rising from \$1,284,872 million in 1995 to \$4,438,695 million in 2020—an increase of nearly 3.5 times, with an annualised growth rate of approximately 5.71% (WITS n.d.-a). This dramatic expansion underscores the increasing importance of production fragmentation in the global economy.

This study focuses specifically on the manufacturing sector for several compelling reasons. Manufacturing has consistently been the dominant contributor to GVC-related trade, never falling below 50% of total GVC trade between 1995 and 2020 (WITS n.d.-b). Additionally, manufacturing remains a key economic sector that receives significant attention from national governments, particularly in export-oriented economies seeking to enhance their position in global production networks. The current U.S. President Trump's strategy of raising import tariffs on various countries as one of his methods to bring manufacturing back to the United States demonstrates the new perspective of the world's largest economy on manufacturing (Dollar and Polaski 2020; Sherman 2025).

While existing research has established that GVC participation generally enhances economic growth and productivity, a critical gap remains in understanding how the direction of integration affects income convergence outcomes. This study's central research question

examines whether GVC participation between lower-income countries generates either income convergence or divergence opportunities compared to participation between lower-income and higher-income countries. Although traditional development literature often emphasises the benefits of North-South integration, this research investigates the relative contributions of different integration patterns to income convergence, recognising that both South-South and North-South linkages may offer distinct advantages depending on context and measurement approaches.

Using the OECD's Inter-Country Input-Output tables spanning 1995-2020, this study constructs a comprehensive bilateral dataset that tracks GVC participation across 76 economies classified into four World Bank income groups. The analysis employs a two-way fixed effects model to examine immediate and total effects across different country-pair combinations.

The thesis proceeds as follows: Section 1 reviews the theoretical evolution of trade theory and GVC frameworks. Section 2 details the data sources and methodology for calculating the value of variables. Section 3 outlines the empirical approach for bilateral analysis. Section 4 presents the results and hypothesis tests. Last section concludes with policy implications and future research directions.

1. Literature Review

This literature review traces the evolution and impact of global value chains (GVCs) across five interconnected sections. The first section examines the progression of trade theory from classical concepts of comparative advantage to modern frameworks that address increasingly complex global production networks. The second section explores theoretical frameworks for production fragmentation and GVC analysis, highlighting concepts such as governance structures, upgrading trajectories, and positional advantages within value chains. The third section introduces input-output analysis as the methodological foundation for measuring global production linkages, explaining how Leontief's mathematical framework enables researchers to trace value flows across borders. The fourth section details the construction and refinement of GVC participation indices, particularly focusing on advancements that accurately capture backward and forward participation while addressing double-counting challenges. The final section synthesises empirical evidence on how GVC participation influences economic development outcomes, examining effects on growth, productivity, and distributional impacts across different country contexts. These sections provide a comprehensive foundation for understanding how global value chains have transformed international trade patterns and development pathways.

1.1 Evolution of Trade Theory

The evolution of international trade theory has progressed from its classical origins of finished goods exchanges between two countries (e.g., wine and cheese) to adapting to increasingly complex, interdependent global production networks (e.g., automobile and electric battery). This evolution provides essential context for understanding how global value chains transform economic landscapes and challenge traditional notions about trade patterns and development outcomes. This section will briefly introduce the earliest trade theories from an economic perspective to analyse how international trade formed. The larger portion will focus on the spatiotemporal context in which business leaders quietly opened the doors to global trade, thereby creating today's global division of labour. This global pattern has influenced the welfare of transaction participants in many aspects of social and personal life.

The earliest trade theory establishing the basic concept of comparative advantage can be traced back to the Ricardian model (Helpman 2011). This theory suggests that even if countries lack absolute advantage in any sector, they can benefit from specialising in goods they produce with relatively higher efficiency. This implies that opening borders to trade with other countries will be profitable. Although influential, the Ricardian model is built on some unrealistic assumptions, the most critical being that countries specialise in producing entire goods, with trade occurring only in final products. This concept fails to capture the increasingly common pattern of transnational production nowadays, where the production process itself is dispersed across national boundaries, with countries specialising in specific tasks or production stages rather than complete goods.

In contrast to the Ricardian model which assumes labour as the only production factor, the Heckscher-Ohlin (H-O) model developed in the early 20th century analyses trade between two countries producing two goods using two production factors (i.e., labour, capital) in its simplest version. Additionally, it introduces factor endowment as the basis for comparative advantage. The model predicts that a country will export goods that intensively use its relatively abundant production factors (Leamer 1995). Nevertheless, it still has key limitations in explaining production fragmentation. The H-O framework's assumptions about factor immobility between countries and its primary focus on final products (Leamer 1995) contradict the reality of global value chains, which involve substantial cross-border flows of capital, technology, and knowledge, as well as complex networks of international division of labour. Therefore, even in the current global trade environment, Leamer (1995) argues that this model still maintains relevant influence and practical applications—including but not limited to explaining the impact of globalisation on job opportunities and wages for local low-skilled workers and providing a framework for understanding how the unequal geographical distribution of production factors relates to international trade—it remains insufficient to explain the phenomenon of global production fragmentation.

International trade experienced fantastic rapid development in the 20th century. Dating back to the 1820s, the world (especially countries in the first wave of industrialisation) greatly improved work efficiency and transportation costs after the emergence of the steam engine. This allowed production and consumption to be geographically separated, enabling factories to be located far from end markets. The international division of labour began to take shape. However, international trade during this period mainly involved the exchange of final

products between countries. Baldwin (2012) refers to this period from 1820 to the 1990s as the "first unbundling."

Then in the 1950s, the establishment of the General Agreement on Tariffs and Trade (GATT) promoted international trade by reducing tariffs and other trade barriers (World Trade Organization n.d.). In the following decades, tariff barriers were gradually eliminated worldwide, whether through the World Trade Organization framework or regional trade agreements (e.g., AFTA, NAFTA). Another landmark event—the end of the Bretton Woods system in the 1970s—contributed significantly to globalisation. In the 1970s, countries finally transitioned from fixed exchange rates to floating exchange rates, providing greater monetary flexibility, stimulating export-oriented growth, and liberalising trade and capital flows. These changes, combined with technological breakthroughs such as containerisation and the internet, accelerated the development of global value chains, profoundly reshaping international trade into the hyperconnected system we see today (Subacchi and Vines 2023; Obstfeld 2024).

Fast forward to the 1980s. By this time, due to the development of Information and Communication Technology (ICT), the world entered the phase of "second unbundling." The rise of ICT greatly reduced the costs of transmitting ideas over long distances and coordinating complex tasks. This led to the fragmentation of production processes, with different stages of manufacturing potentially located in different countries. In other words, intermediate products would cross borders multiple times before final assembly and reaching end consumers. The global value chains emerged as a result (Baldwin 2012).

During the same period, Helpman (1981, 1984) and Krugman (1979, 1980) laid the foundation for the "New Trade Theory" by demonstrating that economies of scale and consumer preferences for product variety could even drive trade between similar countries. They both embedded their work in a Dixit-Stiglitz monopolistic competition framework to explain why firms would specialise and why differentiated goods would cross national boundaries. Krugman's research isolated purely scale-driven trade and market size effects, while Helpman added factor endowment (Heckscher-Ohlin) considerations to this foundation and empirically verified these mechanisms. Together, they created a microeconomic theoretical and empirical toolkit that forms the basis of modern intra-industry trade analysis. However, just like the previous classical theory and model, these

models still primarily addressed trade in final goods, with limited attention to production fragmentation or intermediate input flows. However, it is worth noting that intra-industry trade will become one of the important forms of future production fragmentation.

As global value chains became increasingly prevalent in international trade, concerns about the inadequacy of traditional trade statistics began to emerge. By the mid-1990s, significant awareness of this issue had developed. Traditional statistical information systems, designed to measure economic activity in the pre-global value chain era, had limitations because production processes were increasingly dispersed across multiple countries, creating complex networks of intermediate inputs and final products. This fragmentation of production processes made it difficult to accurately track value creation and understand authentic trade relationships using traditional gross value measurement methods. Consequently, research on global value chains surged after the 1990s (Dollar 2017). The next section will explore theoretical frameworks related to production fragmentation and global value chains.

1.2 Theoretical Frameworks for Production Fragmentation and GVC Analysis

The previous section repeatedly introduced the concepts of global value chains and production fragmentation. Regarding the definition of global value chains, Kaplinsky and Morris (2000) provided their definition from their book “A Handbook for Value Chain Research”:

The value chain describes the full range of activities which are required to bring a product or service from conception, through the different phases of production (involving a combination of physical transformation and the input of various producer services), delivery to final consumers, and final disposal after use.

Figure 1.1 shows a relatively basic value chain for reference. The production itself is just one of many value-adding links. Within each link of the chain, there is a series of activities, and these activities might also involve other extended value chains.

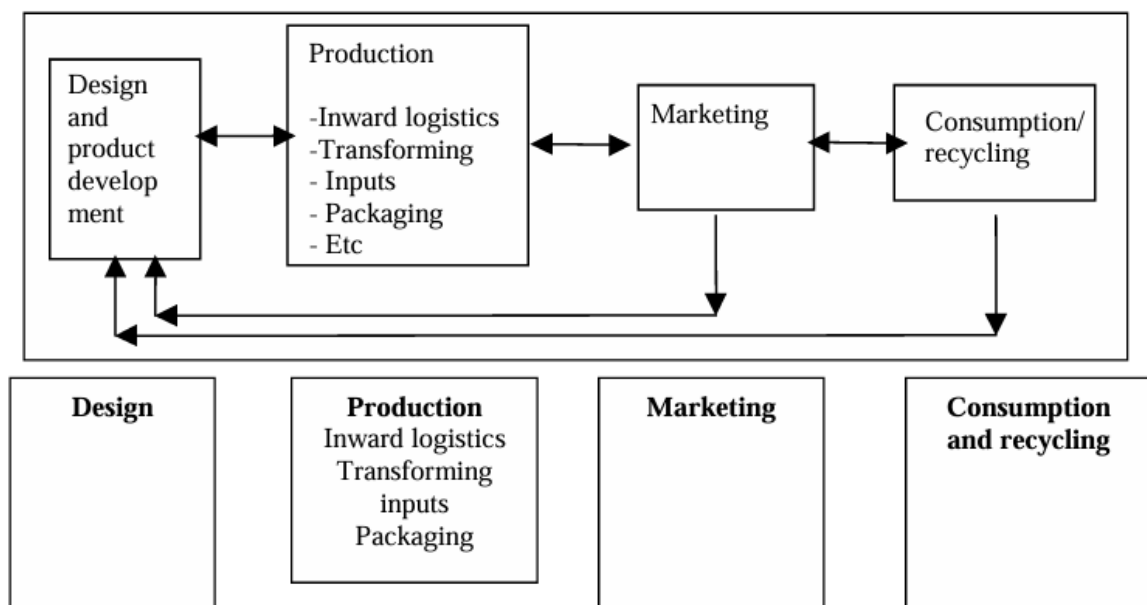


Figure 1.1. Four Links in a Simple Value Chain. Source: Kaplinsky and Morris (2000)

The concept of production fragmentation was first proposed by Jones and Kierzkowski (1990) (Venables 1999). Production fragmentation refers to a production process where the growth of enterprise output, increased returns, and advantages of factor specialisation within firms encourage companies to shift toward a production model of fragmented production blocks connected by service links. As production processes become fragmented, there is an increasing demand for service links, including activities such as coordination, management, transportation, and financial services. This differentiation may extend to international markets. By summarising these two definitions, the emergence of global value chains could be attributed to production fragmentation.

Jones and Kierzkowski (1990) argued that productivity and factor prices across countries significantly influence production fragmentation. Drawing on Ricardo's theory of comparative advantage, they argued that larger differences in productivity and factor prices between countries (compared to within a single country) could encourage the use of multiple international locations for production blocks within a given production process. Furthermore, increasing returns that may exist within production blocks further contribute to this dispersion.

The apparel industry, for example, demonstrates how differences in relative costs lead to international division of labour under the influence of factors such as productivity and factor

prices, with certain production stages being reallocated to developing countries. Jones and Kierzkowski developed a framework emphasising how service links coordinate geographically dispersed production blocks. In other words, the possibility of service inputs linking internationally dispersed production units can lower the best cost-output line, potentially leading to decisions to locate different production blocks in different countries. When the cost of international service links is relatively low, firms are encouraged to engage in more fragmented production processes across countries.

Feenstra (1998) explores the relationship between the integration of trade and the disintegration of production in the global economy. The study first assumes two countries with different factor endowments and points out that under these circumstances, trade in final goods cannot balance factor prices. As companies decompose production processes across different countries, low-skilled, labour-intensive activities shift to countries abundant in these factors. He presented empirical evidence highlighting how technological progress and trade liberalisation lead firms to slice up their value chains. Table 1.1 (Feenstra 1998) illustrates how outsourcing can be measured through imported intermediate inputs within each industry. At that time, the value-added trade statistics could be constructed through input-output tables¹ already. Research on the United States' textiles, apparel and footwear sectors found that the proportion of imported inputs in total intermediate product purchases rose from 5.7% in 1972 to 8.6% in 1979 and 13.9% in 1990.

Table 1.1. The ratio of Imported to Domestic Intermediate Inputs—Textiles, Apparel and Footwear (%)

<i>Country</i>	<i>Early 1970s</i>	<i>Mid/late 1970s</i>	<i>Mid-1980s</i>
Canada	41	50	60
France	15	26	42
Germany	na	49	64
Japan	3	6	9
United Kingdom	19	33	48
United States	7	6	13

Source: Audet (1996, Table 8.18).

Venables (1999) connects the phenomenon of fragmentation with the development of

¹ There will be a more detailed discussion in the input-output analysis in the next section.

vertical or horizontal multinational corporations. Depending on the relative factor intensity of upstream and downstream production, either vertical or horizontal multinational production patterns emerge. For example, vertical multinational corporations will develop if upstream production is relatively labour-intensive. All upstream activities are concentrated in a location with comparative advantage in labour, while downstream activities are distributed elsewhere.

In horizontal multinational corporations, at least some of the company's activities are replicated in two locations. For instance, when downstream production is labour-intensive, a company might retain all upstream production in one country while distributing downstream production across different countries. Ando (2006), in his study of East Asian economies², confirmed that vertical intra-industry trade increased significantly during the 1990s, and vertical international production sharing became an important component of East Asian economies.

Modern global value chain theory saw significant development in Grossman and Rossi-Hansberg's (2008) influential "trading tasks" model, which conceptualised offshore outsourcing as trade-in tasks rather than trade-in goods. This paradigm shift recognised that comparative advantage increasingly applies to specific activities within production processes rather than entire industries. Antràs and Chor (2013) advanced this literature by developing a property rights model of global value chain organisation that explains how firms optimise the ownership structure of their production networks based on sequential production and contractual incompleteness. Specifically, firms decide whether to integrate or outsource each stage based on their position in the industry chain and the elasticity of final demand: when demand is elastic, downstream stages are more likely to be integrated to protect investments with high profit margins, while when demand is inelastic, upstream stages may be internalised. This framework explains non-monotonic patterns of vertical integration and emphasises how optimal ownership structures change systematically along the production sequence.

This concept seems to echo the global value chain governance perspective originally pioneered by Gereffi, Humphrey, and Sturgeon (2005). Their framework helps understand

² China, ASEAN4 (Indonesia, The Philippines, Thailand, and Malaysia), NIEs3 (Korea, Hong Kong, and Singapore), and Japan.

how leading firms organise and coordinate globally dispersed production networks. The framework identifies five governance structures (see appendix no.1), ranging from high to low degrees of explicit coordination and power asymmetry—hierarchy, captive, relational, modular, and market structures, which are determined by three variables: transaction complexity, codifiability of information, and supplier capabilities. The market governance structure involves simple, standardised transactions with capable suppliers and minimal coordination, primarily relying on price signals. Moving up, in captive governance, suppliers with limited capabilities face complex tasks, resulting in strong dependence on lead firms for support and control. The hierarchy structure reflects complete vertical integration, where lead firms internalise production to manage highly complex, non-codifiable processes requiring strict coordination and control.

This framework explains how power asymmetries in value chains affect the distribution of risks, resources, and economic rents. For example, in captive value chains, powerful lead firms exert significant control over less capable suppliers, often capturing disproportionate shares of value while limiting suppliers' upgrading opportunities. In contrast, relational value chains are characterised by more balanced power dynamics and mutual dependence, potentially allowing suppliers to capture greater value (Gereffi & Lee, 2012).

Baldwin and Venables (2013) vividly distinguish patterns of division of labour as animal-shaped "snake-like" sequential production processes and "spider-like" component assembly. In the "snake" form, production is sequential, with each stage depending on the previous stage; in the "spider" form, multiple components are assembled independently before being combined. They demonstrate that these structures respond differently to declining trade costs—snakes exhibit non-linear "overshooting"³ and potential reshoring, while

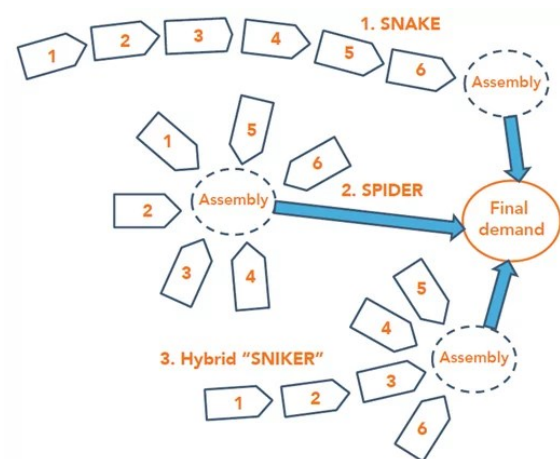


Figure 1.2. The global value chain: spiders, snakes, and "snikers". Source: Diakantoni et al. (2017) based on Baldwin and Venables (2013).

³ Overshooting refers to the phenomenon where, as international transaction and coordination frictions (unbundling costs) initially fall, production stages such as parts manufacturing—relocate to a country that is not their static cost-optimal location in order to capture co-location benefits with assembly. As these frictions decline further, the production process then reverses (or "reshores"), shifting back toward the fundamental

spiders adjust more gradually. The model emphasises how patterns of spatial unbundling in production processes influence fragmentation patterns, trade flows, and agglomeration dynamics in the global economy. Building on this, Diakantoni et al. (2017) argue that real-world supply chains more closely resemble "sniker," a hybrid mode of these two forms (Figure 1.2).

The theories and models mentioned above mainly focus on the causes and operational modes of production fragmentation and global value chain formation. Economic upgrading—the process by which firms, regions, or countries improve their position within global value chains to capture greater value—is another core theoretical concept in global value chain analysis. Humphrey and Schmitz (2002) established four distinct upgrading trajectories: process upgrading (improving efficiency), product upgrading (moving to higher-value products), functional upgrading (acquiring new functions in the chain), and inter-sectoral upgrading (applying capabilities developed in one sector to another).

Pietrobelli and Rabellotti (2011) demonstrated that different types of global value chain governance structures promote different forms of upgrading. For example, when learning is driven by external pressure—companies are forced to adapt and improve simply because they need to meet international standards. This mechanism typically occurs in parts of value chains where transactions are codified and standardised, such as in modular governance structures. Compliance with stringent standards forces suppliers to modify their processes, often resulting in imitation and incremental improvements.

Furthermore, Pietrobelli and Rabellotti also emphasise how innovation systems (IS) and global value chain configurations influence each other. Improvements in IS enable firms to better absorb and transfer knowledge flowing through global value chains. Simultaneously, firm participation in global value chains creates new demands and opportunities for innovation, thereby driving enhancements within IS. This dynamic interaction makes the relationship between domestic innovation capabilities and global production networks complex and cyclical.

The upgrading framework provides valuable insights into how countries at different stages of development can derive various benefits from participation in global value chains. This

comparative cost advantages, thus creating a non-monotonic, jump-like adjustment in production location (Baldwin and Venables 2013).

suggests potential complementarities between countries at different development stages participating in global value chains, a hypothesis that this study empirically tests.

The final theory presented in this section concerns how different positions within global value chains can create asymmetrical economic development outcomes. The most famous theory comes from the founder of Acer Inc.—Stan Shih, in 1992, who proposed the "smiling curve." This concept is simple to understand, illustrating the value-added activities in the product production process. It emphasises that the highest value is created at both ends of the supply chain—research and development (R&D) and marketing—while the profit margin in manufacturing segments is often smaller. This has subsequently been confirmed by empirical evidence at different levels (i.e., firm-level, sector-level or country-level) in later research by Baldwin (2012), Rungi and Del Prete (2018), and Meng, Ye, and Wei (2020).

"Upstreamness" and "downstreamness" have become important analytical tools in this context. Koopman et al. (2010) and Antràs et al. (2012) successively developed metrics to determine the position of industries in global supply chains, with upstream sectors providing inputs early in the production sequence and downstream sectors closer to final consumption. Their research indicates systematic differences in value-added between these positions, which has significant implications for development strategies.

This section has explored key theoretical perspectives on global value chains and production fragmentation, highlighting the forces that drive firms and countries to engage in cross-border production activities. While much attention has been given to the structure and governance of GVCs, an equally important question is how participation itself, as well as of position—can shape development outcomes. Through mechanisms like learning, knowledge diffusion, and access to international markets, even initial forms of involvement in GVCs may generate opportunities for growth and upgrading. Before examining the empirical evidence of how countries at different development stages experience the economic effects of GVC participation, an introduction to the input-output analysis and the GVC Participation Index will provide the necessary foundation for understanding the methodology behind this study.

1.3 Input-Output Analysis

Input-output analysis, developed by Wassily Leontief in the 1930s (which earned him the 1973 Nobel Prize in Economics), provides a framework for examining how different industries within an economy are interconnected. This methodology, sometimes called interindustry analysis, employs linear equations to track how products from one sector flow throughout the economic system. The core of this analysis examines how each sector functions as a producer supplying other sectors and as a consumer requiring inputs from various industries (Miller and Blair 2009).

Miller and Blair (2009) illustrate the input-output model through transaction tables (figure 1.3), which map the flow of goods and services between industries. Each row in these tables shows where a sector's output goes in the economy, while columns indicate what inputs that sector requires for production. These tables include sections for final demand (such as consumer purchases or government spending) and value-added components (including labour, capital depreciation, taxes, and imports). Data for these models are collected over a specific period, usually a year, and expressed in monetary terms.

		PRODUCERS AS CONSUMERS								FINAL DEMAND			
		Agric.	Mining	Const.	Manuf.	Trade	Transp.	Services	Other	Personal Consumption Expenditures	Gross Private Domestic Investment	Govt. Purchases of Goods & Services	Net Exports of Goods & Services
PRODUCERS	Agriculture												
	Mining												
	Construction												
	Manufacturing												
	Trade												
	Transportation												
	Services												
	Other Industry												
VALUE ADDED	Employees	Employee compensation								GROSS DOMESTIC PRODUCT			
	Business Owners and Capital	Profit-type income and capital consumption allowances											
	Government	Indirect business taxes											

Figure 1.3. Input-Output Transactions Table. Source: Miller and Blair (2009)

Mathematically, the distribution of a sector's output can be represented as

$$x_1 = z_{11} + z_{12} + \dots + z_{1n} + f_1 \quad (1)$$

where x_1 is the total output, z_{1j} represents sales to other sectors, and f_1 indicates final

demand. This equation structure applies to each sector in the economy, creating a system that can be summarised using matrix notation as $x = Zi + f$, with Z representing the matrix of intermediate exchanges between sectors.

From this foundation, technical coefficients (a_{ij}) are calculated by dividing each element in the intermediate consumption matrix (Z) by the gross output of the purchasing industry (x_j). The notation becomes more specific when extending this framework to a multi-country setting, as illustrated in equation (2).

$$a_{ij}^{rs} = \frac{z_{ij}^{rs}}{x_j^s} \quad (2)$$

The superscripts r and s denote the source and destination countries, respectively⁴. These coefficients indicate the amount of input required from industry i in country r to produce a single unit of output in industry j in country s . When calculated across all countries and industries, this creates a global technical coefficients matrix (A) with dimensions $NK \times NK$ (where N represents the number of countries and K the number of industries), revealing input requirements throughout international supply chains.

With the key components in place, the equation for an economy's total output can be set by replacing the z_{ij}^{rs} with $a_{ij}^{rs}x_j^s$ (rearranging the technical coefficient).

$$\begin{aligned} x_1 &= a_{11}x_1 + \dots + a_{1i}x_i + \dots + a_{1n}x_n + f_1 \\ &\vdots \\ x_i &= a_{i1}x_1 + \dots + a_{ii}x_i + \dots + a_{in}x_n + f_i \\ &\vdots \\ x_n &= a_{n1}x_1 + \dots + a_{ni}x_i + \dots + a_{nn}x_n + f_n \end{aligned} \quad (3)$$

The matrix expression for equation (3) is:

$$x = Ax + y \quad (4)$$

x is the vector of total output, and y is the final demand vector. Add the identity matrix I and solve for x yields the Leontief inverse matrix:

$$x(I - A) = y$$

⁴ This notation aligns with the notation by OECD (2023).

$$x = (I - A)^{-1} y = Ly \quad (5)$$

where $(I - A)^{-1} = L = [l_{ij}]$ is known as the Leontief inverse⁵ (Miller and Blair 2009). The Leontief inverse matrix is essential for calculating the GVC participation index. It is because it reveals the total (direct and indirect) requirements from each sector to satisfy one unit of final demand. Each element l_{ij} shows how much output from sector i is needed to produce one unit of final demand for sector j 's output. Simply put, with known final demand, the Leontief inverse allows us to trace value added throughout global supply chains to decompose each country's backward and forward contribution to the value of a final product (Borin and Mancini 2019). In the next section, we will see how the Leontief inverse matrix is used to compute the GVC participation index.

1.4 GVC Participation Index

Hummels et al. (2001) provided the first influential approach to measure participation in global production networks through their Vertical Specialization Index (VS). Their approach focused on measuring the import content of exports - the portion of a country's exports that consists of imported inputs. In an Inter-Country Input-Output (ICIO) framework, the bilateral VS indicator is expressed as:

$$VS_{sr} = \frac{u_N \sum_{t \neq s} A_{ts} (I - A_{ss})^{-1} E_{sr}}{u_N E_{sr}} \quad (6)$$

Where:

- u_N is a $1 \times N$ sectors row vector. Hence, $u_N E_{sr}$ means aggregate exports of all sectors (N) from country s to country r.
- $(I - A_{ss})^{-1}$ is the domestic inverse Leontief matrix.
- A_{ts} is the matrix of direct input coefficients from country t to country s

The VS index was groundbreaking but had limitations. The approach only measured backward linkages and did not distinguish between foreign value-added and domestic value-added that returns after being processed abroad. While Hummels et al. (2001) conceptually

⁵ It is denoted as $B = (I - A)^{-1}$ in OECD TiVA's guideline (OECD, Directorate for Science, Technology and Innovation 2023).

proposed a forward linkage measure (VS1), they did not formally derive it, attributed to the fact that an established ICIO was not available at the time of writing (Borin and Mancini 2019).

Koopman et al. (2010) extended the analysis by using ICIO tables to decompose exports according to the origin of value-added. The two key concepts were hatched: the Domestic Content of Exports (DC), which refers to the value of exports that originated in the exporting country, and the Foreign Content of Exports (FC), indicating the value of exports that originated in other countries. Additionally, the GVC Participation Index was first proposed by Koopman et al. (2010). The initial framework is:

$$GVC\ Participation_{ir} = \frac{IV_{ir}}{E_{ir}} + \frac{FV_{ir}}{E_{ir}} \quad (7)$$

Where IV measures the domestic value added from country i that is transmitted indirectly via the use of its intermediate inputs by other countries into the final exports to country r , and FV measures the contribution of foreign sources that are embodied in the gross exports sent from country i to country r . However, Borin and Mancini (2019) claimed that these measures still represent a form of ‘gross accounting’ because they include items that cross country's borders multiple times throughout the production process. Only by isolating these double-counted items can we measure the ‘net’ production (value-added) embedded in exports.

Johnson and Noguera (2012) address this gap by introducing Value-Added Exports (VAX) to measure the net value-added produced by country s that is absorbed by foreign economies. A key feature of VAX is that it partially reduces double-counting, as stated above, by focusing on value-added absorbed abroad. Nevertheless, it does not account for value-added reimported and absorbed in the home country, and it does not identify the specific trade linkages through which value-added reaches its final destination. In other words, VAX cannot fully isolate the value-added exports from country s that are re-exported to third countries from those directly absorbed by a specific partner country r (Borin and Mancini 2019). This is a crucial limitation because the final GVC participation index only incorporates intermediate inputs that are re-exported, while value-added that the destination country has already absorbed cannot be considered GVC participation.

Building on the contributions of Koopman et al. (2010) and Johnson and Noguera (2012),

Koopman et al. (2014) provided a comprehensive framework for decomposing gross exports by distinguishing the domestic and foreign value-added components embedded in country s 's aggregate exports, as well as items double-counted from both domestic and foreign origins (figure 1.4). This approach has since been widely used by academia and found its way into the working papers of international organisations such as the European Central Bank, the OECD and the IMF (Aslam, Novta, and Rodrigues Bastos 2017; Ahmad et al. 2017; Dorrucchi et al. 2019). It has also been adopted to construct OECD's Tiva indicator (Ahmad et al. 2017). While groundbreaking, the decomposition of Koopman et al. had limitations. Borin and Mancini (2019) argued that it applied only to aggregate country exports and did not extend to bilateral or sectoral trade flows, limiting its applicability to certain empirical questions. The second major issue concerns how Koopman et al. classify the foreign content of a country's exports. Borin and Mancini (2019) asserted that Koopman et al. incorrectly classify some foreign value-added as "foreign double counted." Specifically, Koopman et al. treat the entire foreign content of country s 's exports that the importing country r re-exports abroad as "foreign double counted". This approach fails to recognise that some of this content—particularly the value originating in the country r itself—has not been counted as "foreign value-added" in any previous trade flow. As a result, Koopman et al.'s approach systematically underestimates the true foreign value-added in exports.

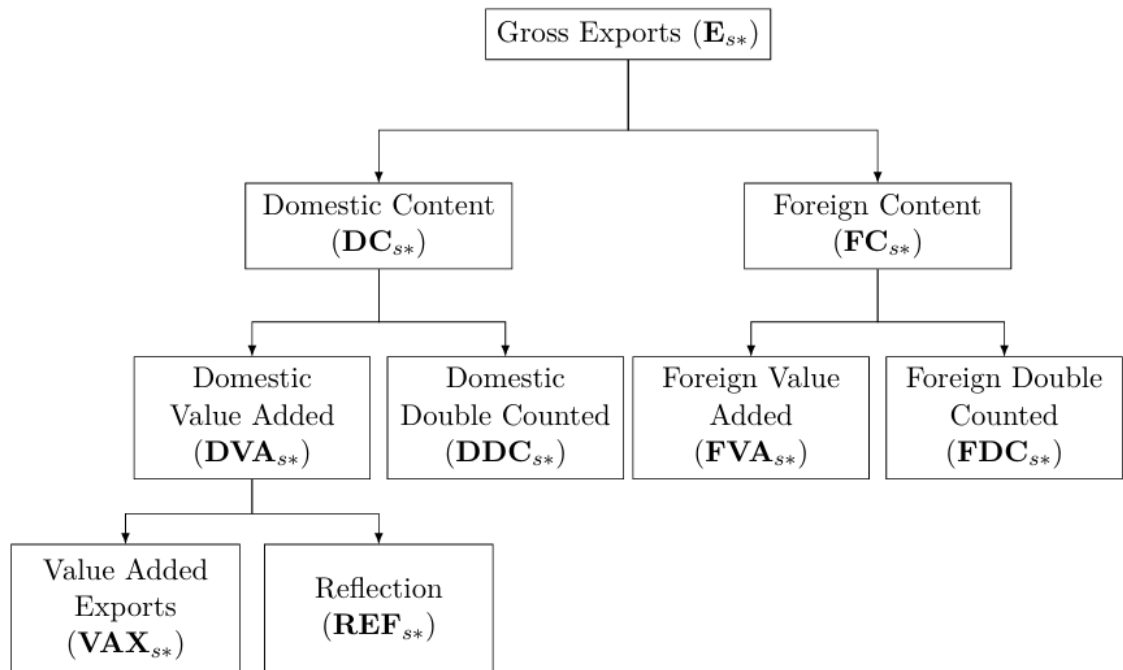


Figure 1.4: Basic scheme of decomposition of gross exports by Koopman et al. (2014). Source: Borin and Mancini (2019).

Then, a central methodological insight contributed by Borin and Mancini (2019, 2023) is the concept of different accounting “perspectives” and “approaches”. Perspectives define different perimeter for classifying what constitutes "value-added" versus "double-counted" components in trade statistics. They argued that there is no uniquely correct way to account for value-added in trade flows; instead, the appropriate methodology depends on the specific empirical question being addressed. Take the exporting country perspective, for example, which is the perspective used in this study; the boundaries are defined at the level of the exporting country as a whole. Value-added is considered double-counted when it crosses the same country's borders more than once. This perspective is appropriate for measuring a country's GDP in exports. The other perspectives include bilateral and sectoral-bilateral perspectives, where their perimeters are defined at the level of the bilateral relationship and at the level of a specific sector within a bilateral relationship. The choice of perspective fundamentally affects how value-added is measured and interpreted. Different perspectives yield different decompositions of the same gross trade flows, each providing insights into different aspects of global value chains.

Within the exporting country perspective, drawing on Nagengast and Stehrer (2014), Borin and Mancini (2019) proposed two approaches for assigning value-added to specific bilateral trade flows. For the source-based approach, the value-added is recorded the first time it leaves the country of origin. In subsequent border crossings of the same country, it is recorded as double-counted. On the other hand, the sink-based approach records the value added the last time it leaves the country of origin. All previous border crossings are recorded as double-counted. The source-based approach is more appropriate for analysing production linkages and supply chain structures, as it records value-added closer to the moment of production. The sink-based approach is better suited for studying the relationship between production and final demand, as it records value-added closer to final absorption.

Another crucial innovation in Borin and Mancini's (2019) framework is the concept of Directly Absorbed Value-Added (DAVAX). This measures the portion of bilateral exports that the direct importer absorbs without further international processing.

$$DAVAX_{sr} = V_s(I - A_{ss})^{-1}Y_{sr} + V_s(I - A_{ss})^{-1}A_{sr}(I - A_{rr})^{-1}Y_{rr} \quad (8)$$

The first term captures domestic value-added in final goods exports directly consumed in country r . The second term represents domestic value-added in intermediate goods processed in country r and consumed as final goods without crossing other international borders. Figure 1.5 illustrates an updated scheme based on Koopman et al. (2014) and extended by Borin and Mancini (2019). It shows that DAVAX is a subcomponent of DVA_s . Nevertheless, it is worth noting that the schema is incomplete because when we look at the equation for VAX (Borin and Mancini 2019):

$$VAXsource_{sr} = V_s(I - A_{ss})^{-1}[Y_{sr} + A_{sr}(I - A_{rr})^{-1}Y_{rr} + A_{sr}(I - A_{rr})^{-1}\sum_{j \neq r,s}^G Y_{rj} + A_{sr}(I - A_{rr})^{-1}\sum_{j \neq r}^G A_{rj} \sum_k^G \sum_{l \neq s}^G B_{jk} Y_{kl}] \quad (9)$$

The first component indicates the value added in country s embodied in final demand in country r without further re-export (DAVAX and indirectly absorbed VAX in figure 1.5). In contrast, the second component reveals the value-added intermediate inputs from s to r that are re-exported to third countries and more complex global value chains that flow through country r . The missing part in Figure 1.5 is the second component, a key component in constructing the *GVCforward*, which will be explained further below.

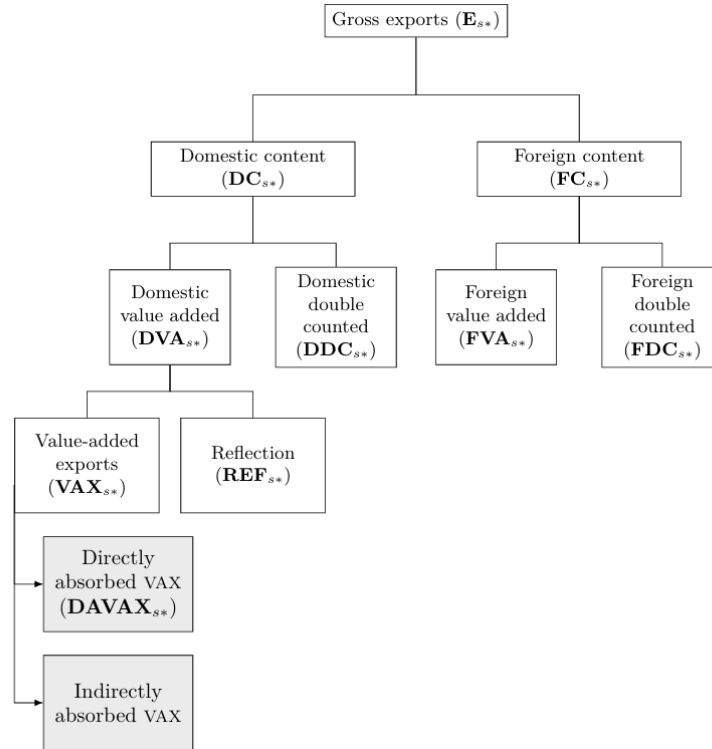


Figure 1.5. Updated basic scheme of decomposition of gross exports based on Koopman et al. (2014) and Borin and Mancini (2019). Source: Belotti, Borin, and Mancini (2021).

DAVAX identifies value-added in what could be called "traditional trade"—exchanges that do not involve complex cross-border production sharing, as stated in the first component above. Contrastingly, value-added that crosses multiple borders represents participation in global value chains. Building on this distinction, Borin and Mancini defined “GVC-related trade” as all traded items that cross at least two international borders before reaching final consumers, therefore “GVC-related trade” can be measured by deducting the DAVAX from country s ’s gross exports.

$$GVCX_{sr} = u_N E_{sr} - DAVAX_{sr} \quad (10)$$

With this, the GVC share in bilateral exports can be measured as:

$$GVC_{sr} = \frac{GVCX_{sr}}{u_N E_{sr}} \quad (11)$$

The country-level GVC participation:

$$GVC_s = \frac{\sum_{r \neq s}^G GVCX_{sr}}{u_N E_{s*}} \quad (12)$$

Equation (12) captures the overall involvement of country s in global value chains across all its trading partners. Then, Borin and Mancini (2019) further decompose GVC participation into backward and forward components, corresponding to the two directions of participation in global value chains:

$$GVC_{sr} = \underbrace{GVC_{backward}_{sr}}_{VS_{sr}} + \underbrace{GVC_{forward}_{sr}}_{VS1_{sr}} \quad (13)$$

$$GVC_{backward}_{sr} = \frac{V_s(I - A_{ss})^{-1} \sum_{j \neq s}^G A_{sj} B_{js} E_{sr} + \sum_{t \neq s}^G V_t B_{ts} E_{sr}}{u_N E_{sr}} \quad (14)$$

$$GVC_{forward}_{sr} = \frac{V_s(I - A_{ss})^{-1} A_{sr}(I - A_{rr})^{-1} \left(\sum_{j \neq r}^G Y_{rj} + \sum_{j \neq r}^G A_{rj} \sum_k^G \sum_{l \neq s}^G B_{jk} Y_{kl} \right)}{u_N E_{sr}} \quad (15)$$

This breakdown offers a comprehensive view of how countries participate in global value chains, distinguishing between upstream (forward) and downstream (backward) activities. It represents a significant improvement over previous attempts to measure forward participation, such as Koopman et al.’s (2014) VS1 measure, which suffered from double-

counting issues and asymmetric treatment compared to backward participation. The VS1 index by Koopman et al. aggregates the value of a country's production that is embedded in the exports of other countries. This means that while $GVCforward_{sr}$ focuses on the exports of a specific country s , the VS1 index looks at how much of country s 's production is included in the exports of other countries. Consequently, the original component from country s can be counted multiple times in the calculations if an intermediate product exported by country s is further processed in other countries before being re-exported. Furthermore, the discrepancy between the original value of goods exported by country s and the value that appears in Koopman et al.'s VS1 increases with the "upstreamness" of country s 's production. "Upstreamness" refers to how far back the country's production process is positioned. A more upstream country typically provides raw materials or components that are used in the production of final goods in other countries. The more upstream a country is, the more likely its exports will be double-counted when those components are processed and exported again (Borin and Mancini 2019).

As time passes, new versions of ICIO tables will expand to include more countries and even more granular industry classifications. Borin and Mancini's multi-perspective method will be robust enough to handle more complex data structures and provide analytical approaches for multifaceted research needs.

1.5 GVC and Economic Development

Global Value Chains (GVC) have transformed development pathways available to countries, creating opportunities and challenges that earlier development models could not fully anticipate. This section examines the empirical evidence on how GVC participation affects economic development outcomes across different country contexts, with particular attention to growth, structural transformation, and inequality.

Numerous studies demonstrate a positive correlation between global value chain participation and economic growth. Kummritz (2016), based on data analysis from the World Input Output Database (WIOD) covering 34 industries across 61 countries, found that for every 1% increase in backward participation and forward participation in global value

chains, domestic value-added increases by 0.11% and 0.60% respectively. Similarly, Constantinescu, Mattoo, and Ruta (2019), using the WIOD database as well, presented that participation in global value chains is a significant driver of labour productivity. For every 10% increase in global value chain participation, average productivity increases by nearly 1.6%.

Similarly, research by Baldone, Sdogati, and Tajoli (2007) and Foster, Stehrer, and Timmer (2013) reached conclusions comparable to those of Constantinescu, Mattoo, and Ruta (2019). Baldone, Sdogati, and Tajoli found that international fragmentation of production plays a specific and important role in determining annual changes in GDP, with inward processing flows making a particularly strong contribution to GDP growth, exceeding that of traditional final product exports. The study by Foster, Stehrer, and Timmer indicates that countries successfully integrated into global or regional production systems benefit from value-added growth and are positively influenced by vertical specialisation and upstreamness. These growth effects stem from the gains of comparative advantage and specialisation, not only between industries but also within industries, as emphasised by the "trade-in-tasks" literature.

Hermida, Santos, and Bittencourt (2022) provide further evidence for the long-term impact of global value chain participation, showing that both vertical specialisation of production and overall participation in global value chains have positive effects on long-term per capita GDP growth. Notably, they found that the contribution of production fragmentation and global value chain participation to GDP growth is more significant than the percentage of total exports to GDP, highlighting the unique impact of value chain integration on development compared to traditional trade.

The mechanisms and scale behind these growth effects appear to be multifaceted. Using firm-level data from Vietnam, Newman et al. (2015) found that foreign direct investment (FDI) boosted the productivity of domestic enterprises through direct forward linkages, where technology transfer and procurement of inputs from foreign investment suppliers drove significant efficiency improvements. This effect further spilled over to domestic firms with indirect linkages. On the other hand, Pahl and Timmer (2019) found strong evidence that deeper global value chain integration has a positive impact on productivity. Notably, consistent with Rodrik (2013), they found that countries with relatively lower productivity can benefit more from global value chain participation in terms of productivity growth, as

they are far from the technological frontier. This provides counter-evidence to concerns that developing countries' participation in global value chains might trap them in unproductive activities.

Participation in GVC generally enhances economic growth and productivity, with studies showing consistent positive effects across countries and industries. Gains can be observed through backward and forward linkages, inward processing, and technology spillovers from foreign firms, although at different magnitudes. However, the nature of participation matters—countries benefit most when integration enables learning, specialisation, and movement up the value chain, highlighting both the opportunities and nuances of GVC-driven development.

1.6 Distributional Effects and Integration Patterns

Research reveals complex distributional effects of GVC participation within and between countries, with significant variation across different integration patterns. Within countries, Timmer et al. (2014) documented declining value-added shares for low-skilled workers in both advanced and emerging economies, as firms in mature economies relocate labour-intensive activities while retaining high-value functions domestically. Szymczak (2018) confirmed the negative employment impacts of production fragmentation, finding that higher Global Import Intensity Index values correlate with lower employment growth in over 60% of analysed countries. Between countries, the effects vary by integration type. Darku et al. (2023) directly compared North-North, North-South, and South-South trade relationships, finding that North-South integration (OECD to Sub-Saharan Africa) generated the strongest income convergence through knowledge spillovers, while South-South trade showed no significant convergence effects. They attributed this to similar productivity levels and homogeneous goods production among developing countries, which maintains rather than reduces income differences.

The quality dimension of integration significantly influences outcomes. Cingolani, Felice, and Tajoli (2015) demonstrated that offshoring to low-income/low-product quality countries worsens current accounts in EU nations while sourcing from high-income/high-quality partners improves them. This suggests that the nature of integration matters more than

simply participation levels. Rodrik (2018) offered a critical perspective, arguing that GVCs pose a "double whammy" for developing economies: new technologies are skill-biased, reducing comparative advantage in labour-intensive sectors, while GVCs limit the ability to substitute unskilled labour for other inputs. He suggested that development strategies should prioritise "domestic integration" over international integration.

A more optimistic view comes from Sposi, Yi, and Zhang (2021), who identified a two-way interplay between capital accumulation and comparative advantage in GVCs. Their model demonstrates that the additional aggregate productivity gains from GVC specialisation induce significant boosts to capital accumulation. While higher-income countries may initially have comparative advantages in capital-intensive production stages, lower-income countries with faster productivity growth can accumulate capital more rapidly, altering their comparative advantages over time. This dynamic allows developing economies to increasingly specialise in different stages of production, particularly moving beyond purely labour-intensive tasks. Importantly, their research indicates that the gains from trade in frameworks with GVCs are several times larger than in dynamic frameworks without GVCs, underscoring the enhanced growth potential of value chain integration.

Collectively, this research indicates that the developmental impact of GVC participation depends on specific integration patterns, country characteristics, and complementary policies rather than just overall participation levels. The question of whether South-South or North-South integration generates more favourable outcomes remains contested, with evidence suggesting that product quality, capital accumulation dynamics, and institutional factors may be more important determinants than simply the income levels of trading partners.

2. Data

2.1 Variables

This study employs several key variables to examine the relationship between GVC participation and economic development across countries. The dependent variable is GDP per capita, while the primary explanatory variable is the GVC participation index. Additional control variables include income group classifications and regional organisation memberships.

GDP per capita data is primarily extracted from the World Bank's World Development Indicators database, with the Asian Development Bank (ADB) serving as a secondary reference for missing observations (Asian Development Bank, n.d.; World Bank Group n.d.-a). The variable is expressed in current international dollars (as of January 2025) converted using purchasing power parity (PPP) conversion factors. PPP-adjusted GDP provides a more accurate comparison of living standards across countries by accounting for price level differences. For the econometric analysis, GDP per capita is transformed to natural logarithm form to address skewness and to interpret coefficients as elasticities.

Income group classifications are based on the World Bank's categorisation as of January 2025, which divides economies into four groups: High-income economies (HIC), Upper-middle-income economies (UMC), Lower-middle-income economies (LMC), and Low-income economies (LIC) (World Bank Group, n.d.-b). These classifications are determined using gross national income (GNI) per capita thresholds. The income group classifications serve important purpose in this study. They form the foundation for constructing country-pair income group combinations (e.g., HIC-LIC, LMC-UMC, LIC-LIC) in the bilateral analysis, which is essential for testing the hypothesis regarding the differential effects of GVC participation between countries at varying development stages.

Regional organisation memberships include EU27, G20, OECD, APEC, ASEAN, NAFTA, and EMU. Information on membership and accession years was compiled from the official websites of these organisations. These variables are included as controls for several important economic factors that could influence both GVC participation and economic development.

First, regional organisations often create institutional frameworks that reduce trade barriers and transaction costs between member countries. The EU Single Market, ASEAN Economic Community, and NAFTA/USMCA trade provisions facilitate production sharing by standardising regulations, reducing tariffs, and simplifying customs procedures. These institutional factors could independently affect both GVC participation and economic growth. Second, these organisations often reflect geographical proximity factors that naturally promote production sharing. In accordance with the gravity model of trade, which posits that trade flows are proportional to economic size and inversely proportional to distance, membership in regional groups serves as a proxy for the distance-related variables that could otherwise confound the analysis of how global value chain participation affects economic growth.

Finally, for bilateral analysis, in particular, shared membership in regional organisations may explain convergence patterns between country pairs that are unrelated to their bilateral GVC integration. Including these variables helps distinguish between convergence driven by broader regional integration and that specifically attributable to bilateral production linkages.

By controlling for these memberships, the study can more confidently attribute estimated effects to GVC participation rather than to these correlated institutional and geographical factors.

2.2 Input-Output Data from Inter-Country Input-Output tables (ICIO)

The calculation of the GVC participation index relies on data from the OECD's Inter-Country Input-Output (ICIO) tables, which capture the complex interdependencies of international production networks (OECD 2023).

The 2023 release is used for this study. The tables cover 76 economies across 45 industries, spanning the period from 1995 to 2020, providing detailed information on the flows of goods and services between industries and across countries, capturing both intermediate and final consumption. The countries covered include all OECD members, G20 countries, most East

and Southeast Asian economies, and selected others, collectively representing over 85% of world GDP (see appendix no.2).

Figure 2.1 illustrates a basic input-output table structure on a yearly basis with N countries and K industries⁶. The key components like intermediate inputs (Z), gross output (x) and final demand (y)⁷ that is needed to construct the Leontief inverse matrix (L) can be obtained from the tables. Other data, such as VA , will also be captured to further compute the other components in GVC Participation Index. Echoing the research question of this study, only the data from the manufacturing industry was downloaded for analysis. Specifically, the focus is on aggregated exports from the manufacturing sector in country r to the aggregated manufacturing sector in country s . The complete list of manufacturing sectors is attached in the appendix no.3.

		Intermediate Consumption				Final Demand				G.O.				
		Country 1		...	Country N		Country 1		...		Country N			
		Ind. 1	...	Ind. K	...	Ind. 1	...	Ind. K	FD ' ...		FD F	FD ' ...	FD F	
Country 1	Ind. 1	Z^{11}		...		Z^{1N}		Y^{11}		...		Y^{1N}		X^1
	Ind. K													
...	...	Z^{21}		Z^{2K}		Z^{2N}		Y^{21}		Y^{2K}		Y^{2N}		...
Country N	Ind. 1	Z^{N1}		...		Z^{NN}		Y^{N1}		...		Y^{NN}		X^N
	Ind. K													
Taxes less subsidies		... on intermediate products												
		... on final products												
Value Added at basic prices		VA^1		...		VA^N								
Gross Output		X^1		...		X^N								

Figure 2.1. OECD ICIO Basic Structure. Source: (OECD, Directorate for Science, Technology and Innovation 2023)

2.3 GVC Participation Index

The Global Value Chain participation index used in this study follows the methodology

⁶ In some input-output literature, countries are denoted as G and sectors are denoted as N within a standard Inter-Country Input-Output (ICIO) model (Borin and Mancini 2019; Koopman, Wang, and Wei 2014).

⁷ It is denoted as f in Miller and Blair (2009) but y in OECD (2023).

developed by Borin and Mancini (2019, 2023). This section focuses on the technical aspects of calculating this index, while the conceptual evolution of GVC measurement approaches is discussed in the section 1.4.

Nearly all data extraction, processing, and analysis in this study are conducted in R. A key R package used for computing the GVC Participation Index is `exvtools`⁸, developed by Feas (2023b). Feas acknowledged that no compatible and equivalent software tools are available for comprehensive decomposition of value-added in exports. Existing packages such as `ioanalysis` and `decompr` have limitations that hinder this type of analysis. Although the OECD's Trade in Value Added (TiVA) online portal displays processed indicators, it lacks certain metrics detailed in its 2023 guidelines. Within the Stata ecosystem, a module called `icio` was developed in 2021 by a team including Borin and Mancini, who authored the approach used in this study to calculate the GVC Participation Index (Belotti, Borin, and Mancini 2021). While `icio` offers comprehensive functions for decomposing value-added in exports that would fulfil the requirements of this research, its proprietary and closed-source nature prevented its use.

This open-source package provides functions for loading ICIO table data (OECD 2023) that is downloaded beforehand into R and calculating the necessary matrices, including the Z matrix of intermediate inputs, A matrix of global technical coefficients, VA of value-added vector, B matrix of global Leontief inverse and so on.

```
wio <- make_wio("icio2023", year = 2020)
# Load ICIO table of a specific year into R and calculate all matrices

exvadec.all <- make_exvadec(wio, exporter = "all", method = "bm_src",
                           output = "standard", quiet = TRUE)
# Decompose the value added in exports for every country or for a
# particular country or country group, according to different methodologies.

get_exvadec_bkdown(exvadec.all, exporter = "ARG",
                   sector = "MANUF", importer = "USA")
# Select a specific exporter, sector and importer.
```

The package includes specialised functions (`method = "bm_src"`) for decomposing gross exports into domestic and foreign content and calculating the GVC participation index

⁸ [CRAN: Package exvtools](#)

following the Borin and Mancini (2023) source-based methodology. Table 2.1 presents an overall decomposition of value-added in Argentina's manufacturing exports for 1995. The table includes multiple value-added components: gross exports, domestic value-added content, foreign value-added content, and the primary focus of this study—GVC participation index (denoted as “GVC”). The GVC is further disaggregated into backward participation (GVCB) and forward participation (GVCF). Table 2.2 demonstrates how value-added exports to specific partner countries can be isolated and examined for bilateral analysis.

Table 2.1. The Overall Decomposition of Value-added in Exports of Manufacturing Sector of Argentina in 1995

VA_components	USD_MM	Percent
Gross exports of goods and services (EXGR)	10909.13	100.00
Domestic Content in VA (DC)	10010.73	91.76
Domestic Value Added (DVA)	10008.74	91.75
Value Added Exported (VAX)	9988.14	91.56
Reflection (REF)	20.61	0.19
Domestic Double Counting (DDC)	1.99	0.02
Foreign Content in VA (FC)	898.40	8.24
Foreign Value Added (FVA)	898.23	8.23
Foreign Double Counting (FDC)	0.17	0.00
Global Value Chain-related trade (GVC)	1856.88	17.02
GVC-related trade, backward (GVCB)	900.39	8.25
GVC-related trade, forward (GVCF)	956.50	8.77

Method: Borin and Mancini (2023), source-based, standard output
Exporting country perspective, source approach

Table 2.2. The Decomposition of Value-added in Exports of Manufacturing Sector of Argentina to The United States in 1995

VA_components	USD_MM	Percent
Gross exports of goods and services (EXGR)	1219.83	100.00
Domestic Content in VA (DC)	1138.06	93.30
Domestic Value Added (DVA)	1137.88	93.28
Value Added Exported (VAX)	1137.28	93.23
Reflection (REF)	0.59	0.05
Domestic Double Counting (DDC)	0.19	0.02
Foreign Content in VA (FC)	81.77	6.70

Foreign Value Added (FVA)	81.75	6.70
Foreign Double Counting (FDC)	0.01	0.00
Global Value Chain-related trade (GVC)	160.83	13.18
GVC-related trade, backward (GVCB)	81.96	6.72
GVC-related trade, forward (GVCF)	78.87	6.47

Method: Borin and Mancini (2023), source-based, standard output
Exporting country perspective, source approach

While still relatively new and not yet widely adopted in academic research, this package has been successfully utilised in recent studies by Minondo (2024) and Jahangard (2024). As a validation measure, the results generated through this package were compared with figures from OECD's TiVA online platform and confirmed to be consistent, providing additional confidence in the reliability of the approach.

2.4 Data Imputation for Missing Values

Despite the comprehensive coverage of the ICIO tables and other data sources, some observations were missing due to data availability issues for specific countries and years. The original panel was slightly unbalanced, with 57 countries having complete data for all 26 years (1995-2020), 19 countries with 25 years of data, and 1 country with 24 years of data. The missing observations were minimal - 31 missing values for GDP per capita, while GVC participation was complete for all country-year combinations.

To address these missing values and maximise the usable sample size, multiple-imputation techniques was employed using the `amelia` package in R (Honaker, King, and Blackwell 2011). Amelia implements a bootstrapped-based algorithm for multiple imputation that is particularly well-suited for time-series cross-sectional data like the dataset used in this study.

The imputation model was specified as follows:

```
imputed_data2 <- amelia(
  x = imputation_data2,
  m = 5,
  ts = "year",
  cs = "country",
  polytime = 1,
  p2s = 2
```

)

m determines the number of imputed datasets to create. For simplicity, only the first of the five generated datasets is adopted for the subsequent analysis. *ts* and *cs* explicitly identifying the time-series and cross-sectional dimensions in the dataset. *polytime* indicates what power of polynomial should be included in the imputation model to account for the effects of time. 1 indicates linear time effects. Lastly, *p2s* determine the type of screen output.

Given that missing values constituted only less than 2% of the dataset and the GVC participation variable (the primary focus of this study) had no missing values, the impact on results should be minimal. Nevertheless, to avoid listwise deletion and maintain a balanced panel structure, implementing this imputation approach provides a methodologically sound foundation for econometric analysis.

3. Methodology

This study's central research question examines whether GVC participation between lower-income countries generates either income convergence or divergence opportunities compared to participation between lower-income and higher-income countries. To address this question, we structured our data to focus on country pairs. For each unique directional country pair (i, j) , the following variables are calculated:

- GDP per capita gap (gdp_gap) - The dependent variable, measured as the difference in natural log of GDP per capita between country i and country j .
- Bilateral GVC participation (ln_bi_gvc) - The key explanatory variable, measured as the natural log of the ratio between GVC-related trade and gross exports from country i and country j .
- Income group pairs - A set of 16 directional dummy variables identifying the income classification combination of each country pair. Country i refers to the exporting country, while country j refers to the destination country. For example, if the pair is “LIC-UMC”, it means the GVC participation rate in the exports of country i from the LIC group to country j from the UMC group. Meanwhile, the pair of “UMC-LIC” is not the same as “LIC-UMC”, as it represents the GVC participation rate in the exports of country i from the UMC group to country j from the LIC group.

		Country j			
		LIC	LMC	UMC	HIC
Country i	LIC				
	LMC				
	UMC				
	HIC				

- Shared membership dummies - Binary indicators for whether both countries in a pair belong to the same regional organisation (EU27, G20, OECD, APEC, ASEAN, NAFTA, EMU).

This approach provides several key advantages. First, it focuses on the asymmetrical effects of GVC participation across economies at different development stages, using income

groups as a proxy. When the estimated coefficient of the GDP gap between countries i and j is negative at a given GVC participation level, it indicates the income gap between these countries is narrowing—a potentially positive signal of convergence—or widening if the coefficient is positive. This framework allows for a direct examination of convergence dynamics between different income groups. Second, the approach enables the exploration of heterogeneous effects across various country-pair income combinations, offering more nuanced insights into how GVC participation affects countries at different stages of economic development.

Using the Pesaran (2004) CD test, significant cross-sectional dependence is found in the panel ($z = 13.991$, $p < 2.2e-16$), indicating that countries pairs' economic outcomes are not independent of each other. Given the strong cross-sectional dependence detected, a full Common Correlated Effects Mean Group (CCEMG) estimator would have been ideal. The CCEMG estimator is specifically designed for panel datasets characterised by unobserved common factors that induce cross-sectional dependence — a condition that is highly plausible in this study's context (Millo n.d.; Pesaran 2006). CCEMG directly accounts for this issue by incorporating the cross-sectional means of all regressors as proxies for unobserved global factors. Additionally, slope heterogeneity across cross-sectional units is allowed with CCEMG, as it does not impose the unrealistic assumption that all country pairs respond uniformly to changes in production fragmentation (Pesaran 2006). This is particularly relevant to the research question, as different country-pair combinations, such as high-income versus low-income pairings — may experience systematically different relationships between production fragmentation and income convergence.

However, the combination of high-dimensional regressors (including income-group dummies, interactions, and regional membership controls) and limited time coverage ($T = 26$) made implementing CCEMG infeasible in this study. As a methodological compromise, the bilateral analysis employs a two-way fixed effects (`effect = "twoways"` in `plm`) approach with Driscoll-Kraay standard errors (Driscoll and Kraay 1998). This methodological choice is appropriate for several reasons. The complex interdependence in bilateral data—where countries appear in multiple pairs—creates network relationships that simple cross-sectional means may not adequately capture. Fortunately, the two-way fixed effects specification effectively controls for both country-pair-specific heterogeneity (α_{ij}) and common global shocks (δ_t), which are major sources of cross-sectional dependence

(Croissant and Millo n.d.; Wooldridge 2021). Besides, the Driscoll-Kraay standard errors approach is robust to cross-sectional dependence, meaning it accounts for correlations in errors across different cross-sectional units and provides robust standard error estimates that remain consistent even in the presence of spatial and temporal dependence (Driscoll and Kraay 1998). In fact, the presence of serial correlation and heteroskedasticity in the model is also confirmed. Therefore, the Driscoll-Kraay standard errors approach is justified. In R, this approach is implemented using the `vcovSCC` function from the `plm` package (Millo, n.d.).

Regarding lag structure, the bilateral analysis approached the optimal one through a trial-and-error method by testing different lag structures separately and observing the regression outputs. This approach was chosen for several reasons. First, the primary research question for the bilateral analysis concerns how GVC effects differ across income group combinations, not how they differ across lag structures. Determining appropriate lag structures simply aimed to account for serial correlation and reduce bias in the results. Through model comparison, the three-lag structure likely emerged as sufficient to capture the dynamic adjustment processes while maintaining model parsimony. Second, adding variable lag structures would make interpretation extremely difficult with 16 income group pairs and their interactions with GVC participation. The uniform lag structure ensures that differences in coefficients across income groups can be directly compared. Finally, the complexity of a bilateral model increased the risk of errors and posed significant challenges for coding in R. Ultimately, a more straightforward and practical approach was adopted. The following is the final model specification:

$$\begin{aligned}
gdp_gap_{ij,t} = & \alpha_{ij} + \delta_t + \sum_{k=1}^3 \gamma_k gdp_gap_{ij,t-k} \\
& + \sum_{k=0}^3 \beta_{k+1} ln_bi_gvc_{ij,t-k} + \sum_{m=1}^{15} \theta_m IG_{ij,m} \\
& + \sum_{m=1}^{15} \lambda_m (ln_bi_gvc_{ij,t} \times IG_{ij,m}) + \sum_{r=1}^8 \phi_r R_{ij,r,t} + \epsilon_{ij,t}
\end{aligned} \tag{16}$$

Where:

- $\sum_{k=1}^3 \gamma_k gdp_gap_{ij,t-k}$ denotes three lags of the dependent variable.
- $\sum_{k=0}^3 \beta_{k+1} ln_bi_gvc_{ij,t-k}$ represents contemporaneous and three lags of bilateral GVC participation.

- $\sum_{m=1}^{15} \theta_m IG_{ij,m}$ is a set of dummy variables for 15 income group pairs (with LIC-LIC as the reference category that is omitted intentionally).
- $\sum_{r=1}^8 \phi_r R_{ij,r,t}$ indicate shared membership in eight regional organisations.

After introducing the model design and techniques for bilateral country-pair analysis, we connect back to the "perspective" and "approach" concepts discussed in section 1.4 by Borin and Mancini (2019, 2023). This study employs the exporting country perspective and source-based approach. The exporting country perspective is appropriate as it effectively measures GDP embedded in exports, aligning with our examination of how GVC participation affects economic outcomes. The study chose the source-based approach over the sink-based approach because our primary interest lies in examining GVC integration effects from exporters' perspectives. Furthermore, Feas (2023a) demonstrated that the decomposition method by Borin and Mancini (2023)—using exporting country perspective with source-based approach—proves superior to alternative perspectives and approaches. Another practical consideration is that the `exvatoools` package developed by Feas (2023b) does not provide other perspective options, so the exporting country perspective is used uniformly in analysing all models.

A limitation of this study is its focus on income gap dynamics rather than the absolute economic growth generated by GVC participation. While the bilateral analysis does not comprehensively capture the overall effects of GVC participation, indirect results can still be derived through specialised analytical techniques. These complementary insights may contribute to understanding the broader implications of GVC integration.

4. Results

Before starting the formal analysis, a simple exploration of the dataset is conducted, aiming to understand some general patterns and the distribution of variables. We first investigated the evolution of GVC participation over time (Figure 4.1). As expected, the trend shows consistent upward movement, with global average participation rates demonstrating continuous growth throughout the 25-year study period. Two pivotal events are particularly prominent: China's accession to the World Trade Organization and the 2008 global financial crisis. China's integration into global industrial chains appears to have elevated the global average participation rate substantially (Figure 4.2). Conversely, the 2008 crisis delivered a pronounced shock to global markets, resulting in a marked decline in participation. However, global production demonstrated remarkable resilience, rebounding rapidly and driving GVC participation to new heights by 2011 (Figure 4.1).

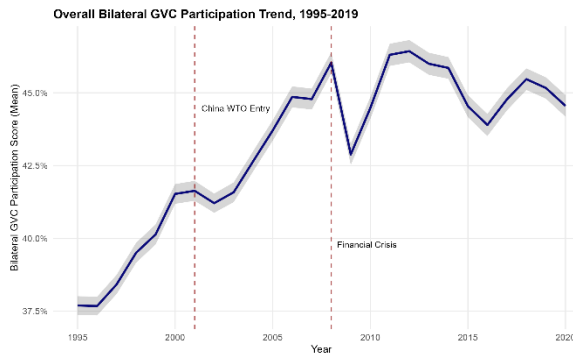


Figure 4.1. Overall GVC Participation Trend, 1995-2020. Shaded area represents 95% confidence interval. Source: Own Calculation based on data from OECD (2023)

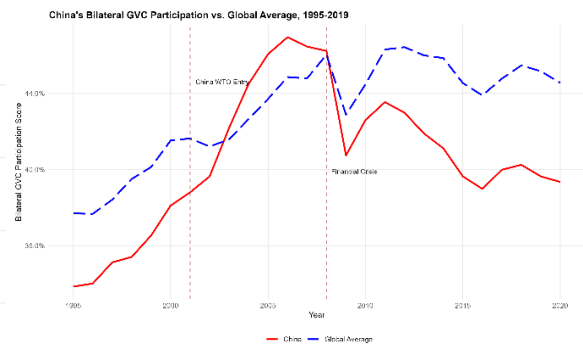


Figure 4.2. China's GVC Participation vs. Global Average, 1995-2020. Source: Own Calculation based on data from OECD (2023)

The next critical question is whether there is a correlation between overall GVC participation and GDP per capita. This can be examined through a simple scatter plot analysis. As illustrated in Figure 5.3, despite considerable dispersion among data points, the linear regression trend

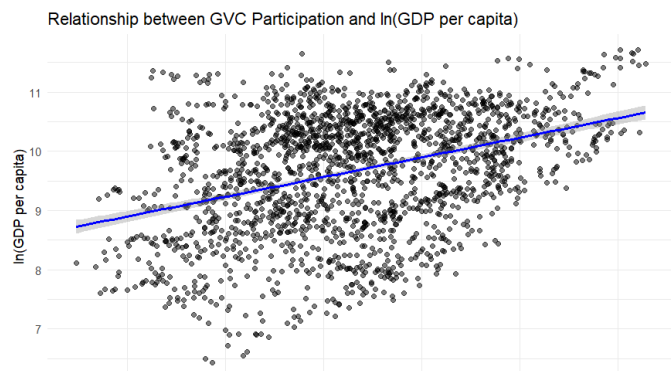


Figure 4.3. Correlation between GVC Participation and ln(GDP per capita). Source: Own Calculation based on data from OECD (2023)

line reveals a distinct upward trajectory. The correlation coefficient of 0.37 confirms a positive, albeit moderate, relationship between these two variables, suggesting that higher GVC participation tends to be associated with higher GDP per capita, though other factors influence this relationship as well.

Table 4.1 reports the number of bilateral observations by income - group pairings. The income group pairs are constructed with the exporting country on the left and the destination country on the right, denoted as “HIC-LIC”, which refers to HIC countries that export intermediate goods to LIC countries. HIC - HIC combination comprises the largest share (32,504), which is not surprising as most economies in the OECD’s ICIO tables come from advanced economies. LIC - LIC pairs are the least frequent (1,934). Generally, all income group pairs seem to have sufficient observations for a comparative analysis.

Table 5.1. Bilateral Income Group Pairs

		Country <i>j</i>			
		LIC	LMC	UMC	HIC
Country <i>i</i>	LIC	1,934	3,512	3,089	6,465
	LMC	3,512	6,964	6,885	15,039
	UMC	3,089	6,885	6,534	15,142
	HIC	6,465	15,039	15,142	32,504

4.1 Formal Analysis

The formal analysis based on model (16) is consolidated in Table 4.2. The results demonstrate that bilateral GVC participation has complex and varied effects on income gaps between countries. The base coefficient for GVC participation ($\ln_bi_gvc$) is negative (-0.0075, $p=0.052$), indicating that for the reference group (LIC-LIC pairs), increased GVC participation is associated with reduced income gaps. This convergence effect strengthens over time, with significant negative coefficients for all three lag periods (-0.0023 for lag 1, -0.0048 for lag 2, and -0.0033 for lag 3). The combined effect across all periods is approximately -0.018, suggesting substantial GDP gap reduction through GVC participation.

Table 4.2. Bilateral Analysis Results⁹

<i>Predictors</i>	gdp_gap	
	<i>Estimates</i>	<i>CI</i>
lag(gdp_gap, 1)	1.2007 *** (0.0044)	1.1920 – 1.2094
lag(gdp_gap, 2)	-0.2399 *** (0.0076)	-0.2549 – -0.2250
ln_bi_gvc	-0.0075 * (0.0039)	-0.0152 – 0.0002
lag(ln_bi_gvc, 1)	-0.0023 * (0.0013)	-0.0048 – 0.0002
lag(ln_bi_gvc, 2)	-0.0048 *** (0.0011)	-0.0070 – -0.0026
lag(ln_bi_gvc, 3)	-0.0033 *** (0.0010)	-0.0053 – -0.0014
is_i_LMC_j_HICTRUE	0.0185 *** (0.0058)	0.0072 – 0.0299
is_i_LMC_j_LICTRUE	0.0271 *** (0.0067)	0.0140 – 0.0401
is_i_LMC_j_LMCTTRUE	0.0102 * (0.0059)	-0.0013 – 0.0217
is_i_UMC_j_HICTRUE	0.0113 * (0.0058)	-0.0002 – 0.0227
is_i_UMC_j_LICTRUE	0.0206 *** (0.0066)	0.0077 – 0.0335
ln_bi_gvc:is_i_LMC_j_HICTRUE	0.0171 *** (0.0046)	0.0081 – 0.0261
ln_bi_gvc:is_i_LMC_j_LICTRUE	0.0174 *** (0.0049)	0.0078 – 0.0271
ln_bi_gvc:is_i_LMC_j_LMCTTRUE	0.0104 ** (0.0045)	0.0015 – 0.0192
ln_bi_gvc:is_i_LMC_j_UMCTTRUE	0.0147 *** (0.0047)	0.0055 – 0.0239
Observations	127341	
R ² / R ² adjusted	0.945 / 0.942	
* $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$		

⁹ To keep the table shorter, only significant coefficients at least 10% level are displayed.

The primary interest would be the interaction terms as they reveal how other income pair types differ from the LIC-LIC base effect. Across all specifications, LMC pairs show the most statistically significant interactions. LMC-HIC pairs have a strong positive interaction (0.017, $p < 0.01$), substantially offsetting the base convergence effect. Similar positive interactions exist for LMC-UMC pairs (0.015, $p < 0.01$), LMC-LIC pairs (0.017, $p < 0.001$), and LMC-LMC pairs (0.010, $p < 0.05$). These positive interactions indicate that when LMCs participate in GVCs with any partners, the convergence benefits are weaker than for LIC-LIC pairs. For HIC pairs and UMC pairs, their interaction coefficients are not statistically significant, suggesting effects similar to the LIC-LIC base case—specifically, a tendency toward narrowing income disparities.

4.2 Immediate Effect & Total Effect

The diverse effects among different income pairs are illustrated more clearly in Table 4.3 and Figure 4.4. For simplicity, countries from the LIC and LMC groups are classified as lower-income, while countries from the UMC and HIC groups are classified as higher-income. Based on this classification, country pairs where the exporting country belongs to the lower-income group are designated as the "Lower-higher group," whereas pairs where the exporting country comes from the higher-income group are labelled the "Higher-lower group." Although income pairs such as LIC-LMC or HIC-UMC represent bilateral relationships within the lower-income and higher-income groups, this analysis attempts to analyse two directions only for better comparison. Lower-higher group reveals a trade direction from emerging economies to higher-income economies, and vice versa. Therefore, pairs like LIC-LMC are grouped into the Lower-higher group, and HIC-UMC is assigned to the Higher-lower group. Comparison as such can produce richer policy implications.

The immediate effect represents the contemporaneous impact of GVC participation on the GDP per capita gap, while the total effect encompasses both the immediate effect and all lagged effects of GVC participation. For example, in LIC-LIC pairs, a 1% increase in bilateral GVC participation is associated with a 0.75% reduction in the GDP gap in the current term and a 1.8% reduction in the long term. Notably, only the LMC pairs show statistical significance in the immediate effect, and they are the only pairs exhibiting income

divergence initially. However, with continued GVC integration, their immediate divergent effect is counteracted by the lagged effect, resulting in varying degrees of income convergence in the total effect, as shown in Figure 4.4. Notably, all income pairs ultimately demonstrate convergence patterns, suggesting long-term GVC participation consistently benefits each economy.

Table 4.3. Immediate Effect and Total Effect of GVC Participation by Different Income Pairs

<i>Income Pairs</i>	<i>Group</i>	<i>Immediate Effect</i>	<i>Total Effect</i>
LIC-LIC	Lower-higher	-0.0075 **	-0.0180
LIC-LMC	Lower-higher	-0.0058	-0.0162
LIC-UMC	Lower-higher	-0.0020	-0.0124
LIC-HIC	Lower-higher	-0.0027	-0.0132
LMC-LIC	Lower-higher	0.0099 ***	-0.0006
LMC-LMC	Lower-higher	0.0028 ***	-0.0076
LMC-UMC	Lower-higher	0.0071 ***	-0.0033
LMC-HIC	Lower-higher	0.0095 ***	-0.0009
UMC-LIC	Higher-lower	-0.0014	-0.0118
UMC-LMC	Higher-lower	-0.0074	-0.0179
UMC-UMC	Higher-lower	-0.0046	-0.0151
UMC-HIC	Higher-lower	-0.0067	-0.0172
HIC-LIC	Higher-lower	-0.0089	-0.0194
HIC-LMC	Higher-lower	-0.0080	-0.0185
HIC-UMC	Higher-lower	-0.0031	-0.0136
HIC-HIC	Higher-lower	-0.0058	-0.0162

* $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$

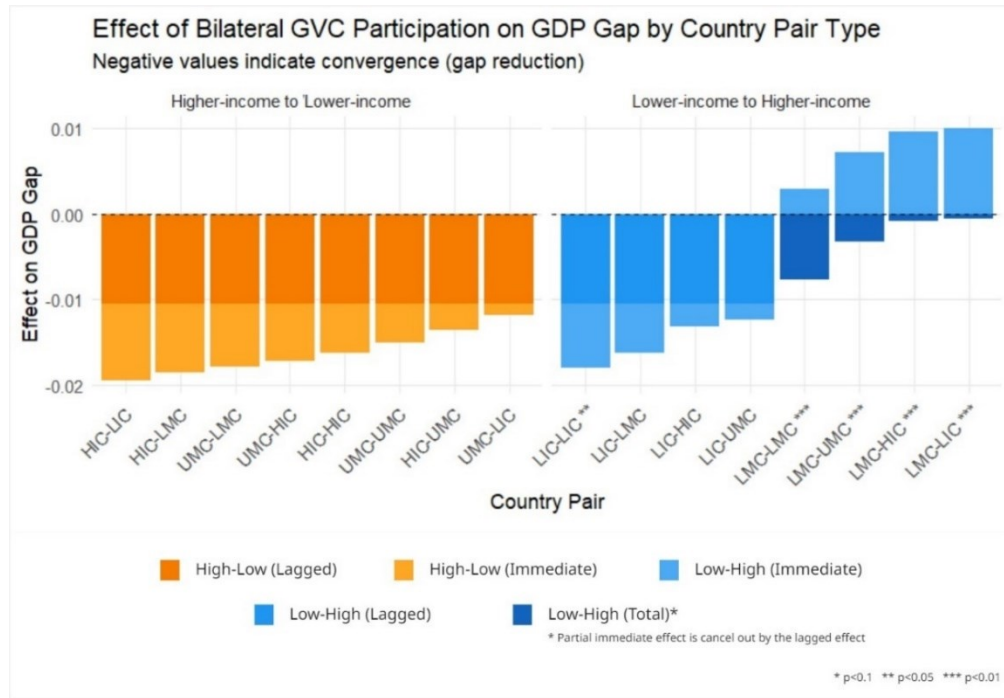


Figure 4.4. Effect of Bilateral GVC Participation on GDP Gap by Countries' Income Pair. Source: Own Calculation based on data from OECD (2023)

We observe varied convergence patterns across income pairs when simulating the total effect of each income pair on the GDP per capita gap over a 25-year period (initial period in 2021) with a constant GVC participation growth rate of 5%. Figure 4.5 shows the most striking result in LIC-LIC pairs, where the simulation projects a gap reduction of approximately 52% over a quarter century. While remarkable, this finding warrants careful interpretation since the initial gap (0.038 in log-transformed terms) was already small; thus, a relatively modest change (-0.0198) generates a substantial convergence effect. Importantly, narrowing the gap with a higher-income economy likely represents greater absolute gains than reducing the gap with an economy at say, \$5,000 per capita. By exporting intermediate goods to higher-income economies, LIC countries can achieve convergence effects of 0.6% with UMC countries and 0.8% with HIC countries.

One caveat in interpreting the total effect of bilateral GVC participation is that the feedback effect—captured by the coefficients on the lagged dependent variable—is not included. As shown in the section 4.1, the lagged dependent variables are statistically significant, indicating that past values of the outcome variable influence its current value. However, these terms are excluded from the calculation of the total effect because the current estimation approach is not suitable for deriving long-run effects in the presence of dynamic

components, following the framework of Pesaran, Shin, and Smith (2001). To properly account for the autoregressive structure and estimate consistent long-run effects, the CCEMG estimator should be used, as discussed in the methodology section. Since a different method is applied here, the long-run multiplier cannot be retrieved. Therefore, as a practical compromise, the total effect is calculated as the sum of the contemporaneous and lagged coefficients of bilateral GVC participation only.

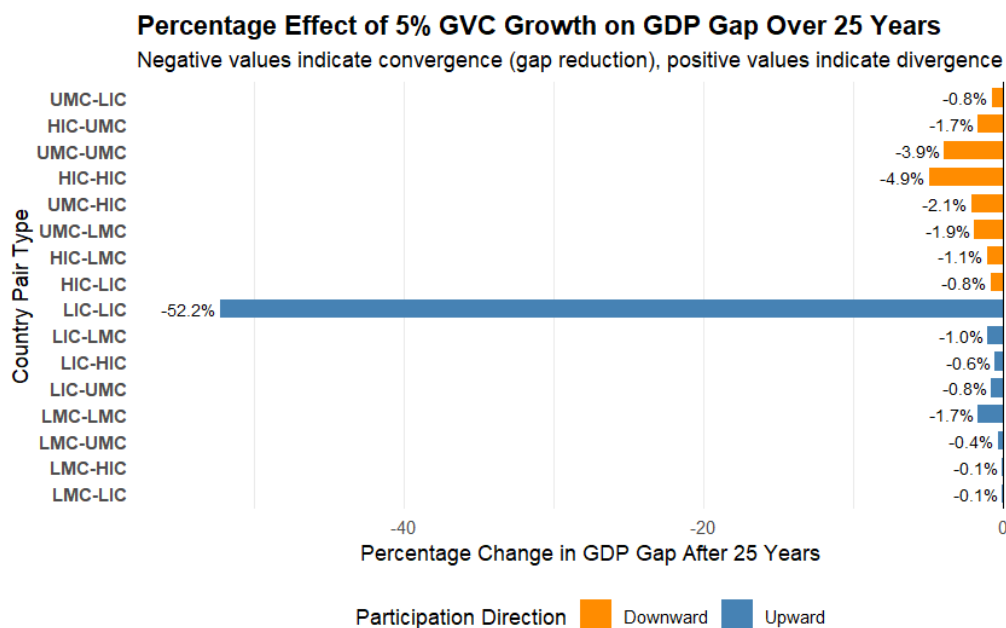


Figure 4.5. Simulation for GVC Participation Total Effect with Constant 5% GVC Participation Growth Rate Over 25 Years. Source: Own Calculation based on data from OECD (2023)

Overall, the effect generated by value-added exports from lower-income countries is relatively limited, with almost all changes being less than one percentage point. In contrast, the effect produced by intermediate goods exports from higher-income to lower-income countries is substantially greater. The smallest changes occur in HIC-LIC and UMC-LIC pairs at -0.8%, followed by -1.1% for HIC-LMC pairs and -1.9% for UMC-LMC pairs. These findings suggest that goods exported by different economies occupy distinct positions within vertical integration chains, thus generating varying degrees of added value. This observation provides a valuable direction for future research, specifically examining the GVC positioning of exporting countries within the manufacturing industry.

4.3 Hypothesis Test

Formal hypothesis tests are conducted to strengthen the empirical foundation of the conclusions regarding the differential impacts of GVC participation across country income pairings. While the coefficient analysis provided valuable insights into the magnitude and direction of effects, formal statistical testing was necessary to determine whether these differences were statistically significant rather than mere sampling variation. This testing directly addresses our research question of whether production fragmentation between lower-income countries generates either income convergence or divergence opportunities compared to participation between lower-income and higher-income countries.

The first step is extracting the GVC participation coefficients for lower-lower and lower-higher income pairs. We want to examine if their differences are statistically significant. With this, the null hypothesis and alternative hypothesis are determined:

$$H_0: \beta_1 - \beta_2 = 0$$

$$H_A: \beta_1 - \beta_2 \neq 0$$

Where:

- β_1 represents the GVC participation coefficient for lower-lower income pairs (South-South). E.g., LIC-LIC.
- β_2 represents the GVC participation coefficient for lower-higher income pairs (South-North). E.g., LIC-HIC.

In addition to examining convergence from lower-income to higher-income pairs, we formally test the reverse direction—higher-income to lower-income pairs too. These complementary analyses illuminate the differential effects of GVC integration on income convergence for both low-income and high-income countries. Beyond this, we distinguish between immediate and total effects in the test. While the coefficient of current GVC participation captures the immediate effect, the total effect incorporates lagged terms of GVC participation to account for dynamic impacts over time. This nuanced approach enables us to present a more comprehensive and detailed narrative of convergence dynamics.

These hypothesis tests were implemented using the `linearHypothesis` function from the `car` package in R, with appropriate weighting to account for the varying number of

observations across different country pair types, as shown in Table 4.1. The tests were conducted on the model with robust standard errors that account for cross-sectional dependence, serial correlation, and heteroskedasticity (vcovSCC approach).

The formal test results are compiled in Table 4.4. It reveals a striking pattern of increasing significance when examining the GVC participation effects for lower-income country exporters (LIC and LMC). For immediate effects, we find a statistically significant difference ($p=0.044$) between South-South and South-North integration patterns, suggesting that the choice of export destination matters considerably for convergence outcomes. Simply put, the convergence effect is statistically more substantial between lower-income countries than between lower-income and higher-income countries. However, this result does not deny that integration between lower-income and higher-income countries contributes to convergence; it simply suggests that this impact is comparatively weaker. While precise quantification is challenging due to varying statistical significance across country pairs, the difference is prominent. In some cases, South-South convergence effects are more than fifty percent stronger than specific South-North integration patterns (such as LIC-LIC vs LIC-HIC). However, this finding should be interpreted cautiously as not all individual country pair coefficients reached statistical significance.

When incorporating lagged effects to measure total impact, this significance strengthens substantially ($p=0.012$), indicating that the temporal dimension further amplifies these differences. This progressive strengthening of statistical significance underscores that the benefits of strategic GVC integration for lower-income exporters accumulate and intensify over time, suggesting that initial integration choices have long-lasting developmental consequences.

Table 4.4. Formal Hypothesis Testing Results

<i>Type</i>	<i>Income Pairs</i>	<i>Res.Df (Df)</i>	χ^2	<i>p-value</i>
Immediate effect	Lower-lower - Lower-higher	121578 (1)	4.075	0.0435 **
Immediate effect	Higher-higher - Higher-lower	121578 (1)	0.416	0.5189
Total Effect	Lower-lower - Lower-higher	121578 (1)	6.322	0.0119 **
Total Effect	Higher-higher - Higher-lower	121578 (1)	2.985	0.0840 *

* $p < 0.1$ ** $p < 0.05$ *** $p < 0.01$

In contrast, higher-income exporters (HIC and UMC) exhibit a markedly different trajectory. The immediate effects test shows no statistically significant difference ($p=0.519$) based on their export destinations, suggesting that advanced economies experience similar convergence effects regardless of their trading partners in the short term. However, when examining total effects, including lags, a marginally significant difference emerges ($p=0.084$) at the 10% level, indicating that temporal dynamics may gradually introduce some differentiation in outcomes. This shift from complete statistical indifference to marginal significance reveals that while higher-income countries' immediate GVC participation outcomes are largely independent of their export destinations, subtle differences may emerge over time—though these never reach the pronounced differentiation seen among lower-income exporters.

These contrasting patterns of statistical significance between exporter groups and across time horizons tell a compelling story about the asymmetric importance of GVC directionality. For lower-income countries, export destination choices constitute a critical strategic decision with significant and intensifying impacts on economic convergence. For higher-income countries, these directional choices have minimal immediate importance, with only subtle differences emerging over longer time horizons. This asymmetry in how exporter development level conditions the importance of trade directionality provides important nuance to our overall finding that rejects the hypothesis that “GVC participation between lower-income countries generates lower or negative convergence opportunities compared to participation between lower-income and higher-income countries”. The rejection of this

hypothesis is particularly pronounced and policy-relevant from the perspective of lower-income exporters, for whom South-South integration appears to offer distinctive convergence benefits that strengthen over time. Such a discovery contradicts the earlier research results of Darku et al. (2023).

Conclusion

This study has examined the complex relationship between GVC participation and income convergence across countries at different development stages. Analysing bilateral GVC integration patterns between 1995 and 2020 contributes to our understanding of how production fragmentation affects economic development outcomes, particularly for lower-income countries.

The primary finding of this research is that GVC participation generally promotes income convergence between countries but with significant variations across different country-pair combinations. Lower-income countries experience statistically stronger convergence effects when they integrate with other lower-income countries compared to when they integrate with higher-income economies. This South-South advantage intensifies over time, suggesting that initial integration choices have lasting developmental consequences.

The analysis reveals important temporal dynamics in these effects. While some country pairs (particularly those involving LMC exporters) show initial divergence in the immediate term, all pairs ultimately demonstrate convergence patterns in the total effect, indicating that long-term GVC participation consistently benefits all participating economies. However, the magnitude of these benefits varies substantially, with South-South integration offering particularly strong convergence effects for lower-income exporters.

For higher-income exporters, the choice of trading partner has minimal impact on immediate convergence outcomes, though subtle differences emerge over longer time horizons. This asymmetry in how exporter development level conditions the importance of trade directionality provides important nuance to our understanding of GVC-driven development.

Several important limitations should be acknowledged when interpreting these findings. First, the study does not account for product quality, capital accumulation dynamics, and institutional factors that may be more important determinants than simply the income levels of trading partners, as discussed in section 1.6. While these factors significantly influence development outcomes, transforming them to a bilateral level presented considerable methodological challenges.

Second, the income group distribution of countries in the dataset is unbalanced, with 28 HIC, 15 UMC, 23 LMC, and only 11 LIC. This imbalance may affect the statistical power and

generalizability of findings across different income groups, particularly for analyses involving LIC countries with the smallest representation in the sample.

This study opens several promising avenues for future research. First, examining GVC positioning, as enlightened by Hermida, Santos, and Bittencourt (2022), could provide deeper insights into why different integration patterns yield varying convergence outcomes. The current GVC participation index aggregates backward and forward participation components, obscuring potentially important distinctions in how countries integrate into value chains. Future research could disaggregate these components to determine whether backward or forward participation drives stronger convergence effects. Moreover, the participation index alone cannot reveal a country's position within GVCs. For example, analysing countries with low GVC participation but high GVC positions could reveal alternative phenomena not captured in the current framework.

Second, complementing the current focus on relative income gaps with analysis in real monetary terms could offer different perspectives, potentially reaching findings similar to those of Darku et al. (2023). This approach would help quantify the absolute economic benefits of different integration patterns rather than just their relative convergence effects.

Lastly, given the significant results for lower-income country pairs, future research should focus on sectoral-level analysis, specifically within these economies. This more granular approach could identify which manufacturing subsectors drive convergence effects in South-South integration, providing deeper insights into the specific mechanisms and industries that offer the greatest development potential for lower-income countries.

Given the findings of this study, two key policy implications emerge for developing nations:

- First, lower-income countries should recognise the value of South-South integration as a viable and potentially advantageous development strategy. Policymakers should facilitate regional trade agreements and investment frameworks that reduce barriers to intra-regional production sharing.
- Second, a balanced approach that leverages both South-South and North-South integration may be optimal. While the findings suggest stronger convergence effects from South-South integration, the absolute gains from connecting with advanced economies remain important. Diversifying integration patterns could help countries maximise both relative convergence and absolute growth.

Since the scope and goals of this research are set at a relatively high level (i.e., national income gaps) and cover mixed economy, concrete policy recommendations cannot be drawn. The findings provide general strategic direction rather than detailed implementation guidance. In the future, if more specific and evidence-based policy recommendations are to be obtained, more targeted research must be conducted. For instance, dependent variables could be set more specifically, or the scope could be narrowed down to relevant industry or firm-level indicators.

In conclusion, this study contributes to our understanding of how GVC participation shapes development trajectories by highlighting the nuanced relationship between integration patterns and income convergence. While traditional emphasis on North-South integration remains valuable, the findings suggest that South-South production relationships offer meaningful and potentially underappreciated pathways for economic development.

List of References

- Ahmad, Nadim, Timon Bohn, Nanno Mulder, Marcel Vaillant, and Dayna Zaclicever. 2017. "Indicators on Global Value Chains: A Guide for Empirical Work." *OECD Statistics Working Papers* No. 2017/08. OECD Publishing.
<https://doi.org/10.1787/8502992f-en>.
- Ando, Mitsuyo. 2006. "Fragmentation and Vertical Intra-industry Trade in East Asia." *The North American Journal of Economics and Finance* 17 (3): 257–81.
<https://doi.org/10.1016/j.najef.2006.06.005>.
- Antràs, Pol, Davin Chor, Thibault Fally, and Russell Hillberry. 2012. "Measuring the Upstreamness of Production and Trade Flows." *American Economic Review* 102 (3): 412–16. <https://doi.org/10.1257/aer.102.3.412>.
- Antras, Pol, and Davin Chor. 2013. "Organizing the Global Value Chain." *Econometrica* 81 (6): 2127–2204. <https://doi.org/10.3982/ecta10813>.
- Asian Development Bank. n.d. "Gross Domestic Product per Capita at Purchasing Power Parity". Asian Development Bank Key Indicators Database.
<https://kidb.adb.org/explore>.
- Aslam, Aqib, Natalija Novta, and Fabiano Rodrigues Bastos. 2017. "Calculating Trade in Value Added." *IMF Working Papers* 2017, no. 178: A001.
<https://doi.org/10.5089/9781484311493.001.A001>.
- Baldone, Salvatore, Fabio Sdogati, and Lucia Tajoli. 2007. "On Some Effects of International Fragmentation of Production on Comparative Advantages, Trade Flows and the Income of Countries." *World Economy* 30 (11): 1726–69.
<https://doi.org/10.1111/j.1467-9701.2007.01054.x>.
- Baldwin, Richard. 2012. *Global Supply Chains: Why They Emerged, Why They Matter, and Where They Are Going*. FGI Working Paper Series No. FGI-2012-1. Hong Kong: Fung Global Institute.
- Baldwin, Richard, and Anthony J. Venables. 2013. "Spiders and Snakes: Offshoring and Agglomeration in the Global Economy." *Journal of International Economics* 90 (2): 245–54. <https://doi.org/10.1016/j.jinteco.2013.02.005>.
- Belotti, Federico, Alessandro Borin, and Michele Mancini. 2021. "Icio: Economic Analysis With Inter-country Input–output Tables." *The Stata Journal Promoting Communications on Statistics and Stata* 21 (3): 708–55.

<https://doi.org/10.1177/1536867x211045573>.

- Borin, Alessandro, and Michele Mancini. 2019. “Measuring What Matters in Global Value Chains and Value-Added Trade.” *World Bank Policy Research Working Paper* No. 8804. <https://doi.org/10.1596/1813-9450-8804>.
- Borin, Alessandro, and Michele Mancini. 2023. “Measuring What Matters in Value-added Trade.” *Economic Systems Research* 35 (4): 586–613. <https://doi.org/10.1080/09535314.2022.2153221>.
- Cingolani, Isabella, Giulia Felice, and Lucia Tajoli. 2015. “External Imbalances in the European Union and International Fragmentation of Production: Is There a Link?” *SSRN Electronic Journal*, January. <https://doi.org/10.2139/ssrn.2608044>.
- Constantinescu, Cristina, Aaditya Mattoo, and Michele Ruta. 2019. “Does Vertical Specialisation Increase Productivity?” *World Economy* 42 (8): 2385–2402. <https://doi.org/10.1111/twec.12801>.
- Croissant, Yves, and Giovanni Millo. n.d. “Panel Data Econometrics in R: The Plm Package.” R-Project.Org. Accessed April 2, 2025. https://cran.r-project.org/web/packages/plm/vignettes/A_plmPackage.html.
- Darku, Alexander Bilson, William Baah-Boateng, Ibrahim Mohammed, and Wassiuw Abdul Rahaman. 2023. “Sorting Out the Bilateral Trade and Income Convergence Relationship: Does Income and the Nature of Bilateral Trade Matter?” *The Journal of Developing Areas* 57 (3): 247–62. <https://doi.org/10.1353/jda.2023.a907745>.
- Diakantoni, Antonia, Hubert Escaith, Michael Roberts, and Thomas Verbeet. 2017. *Accumulating Trade Costs and Competitiveness in Global Value Chains*. WTO Working Paper ERSD-2017-02. Available at SSRN: <https://ssrn.com/abstract=2906866> or <http://dx.doi.org/10.2139/ssrn.2906866>.
- Dollar, David. 2017. “Global Value Chains Shed New Light on Trade.” *Brookings*, July 10, 2017. <https://www.brookings.edu/articles/global-value-chains-shed-new-light-on-trade/>.
- Dollar, David, and Sandra Polaski. 2020. “How Have Trump’s Trade Wars Affected Rust Belt Jobs?” *Brookings*, October 19, 2020. <https://www.brookings.edu/articles/how-have-trumps-trade-wars-affected-rust-belt-jobs/>.
- Dorrucci, Ettore, Vanessa Gunnella, Alexander Al-Haschimi, Konstantins Benkovskis, Francesco Chiacchio, Francois De Soyres, Benedetta Di Lupidio, et al. 2019. “The Impact of Global Value Chains on the Euro Area Economy.” *ECB Occasional Paper*

- No. 221. <https://doi.org/10.2139/ssrn.3381697>.
- Driscoll, John C., and Aart C. Kraay. 1998. "Consistent Covariance Matrix Estimation With Spatially Dependent Panel Data." *The Review of Economics and Statistics* 80 (4): 549–60. <https://doi.org/10.1162/003465398557825>.
- Feás, Enrique. 2023a. "Decomposition of Value Added in Gross Exports: A Critical Review." *Applied Economic Analysis* 31 (93): 182–98. <https://doi.org/10.1108/AEA-11-2022-0300>.
- Feás, Enrique. 2023b. "Exvatoools: Value Added in Exports and Other Input-Output Table Analysis Tools." *The R Journal* 15 (4): 216–35. <https://doi.org/10.32614/rj-2023-092>.
- Feenstra, Robert C. 1998. "Integration of Trade and Disintegration of Production in the Global Economy." *The Journal of Economic Perspectives* 12 (4): 31–50. <http://www.jstor.org/stable/2646893>.
- Foster, Neil, Robert Stehrer, and Marcel Timmer. 2013. "International Fragmentation of Production, Trade and Growth: Impacts and Prospects for EU Member States." *Wiiw Research Reports*, no. 484 (January): 1–55. https://ec.europa.eu/economy_finance/publications/economic_paper/2013/pdf/ecp484_summary_en.pdf.
- Gereffi, Gary, John Humphrey, and Timothy Sturgeon. 2005. "The Governance of Global Value Chains." *Review of International Political Economy* 12 (1): 78–104. <https://doi.org/10.1080/09692290500049805>.
- Gereffi, Gary, and Joonkoo Lee. 2012. "Why The World Suddenly Cares About Global Supply Chains." *Journal of Supply Chain Management* 48 (3): 24–32. <https://doi.org/10.1111/j.1745-493x.2012.03271.x>.
- Grossman, Gene M, and Esteban Rossi-Hansberg. 2008. "Trading Tasks: A Simple Theory of Offshoring." *American Economic Review* 98 (5): 1978–97. <https://doi.org/10.1257/aer.98.5.1978>.
- Helpman, Elhanan. 1981. "International Trade in the Presence of Product Differentiation, Economies of Scale and Monopolistic Competition." *Journal of International Economics* 11 (3): 305–40. [https://doi.org/10.1016/0022-1996\(81\)90001-5](https://doi.org/10.1016/0022-1996(81)90001-5).
- Helpman, Elhanan. 1984. "A Simple Theory of International Trade With Multinational Corporations." *Journal of Political Economy* 92 (3): 451–71. <https://doi.org/10.1086/261236>.

- Helpman, E. 2011. "The Role of Comparative Advantage." *In Understanding Global Trade*, 2. Harvard University Press. <https://doi.org/10.4159/harvard.9780674061019>.
- Hermida, Camila Do Carmo, Anderson Moreira Aristides Dos Santos, and Mauricio Vaz Lobo Bittencourt. 2022. "Does International Fragmentation of Production and Global Value Chains Participation Affect the Long-run Economic Growth?" *Foreign Trade Review* 57 (4): 367–89. <https://doi.org/10.1177/00157325211050448>.
- Honaker, James, Gary King, and Matthew Blackwell. 2011. "Amelia II: A Program for Missing Data." *Journal of Statistical Software* 45 (7): 1–47. <https://doi.org/10.18637/jss.v045.i07>.
- Hummels, David, Jun Ishii, and Kei-Mu Yi. 2001. "The Nature and Growth of Vertical Specialization in World Trade." *Journal of International Economics* 54 (1): 75–96. [https://doi.org/10.1016/s0022-1996\(00\)00093-3](https://doi.org/10.1016/s0022-1996(00)00093-3).
- Humphrey, John, and Hubert Schmitz. 2002. "How Does Insertion in Global Value Chains Affect Upgrading in Industrial Clusters?" *Regional Studies* 36 (9): 1017–27. <https://doi.org/10.1080/0034340022000022198>.
- Im, Kyung So, M.Hashem Pesaran, and Yongcheol Shin. 2003. "Testing for Unit Roots in Heterogeneous Panels." *Journal of Econometrics* 115 (1): 53–74. [https://doi.org/10.1016/s0304-4076\(03\)00092-7](https://doi.org/10.1016/s0304-4076(03)00092-7).
- Jahangard, Esfandiar. 2024. "Participation and Vertical Specialisation in Iran's Economic Activities." *International Journal of New Political Economy* 5(2): 59–86. <https://doi.org/10.48308/jep.5.2.59>.
- Johnson, Robert C., and Guillermo Noguera. 2012. "Accounting for Intermediates: Production Sharing and Trade in Value Added." *Journal of International Economics* 86 (2): 224–36. <https://doi.org/10.1016/j.jinteco.2011.10.003>.
- Johnson, Robert C. 2014. "Trade in Intermediate Inputs and Business Cycle Comovement." *American Economic Journal: Macroeconomics* 6, no. 4 (2014): 39–83. <http://www.jstor.org/stable/43189939>.
- Jones, R.W., and Henryk Kierzkowski. 1990. "The Role of Services in Production and International Trade: A Theoretical Framework." *In The Political Economy of International Trade*.
- Kaplinsky, Raphael, and Mike Morris. 2000. *A Handbook for Value Chain Research*. Vol. 113. Brighton: University of Sussex, Institute of Development Studies.
- Koopman, Robert, William Powers, Zhi Wang, and Shang-Jin Wei. 2010. "Give Credit

- Where Credit Is Due: Tracing Value Added in Global Production Chains.” *NBER Working Papers Series*, No. 16426. www.nber.org/papers/w16426.
- Koopman, Robert, Zhi Wang, and Shang-Jin Wei. 2014. “Tracing Value-Added and Double Counting in Gross Exports.” *American Economic Review* 104 (2): 459–94. <https://doi.org/10.1257/aer.104.2.459>.
- Krugman, Paul R. 1979. “Increasing Returns, Monopolistic Competition, and International Trade.” *Journal of International Economics* 9 (4): 469–79. [https://doi.org/10.1016/0022-1996\(79\)90017-5](https://doi.org/10.1016/0022-1996(79)90017-5).
- Krugman, Paul R. 1980. “Scale Economies, Product Differentiation, and the Pattern of Trade.” *The American Economic Review* 70 (5): 950–59. <https://www.aeaweb.org/aer/top20/70.5.950-959.pdf>.
- Kummritz, Victor. 2016. *Do Global Value Chains Cause Industrial Development?* CTEI Working Paper 2016-01. Geneva: The Graduate Institute of International and Development Studies, Centre for Trade and Economic Integration.
- Leamer, Edward. 1995. The Heckscher–Ohlin Model in Theory and Practice. Graham Lecture, *Princeton Studies in International Finance* 77.
- Meng, Bo, Ming Ye, and Shang - Jin Wei. 2020. “Measuring Smile Curves in Global Value Chains.” *Oxford Bulletin of Economics and Statistics* 82 (5): 988 – 1016. <https://doi.org/10.1111/obes.12364>.
- Miller, Ronald E., and Peter D. Blair. 2009. *Input-Output Analysis: Foundations and Extensions*. 2nd ed. Cambridge University Press. <https://doi.org/10.1017/CBO9780511626982>.
- Millo, Giovanni. n.d. “R: Driscoll and Kraay (1998) Robust Covariance Matrix Estimator.” R-Project.Org. Accessed April 2, 2025. <https://search.r-project.org/CRAN/refmans/plm/html/vcovSCC.html>.
- Minondo, A. 2024. “El desempeño exportador de España: claves de un éxito” (No. eee2024-32). *FEDEA*. <https://documentos.fedea.net/pubs/eee/2024/eee2024-32.pdf>
- Miroudot, S., R. Lanz, and A. Ragoussis. 2009. “Trade in Intermediate Goods and Services.” *OECD Trade Policy Papers* No. 93. OECD Publishing, Paris. <https://doi.org/10.1787/5kmlcxtldlk8r-en>.
- Nagengast, Arne J., and Robert Stehrer. 2014. “Collateral Imbalances in Intra-European Trade? Accounting for the Difference Between Gross and Value Added Trade Balances.” *ECB Working Paper* No. 1695.

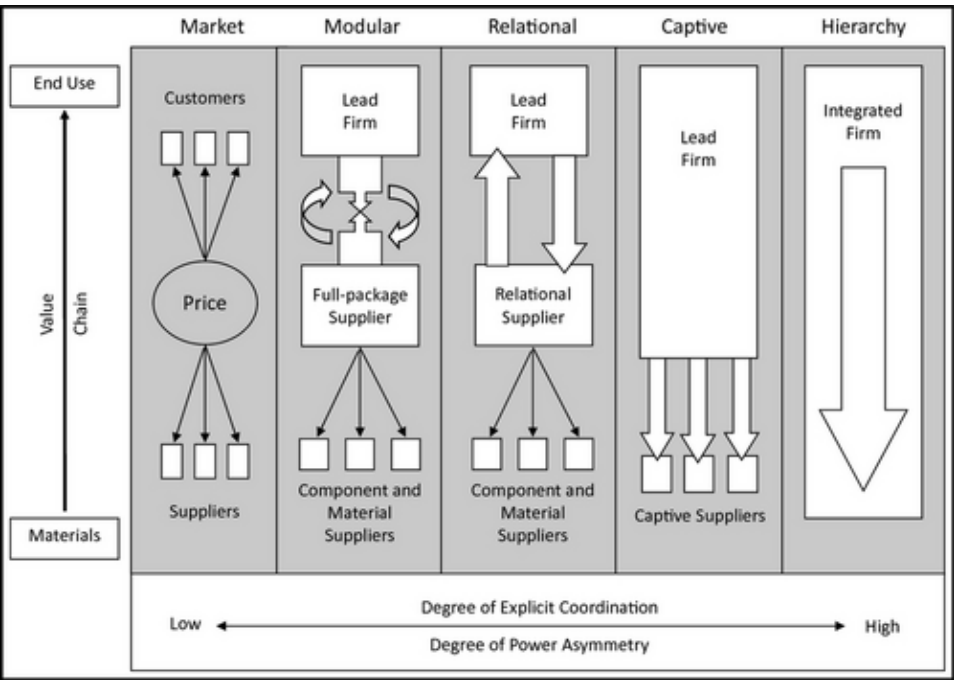
- Newman, Carol, John Rand, Theodore Talbot, and Finn Tarp. 2015. "Technology Transfers, Foreign Investment and Productivity Spillovers." *European Economic Review* 76 (March): 168–87. <https://doi.org/10.1016/j.euroecorev.2015.02.005>.
- Obstfeld, Maurice. 2024. "Economic Multilateralism 80 Years After Bretton Woods." *Oxford Review of Economic Policy* 40 (2): 307–28. <https://doi.org/10.1093/oxrep/grae009>.
- OECD. 2023. "Inter-Country Input-Output Tables." Data set. OECD. <https://www.oecd.org/en/data/datasets/inter-country-input-output-tables.html>.
- OECD, Directorate for Science, Technology and Innovation. 2023. "Guide to OECD Trade in Value Added (TiVA) Indicators, 2023 Edition." *OECD*. <https://stats.oecd.org/wbos/fileview2.aspx?IDFile=afa5c684-c31d-49dd-87db-6fd674f29a43>.
- Pahl, Stefan, and Marcel P. Timmer. 2019. "Do Global Value Chains Enhance Economic Upgrading? A Long View." *The Journal of Development Studies* 56 (9): 1683–1705. <https://doi.org/10.1080/00220388.2019.1702159>.
- Pesaran, M. Hashem, Yongcheol Shin, and Richard J. Smith. 2001. "Bounds Testing Approaches to the Analysis of Level Relationships." *Journal of Applied Econometrics* 16 (3): 289–326. <https://doi.org/10.1002/jae.616>.
- Pesaran, M. Hashem. 2004. "General Diagnostic Tests for Cross Section Dependence in Panels." *SSRN Electronic Journal*, January. <https://doi.org/10.2139/ssrn.572504>.
- Pesaran, M. Hashem. 2006. "Estimation and Inference in Large Heterogeneous Panels With a Multifactor Error Structure." *Econometrica* 74 (4): 967–1012. <https://doi.org/10.1111/j.1468-0262.2006.00692.x>.
- Pietrobelli, Carlo, and Roberta Rabellotti. 2011. "Global Value Chains Meet Innovation Systems: Are There Learning Opportunities for Developing Countries?" *World Development* 39 (7): 1261–69. <https://doi.org/10.1016/j.worlddev.2010.05.013>.
- Rodrik, Dani. 2013. "Unconditional Convergence in Manufacturing." *The Quarterly Journal of Economics* 128: 165–204.
- Rodrik, Dani. 2018. *New Technologies, Global Value Chains, and Developing Economies*. NBER Working Paper No. 25164. Cambridge, MA: National Bureau of Economic Research. <https://doi.org/10.3386/w25164>.
- Rungi, Armando, and Davide Del Prete. 2018. "The Smile Curve at the Firm Level: Where Value Is Added Along Supply Chains." *Economics Letters* 164 (January): 38–42.

- <https://doi.org/10.1016/j.econlet.2017.12.038>.
- Sherman, Natalie. 2025. "Trump Rips up Rulebook on Trade and Businesses Are Left Reeling." *BBC*, April 9, 2025. <https://www.bbc.com/news/articles/c87p12wpgjpo>.
- Sposi, Michael, Kei-Mu Yi, and Jing Zhang. 2021. "Trade Integration, Global Value Chains, and Capital Accumulation." *IMF Economic Review* 69 (3): 505–39. <https://doi.org/10.1057/s41308-021-00141-9>.
- Subacchi, Paola, and David Vines. 2023. "Fifty Years on: What the Bretton Woods System Can Teach Us About Global Macroeconomic Policy-making." *Oxford Review of Economic Policy* 39 (2): 164–82. <https://doi.org/10.1093/oxrep/grad016>.
- Szymczak, Sabina. 2018. "Production Fragmentation and Employment. Country-industry Level Analysis Based on WIOD 2016." *Roczniki Kolegium Analiz Ekonomicznych*, no. 53 (January): 131–46. <https://econpapers.repec.org/RePEc:sgl:annals:i:53:y:2018:p:131-146>.
- Timmer, Marcel P., Abdul Azeez Erumban, Bart Los, Robert Stehrer, and Gaaitzen J. De Vries. 2014. "Slicing up Global Value Chains." *The Journal of Economic Perspectives* 28 (2): 99–118. <https://doi.org/10.1257/jep.28.2.99>.
- Venables, Anthony J. 1999. "Fragmentation and Multinational Production." *European Economic Review* 43 (4–6): 935–45. [https://doi.org/10.1016/s0014-2921\(98\)00106-8](https://doi.org/10.1016/s0014-2921(98)00106-8).
- Wooldridge, Jeffrey M. 2015. "Control Function Methods in Applied Econometrics." *The Journal of Human Resources* 50 (2): 420–45. <https://doi.org/10.3368/jhr.50.2.420>.
- Wooldridge, Jeffrey M. 2021. "Two-Way Fixed Effects, the Two-Way Mundlak Regression, and Difference-in-Differences Estimators." *SSRN Electronic Journal*, January. <https://doi.org/10.2139/ssrn.3906345>.
- World Bank Group. n.d.-a. *GDP per Capita, PPP (Current International \$)*. Accessed April 26, 2025. <https://data.worldbank.org/indicator/NY.GDP.PCAP.PP.CD>.
- World Bank Group. n.d.-b. "World Bank Country and Lending Groups." <https://datahelpdesk.worldbank.org/knowledgebase/articles/906519-world-bank-country-and-lending-groups>.
- World Integrated Trade Solution (WITS). n.d.-a. "Gross Trade Breakdown." Accessed April 26, 2025. <https://wits.worldbank.org/gvc/gvc-gross-trade-disaggregated.html>.
- World Integrated Trade Solution (WITS). n.d.-b. "GVC Trade by Sector." Accessed April 26, 2025. <https://wits.worldbank.org/gvc/gvc-trade-sector.html>.
- World Trade Organization. n.d. "WTO | Legal Texts - the General Agreement on Tariffs

and Trade (GATT 1947).” Wto.Org. Accessed April 21, 2025.
https://www.wto.org/english/docs_e/legal_e/gatt47_e.htm.

List of Appendices

Appendix no. 1: GVC Governance Structure (Source: Gereffi, Humphrey, and Sturgeon 2005) (graph)



Appendix no. 2: ICIO Table – Countries Coverage (Source: OECD, Directorate for Science, Technology and Innovation 2023) (table)

N.	Code	Country
1	AUS	Australia
2	AUT	Austria
3	BEL	Belgium
4	CAN	Canada
5	CHL	Chile
6	COL	Colombia
7	CRI	Costa Rica
8	CZE	Czechia
9	DNK	Denmark
10	EST	Estonia
11	FIN	Finland
12	FRA	France
13	DEU	Germany
14	GRC	Greece
15	HUN	Hungary
16	ISL	Iceland
17	IRL	Ireland
18	ISR	Israel
19	ITA	Italy
20	JPN	Japan
21	KOR	Korea
22	LVA	Latvia
23	LTU	Lithuania
24	LUX	Luxembourg
25	MEX	Mexico
26	NLD	Netherlands
27	NZL	New Zealand
28	NOR	Norway
29	POL	Poland
30	PRT	Portugal
31	SVK	Slovakia
32	SVN	Slovenia
33	ESP	Spain
34	SWE	Sweden
35	CHE	Switzerland
36	TUR	Türkiye
37	GBR	United Kingdom
38	USA	United States

39	ARG	Argentina
40	BGD	Bangladesh
41	BLR	Belarus
42	BRA	Brazil
43	BRN	Brunei Darussalam
44	BGR	Bulgaria
45	KHM	Cambodia
46	CMR	Cameroon
47	CHN	China (People's Republic of)
48	CIV	Côte d'Ivoire
49	HRV	Croatia
50	CYP	Cyprus
51	EGY	Egypt
52	HKG	Hong Kong, China
53	IND	India
54	IDN	Indonesia
55	JOR	Jordan
56	KAZ	Kazakhstan
57	LAO	Lao (People's Democratic Rep.)
58	MYS	Malaysia
59	MLT	Malta
60	MAR	Morocco
61	MMR	Myanmar
62	NGA	Nigeria
63	PAK	Pakistan
64	PER	Peru
65	PHL	Philippines
66	ROU	Romania
67	RUS	Russian Federation
68	SAU	Saudi Arabia
69	SEN	Senegal
70	SGP	Singapore
71	ZAF	South Africa
72	TWN	Chinese Taipei
73	THA	Thailand
74	TUN	Tunisia
75	UKR	Ukraine
76	VNM	Viet Nam

Appendix no. 3: ICIO Table – Manufacturing Sector Group Hierarchy (Source: OECD, Directorate for Science, Technology and Innovation 2023) (table)

Hierarchy Level	Parent	Code	Industry description	3-character code ¹
0		T	TOTAL	TOT
1	T	C	Total Manufacturing	MAN
2	C	C10T12	Food products, beverages and tobacco	FOD
2	C	C13T15	Textiles, textile products, leather and footwear	TEX
2	C	C16T18	Wood and paper products and printing	WPP
3	C16T18	C16	Wood and products of wood and cork	WOD
3	C16T18	C17_18	Paper products and printing	PAP
2	C	C19T23	Chemicals and non-metallic mineral products	CNM
3	C19T23	C19	Coke and refined petroleum products	PET
3	C19T23	C20_21	Chemicals and pharmaceutical products	CPP
4	C20_21	C20	Chemical and chemical products	CHM
4	C20_21	C21	Pharmaceuticals, medicinal chemical and botanical products	PHM
3	C19T23	C22	Rubber and plastics products	RBP
3	C19T23	C23	Other non-metallic mineral products	NMM
2	C	C24_25	Basic metals and fabricated metal products	BMF
3	C24_25	C24	Basic metals	MET
3	C24_25	C25	Fabricated metal products	FBM
2	C	C26_27	Computer, electronic and electrical equipment	EEQ
3	C26_27	C26	Computer, electronic and optical equipment	CEQ
3	C26_27	C27	Electrical equipment	ELQ
2	C	C28	Machinery and equipment, nec	MEQ
2	C	C29_30	Transport equipment	TEQ
3	C29_30	C29	Motor vehicles, trailers and semi-trailers	MTR
3	C29_30	C30	Other transport equipment	TRQ
2	C	C31T33	Manufacturing nec; repair and installation of machinery and equipment	OTM