



PRODUCTIVE INTEGRATION AND THE RETENTION OF ECONOMIC GAINS: EVIDENCE FROM BRAZIL–EUROPEAN UNION PRODUCTION NETWORKS

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Abstract: This study examines productive integration between Brazil and the European Union, focusing on the retention of economic gains generated through international production networks. Although participation in global value chains can expand production and trade, the associated economic benefits are not necessarily distributed evenly among participating countries. In this context, the study aims to identify the sectors responsible for transmitting economic effects between Brazil and the European Union and to assess the domestic retention of production, income, and fiscal gains. The analysis is based on the construction of an interregional input–output matrix derived from the OECD Inter-Country Input–Output (ICIO) database for 2022, in which European Union member states are aggregated into a single economic region. Production, value-added, and tax multipliers were estimated and decomposed into domestic and interregional components to measure cross-border spillover effects. The results reveal a heterogeneous pattern of productive integration across sectors. Industries related to transport equipment, shipbuilding, air transport, and motor vehicles exhibit the strongest spillover effects toward the European Union, reflecting their deep integration into international production networks. In contrast, service-oriented activities such as education, real estate, and financial services display high levels of domestic retention of economic gains. The findings suggest that participation in international production networks does not necessarily imply proportional retention of income and fiscal benefits, highlighting the importance of distinguishing between production expansion and domestic capture of economic gains when evaluating the effects of international economic integration.

Keywords: Productive integration; global value chains; interregional input–output analysis; European Union; economic spillovers.

INTEGRAÇÃO PRODUTIVA E RETENÇÃO DOS GANHOS ECONÔMICOS: EVIDÊNCIAS DAS REDES DE PRODUÇÃO ENTRE O BRASIL E A UNIÃO EUROPEIA

Resumo: Este estudo analisa a integração produtiva entre o Brasil e a União Europeia, com ênfase na retenção dos ganhos econômicos gerados pelas redes internacionais de produção. Embora a participação em cadeias globais de valor possa ampliar a produção e o comércio, os benefícios econômicos associados a essa integração não são necessariamente distribuídos de forma homogênea entre os países participantes. Nesse contexto, o objetivo do trabalho é identificar os setores responsáveis pela transmissão de efeitos econômicos entre Brasil e União Europeia e avaliar a capacidade de retenção doméstica da produção, da renda e da arrecadação tributária. A metodologia baseia-se na construção de uma matriz inter-regional de insumo-produto derivada da base OECD Inter-Country Input–Output (ICIO) para o ano de 2022, agregando os países da União Europeia em um único bloco econômico. Foram estimados multiplicadores de produção, valor adicionado e tributos, bem como seus respectivos efeitos de transbordamento inter-regional. Os resultados revelam que a integração produtiva é heterogênea entre os setores. Indústrias relacionadas a equipamentos de transporte, construção naval, transporte aéreo e fabricação de veículos apresentam os maiores efeitos de transbordamento em direção à União Europeia, refletindo sua forte inserção em cadeias produtivas internacionais. Em contraste, atividades de serviços, como educação, atividades imobiliárias e serviços financeiros, apresentam elevada retenção doméstica dos ganhos econômicos. Conclui-se que a participação em redes internacionais de produção não implica necessariamente maior retenção de renda e benefícios fiscais, evidenciando a importância de distinguir expansão produtiva e captura doméstica dos ganhos econômicos na avaliação dos efeitos da integração internacional.

Palavras-chave: Integração produtiva; cadeias globais de valor; matriz insumo-produto inter-regional; União Europeia; spillovers econômicos.

1 Introduction

The increasing fragmentation of production across national borders has transformed the

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nature of international economic integration. Rather than consisting primarily of exchanges of final goods, contemporary trade is increasingly organized through global value chains (GVCs), in which production stages are distributed across multiple countries according to their relative advantages in technology, skills, logistics, and institutional capabilities (Baldwin, 2016). As a result, the economic benefits associated with international trade are no longer determined solely by export performance but also by the position that countries occupy within international production networks and their ability to retain value generated along these chains (Johnson & Noguera, 2012; Koopman, Wang & Wei, 2014).

This issue is particularly relevant for emerging economies and for the broader debate on regional and national development. Although participation in global value chains may stimulate production, employment, and exports, the distribution of economic gains across countries is often uneven. Sectors that exhibit strong productive integration do not necessarily retain a proportional share of the income generated throughout the production process (Gereffi, Humphrey & Sturgeon, 2005; Gonçalves Junior et al., 2024). Consequently, increases in output may coexist with substantial leakages of value added to foreign economies, limiting the capacity of domestic production systems to translate economic expansion into income generation and fiscal resources that support long-term development (Kegel & Amal, 2015).

The economic relationship between Brazil and the European Union (EU) provides a particularly relevant setting for examining these issues. The EU remains one of Brazil's most important economic partners in terms of trade, investment, and technological cooperation (Suárez-Cuesta & Latorre, 2021). Historically, bilateral trade has been characterized by Brazilian exports of agricultural and resource-based products and European exports of manufactured and technology-intensive goods. However, the expansion of global value chains has increased the complexity of these interactions, creating production linkages that extend well beyond direct trade flows and connecting sectors through increasingly integrated production networks (Dulcich, 2023).

The ongoing discussions surrounding the Mercosur–European Union Trade Agreement have further intensified interest in the consequences of deeper economic integration between the two regions. Existing studies generally emphasize potential gains in trade, productivity, competitiveness, and economic growth (Suárez-Cuesta & Latorre, 2021; Ribeiro et al., 2024). At the same time, concerns persist regarding asymmetric productive relationships, technological dependence, and the extent to which the economic gains generated by international integration are effectively retained within domestic economies. These concerns are particularly relevant from a development perspective, as the capacity to retain income and fiscal revenues influences investment, productive upgrading, and long-term development opportunities (Ribeiro et al., 2024).



Most analyses of Brazil–European Union integration have relied on Computable General Equilibrium (CGE) models, which are particularly useful for evaluating welfare effects, trade expansion, and macroeconomic outcomes associated with trade liberalization (Suárez-Cuesta & Latorre, 2021; Ribeiro et al., 2024). However, these approaches provide limited information regarding the sectoral transmission mechanisms through which economic impacts propagate across production systems. Input–output analysis offers a complementary perspective by explicitly capturing the productive interdependencies linking sectors and regions. Through multiplier analysis, it becomes possible to identify not only how production responds to changes in final demand but also how value added and fiscal revenues are distributed throughout international production networks (Miller & Blair, 2009; Yamano & Webb, 2018).

Despite the strategic importance of Brazil–EU economic relations, relatively little evidence is available regarding the sectoral channels through which productive integration generates cross-border spillovers of production, income generation, and fiscal revenues. In particular, limited attention has been devoted to the distinction between production expansion and the retention of economic gains within domestic economies. Understanding this distinction is essential not only for assessing economic integration itself but also for evaluating its implications for development, since sectors differ substantially in their capacity to internalize the benefits associated with productive expansion. Moreover, while previous input–output studies on Brazil have primarily focused on participation in global value chains or on domestic intersectoral linkages, comparatively less attention has been devoted to simultaneously examining production, value-added, and tax spillovers within the context of Brazil–European Union productive integration. This integrated perspective allows a broader assessment of how economic gains generated by international production networks are distributed and retained across sectors.

Against this background, this study analyzes productive integration between Brazil and the European Union using an interregional input–output framework derived from the OECD Inter-Country Input–Output (ICIO) database. The study estimates production, value-added, and tax multipliers and decomposes these effects into domestic and interregional components. By identifying the sectors through which economic effects are transmitted and by comparing production expansion with income and fiscal retention, the analysis contributes to a deeper understanding of the structural dimensions of Brazil–EU integration and provides evidence on how participation in international production networks affects the distribution and retention of economic gains relevant to development processes.

2 Literature Review

2.1 Brazil–European Union Economic Integration and Global Value Chains



Economic integration has become one of the defining features of the contemporary global economy. Advances in transportation, information technologies, and trade liberalization have facilitated the fragmentation of production processes across national borders, giving rise to increasingly complex global value chains (GVCs). In this environment, international trade is no longer limited to exchanges of final goods but increasingly involves flows of intermediate inputs, services, technology, and knowledge that connect production stages located in different countries (Baldwin, 2016).

The expansion of global value chains has altered the way countries participate in the international economy. Rather than competing solely through exports, economies increasingly specialize in specific stages of production networks, contributing different combinations of labor, capital, technology, and services. As a result, economic performance depends not only on participation in international trade but also on the position occupied within global value chains and on the capacity to retain value generated throughout production processes (Johnson & Noguera, 2012; Koopman, Wang & Wei, 2014).

The relationship between Brazil and the European Union (EU) represents one of the most important economic linkages between South America and a major advanced economic bloc. The EU has historically been among Brazil's principal trading partners and foreign investors, accounting for a substantial share of bilateral trade and investment flows (Lehmann, 2024). Traditionally, Brazilian exports to the EU have been concentrated in agricultural commodities, mineral products, and resource-based manufactures, while European exports to Brazil have been dominated by machinery, transport equipment, chemicals, and other technology-intensive products (Ribeiro et al., 2024; Maihold, 2026).

Over recent decades, however, economic relations between Brazil and the European Union have become increasingly embedded within international production networks (Tayar, 2024). As production processes have become more fragmented across countries, bilateral economic interactions have expanded beyond direct trade flows to include intermediate goods, business services, technological cooperation, and foreign direct investment. Consequently, the economic effects associated with trade between the two regions increasingly depend on productive linkages distributed throughout global value chains rather than on commercial exchanges alone (Dulcich, 2023; Jung, 2025).

The literature on global value chains emphasizes that participation in international production networks does not necessarily imply proportional capture of economic gains. Countries may become deeply integrated into global production systems while retaining only a limited share of the value generated throughout the chain. Higher-value activities such as research and development, engineering, design, branding, and advanced business services frequently remain



concentrated in technologically advanced economies, whereas developing countries often specialize in activities associated with lower value-added generation (Gereffi, Humphrey & Sturgeon, 2005; Timmer et al., 2014).

This distinction between participation and value capture is particularly relevant in the Brazilian case. Although the country has expanded its integration into international production networks, several studies suggest that its participation remains concentrated in activities characterized by lower technological intensity and more limited domestic value retention (Gonçalves Junior et al., 2024; Dulcich, 2023). Consequently, increases in production and exports do not necessarily translate into proportional gains in domestic income generation, fiscal revenues, or long-term development opportunities (Tayar, 2024).

From a regional and national development perspective, the capacity to retain economic gains is particularly important. The benefits generated by productive integration are not restricted to increases in output but also involve the generation of income, tax revenues, investment opportunities, and productive upgrading. Therefore, understanding how economic gains are distributed throughout international production networks is essential for assessing whether deeper integration contributes to strengthening domestic productive structures or reinforces existing patterns of international specialization (Füzesi, 2020; Werner, Bair & Fernández, 2014).

The proposed Mercosur–European Union Trade Agreement has intensified these debates. Supporters of the agreement emphasize potential gains associated with greater market access, productivity growth, technology diffusion, and stronger participation in global value chains. At the same time, concerns remain regarding asymmetries in productive structures, competitive pressures on domestic industries, and the possibility that a substantial share of economic gains generated by increased trade may be captured outside the domestic economy (Suárez-Cuesta & Latorre, 2021; Ribeiro et al., 2024).

These discussions suggest that assessing economic integration requires looking beyond conventional trade statistics. While trade flows provide valuable information regarding the intensity of economic exchanges, they offer limited insights into how production, income generation, and fiscal effects are distributed throughout international production networks. A more comprehensive understanding of Brazil–European Union integration therefore requires analytical approaches capable of capturing the productive interdependencies embedded in global value chains and identifying the extent to which economic gains are retained domestically or transmitted across borders.

2.2 Productive Integration, Value Capture, and Economic Spillovers

The expansion of global value chains has transformed the way economists analyze



international trade and economic integration. Traditional trade statistics record the gross value of exports and imports but provide limited information regarding how economic gains are distributed across countries participating in international production networks. As production processes become increasingly fragmented across borders, understanding who produces, who captures value, and where income is ultimately generated has become as important as measuring trade flows themselves (Johnson & Noguera, 2012).

The literature on global value chains emphasizes that participation in international production networks and the capture of economic benefits are not necessarily equivalent phenomena. Countries may increase their involvement in cross-border production processes while retaining only a limited share of the value generated throughout the chain. This distinction has stimulated a growing body of research focused on domestic value added, value capture, and the distribution of gains arising from international trade (Koopman, Wang & Wei, 2014; Timmer et al., 2014).

According to Gereffi, Humphrey, and Sturgeon (2005), the governance structure of global value chains plays a crucial role in determining how economic benefits are distributed among participating economies. Activities associated with research and development, engineering, design, branding, and advanced business services generally capture a larger share of total value creation and tend to remain concentrated in technologically advanced economies. By contrast, activities centered on assembly, processing, and the supply of standardized intermediate goods often generate lower levels of value added and retain a smaller share of the gains associated with production.

This distinction is particularly relevant for emerging economies. Although participation in global value chains may stimulate production growth, employment, and export expansion, the associated gains in domestic income generation may be considerably smaller if a substantial share of value creation remains embedded in foreign production networks. Consequently, increases in output do not necessarily imply proportional increases in domestic value added, fiscal revenues, or productive upgrading. From a development perspective, this distinction is critical because long-term economic progress depends not only on production growth but also on the capacity of economies to retain and reinvest the benefits generated by economic activity (Koopman, Wang & Wei, 2014; Rodrik, 2011).

The concept of economic spillovers provides an important framework for analyzing these processes. Spillovers occur when changes in economic activity in one sector, region, or country generate direct and indirect effects in other parts of the production system. In an international context, demand originating in one economy may stimulate production, income generation, and fiscal revenues in another through cross-border supply chains. The magnitude of these spillovers



reflects the degree of productive integration among economies and their relative positions within global value chains (Dietzenbacher et al., 2012; Koopman, Wang & Wei, 2014).

Previous studies have shown that sectors characterized by higher technological intensity and more complex supply-chain structures tend to exhibit stronger international spillover effects. Industries such as transport equipment, machinery, electronics, and chemical products frequently rely on specialized inputs sourced from multiple countries, creating extensive cross-border transmission mechanisms (Timmer et al., 2014). By contrast, primary activities and locally oriented service sectors generally display lower levels of international integration and therefore retain a larger share of production, income, and fiscal effects within domestic economies (Koopman, Wang & Wei, 2014).

From this perspective, evaluating productive integration requires considering not only production expansion but also the distribution of the associated economic gains. A sector may generate substantial output growth while simultaneously transferring part of the resulting income and value creation to foreign economies. Likewise, fiscal effects associated with productive expansion may differ from production and value-added effects depending on the structure of taxation, the composition of supply chains, and the location where economic activities are performed. As a result, production generation, income retention, and fiscal retention represent distinct dimensions of economic integration that should be examined simultaneously (Johnson & Noguera, 2012; Dietzenbacher et al., 2012).

These considerations are particularly relevant in the context of Brazil–European Union economic relations. As productive integration deepens through trade, investment, and participation in global value chains, understanding the distinction between production generation and the retention of economic gains becomes essential for assessing the broader implications of economic integration. This issue is especially important in sectors characterized by strong cross-border linkages, where increases in production may coexist with significant leakages of income and value creation toward foreign economies.

2.3 Input–Output Analysis and International Production Networks

Input–output analysis has long been recognized as one of the principal frameworks for investigating economic interdependence among sectors, regions, and countries. Originally developed by Leontief (1951), the approach provides a systematic representation of the flows of goods and services within an economy, enabling the identification of both direct and indirect effects generated by changes in final demand. By explicitly capturing intersectoral linkages, input–output models offer a detailed perspective on the structural relationships underlying economic activity (Miller & Blair, 2009).



One of the main strengths of the input–output framework is its ability to trace how economic shocks propagate throughout production systems. Through the Leontief inverse matrix, it becomes possible to estimate the total production requirements associated with a given increase in final demand, including not only the immediate effects on the sector receiving the stimulus but also the indirect effects transmitted through upstream and downstream supply chains. Production multipliers derived from the Leontief inverse therefore provide a measure of the overall economic interconnectedness of sectors and production systems (Yamano & Guilhoto, 2020).

As globalization intensified and production processes became increasingly fragmented across borders, traditional national input–output models evolved into interregional and multi-regional input–output (MRIO) frameworks. These extensions explicitly incorporate transactions among countries and regions, making them particularly suitable for analyzing international production networks and global value chains. Within MRIO systems, final demand originating in one economy may generate production, income, and fiscal effects across multiple countries connected through intermediate input flows (Dietzenbacher et al., 2012).

The development of international databases such as the OECD Inter-Country Input–Output (ICIO) system, the World Input–Output Database (WIOD), and EXIOBASE has significantly expanded the possibilities for empirical research on global production networks. These databases allow researchers to trace productive linkages across countries, estimate domestic and foreign value-added contents of trade, and identify the channels through which economic effects are transmitted internationally (Timmer et al., 2015). In particular, the OECD ICIO database has become one of the principal tools for examining cross-border production structures and the economic interdependencies associated with global value chains (Yamano et al., 2023).

Recent applications of inter-country input–output systems have demonstrated their usefulness in measuring international spillovers and productive integration. Amar and García Díaz (2018), for example, employed inter-country input–output tables to examine vertical specialization and cross-border multiplier effects, showing how changes in production and exports propagate through fragmented production systems. Similarly, Espigares (2016) demonstrated the use of Leontief-based decompositions to distinguish domestic and international production effects, highlighting the capacity of MRIO models to identify the geographical distribution of economic impacts. More recently, Yamano et al. (2024) illustrated how technical coefficients and the Leontief inverse can be used to trace both direct and indirect effects across countries and sectors, reinforcing the suitability of the ICIO framework for analyzing complex international production networks.

Within the context of global value chains, input–output analysis offers a particularly valuable perspective because it allows researchers to move beyond gross trade statistics. While



conventional trade data indicate the magnitude of commercial exchanges, input–output frameworks make it possible to identify where production occurs, where value is generated, and how economic gains are distributed among participating economies. As a result, MRIO models have been increasingly employed to investigate value capture, international spillovers, and the distribution of benefits associated with economic integration (Johnson & Noguera, 2012; Koopman, Wang & Wei, 2014).

In addition to production effects, input–output models permit the estimation of value-added and fiscal multipliers. Production multipliers measure the total output generated throughout the economic system, whereas value-added multipliers provide information regarding the income effectively retained within productive structures. Fiscal multipliers capture the tax revenues associated with productive expansion and therefore add an additional dimension to the analysis of economic integration. Examining these indicators simultaneously allows a more comprehensive assessment of how economic gains are generated, transmitted, and retained across sectors and regions (Miller & Blair, 2009).

Previous studies employing interregional and multi-regional input–output models generally find that technologically intensive manufacturing industries and transport-related activities exhibit stronger international spillover effects than primary sectors and domestically oriented services, reflecting their deeper integration into global value chains and more complex production structures (Timmer et al., 2014; Johnson & Noguera, 2012). These industries typically depend on specialized intermediate inputs, fragmented production stages, and extensive cross-border production networks, making them central nodes within global production systems. In contrast, primary activities and locally oriented service sectors tend to display lower levels of international fragmentation and therefore retain a larger share of production, income, and fiscal effects within domestic economies (Koopman, Wang & Wei, 2014; Miller & Blair, 2009).

Despite the growing literature on global value chains and international economic integration, relatively limited evidence is available regarding the sectoral mechanisms through which productive integration between Brazil and the European Union generates production, value-added, and fiscal spillovers. Existing studies have largely concentrated on trade performance, competitiveness indicators, and simulations based on Computable General Equilibrium (CGE) models, which provide valuable insights into aggregate welfare and macroeconomic outcomes but offer limited information on the structural and sectoral channels through which economic effects are transmitted across bilateral production networks. By contrast, input–output and multi-regional input–output approaches allow for a more detailed mapping of intersectoral and interregional linkages, making it possible to trace the propagation of shocks along global value chains (Dietzenbacher et al., 2012; Johnson & Noguera, 2012; Koopman, Wang & Wei, 2014).



Furthermore, while the literature increasingly recognizes the distinction between participation in international production networks and the capture of economic gains, relatively few studies have simultaneously examined production generation, income retention, and fiscal retention in the context of Brazil–European Union economic relations. This limitation is particularly relevant from a development perspective, as the capacity to retain income and fiscal resources is closely associated with investment capacity, structural upgrading, and long-term development trajectories, as emphasized in the global value chain and development literature (Werner, Bair & Fernández, 2014; Koopman, Wang & Wei, 2014; Rodrik, 2011).

This study contributes to the literature by employing an interregional input–output framework derived from the OECD Inter-Country Input–Output database to analyze productive integration between Brazil and the European Union. By estimating production, value-added, and tax multipliers and decomposing these effects into domestic and interregional components, the analysis identifies the sectors that generate the strongest cross-border transmission mechanisms and evaluates the extent to which economic gains are retained within the domestic economy. In doing so, the study provides new evidence on the distinction between productive integration and economic retention, contributing to a broader understanding of how international production networks shape development opportunities and the distribution of economic gains between regions.

3 Methodology

3.1 Data Source

This study employs data from the 2025 edition of the OECD Inter-Country Input–Output (ICIO) database to examine productive integration and the distribution of economic gains between Brazil and the European Union. The ICIO database provides harmonized inter-country input–output tables covering 81 economies, including 80 individual countries and a Rest of the World (ROW) aggregate, over the period 1995–2022. Economic activities are classified into 50 productive sectors, allowing a detailed representation of intersectoral and international production linkages.

The OECD ICIO database is particularly suitable for the analysis of productive integration because it explicitly records transactions of intermediate and final goods and services among countries and sectors. This structure makes it possible to identify the direct and indirect effects transmitted through international production networks and global value chains. In addition, the database provides consistent information on sectoral output, intermediate consumption, final demand, value added, and taxes less subsidies on products, allowing the simultaneous estimation of production, value-added, and tax multipliers.



A further advantage of the ICIO framework is its ability to capture cross-border production interdependencies within a consistent accounting structure. By incorporating international intermediate-input flows, the database enables the identification of spillover effects transmitted between economies and provides a suitable basis for evaluating the extent to which production, income generation, and fiscal effects are retained domestically or transmitted abroad through global value chains.

The sectoral classification follows the standard OECD ICIO structure, comprising 50 economic activities based on ISIC Rev. 4. The complete correspondence between sector codes, economic activities, and ISIC classifications is presented in Annex A.

The year 2022 was selected for the empirical analysis because it is the most recent year available in the current release of the database and therefore reflects the contemporary structure of economic relations between Brazil and the European Union.

3.2 Construction of the Brazil–European Union Interregional Input-Output Matrix

The original OECD ICIO database represents a global multi-regional input–output system that records productive interactions among all economies included in the dataset. To examine productive integration specifically between Brazil and the European Union, an aggregation procedure was performed to construct a bilateral interregional framework suitable for multiplier and spillover analysis.

Initially, the 27 member states of the European Union were aggregated into a single economic region, while Brazil was maintained as an individual region. Consequently, the analytical framework consists of two regions: Brazil and the European Union, each represented by 50 productive sectors. This aggregation preserves sectoral detail while allowing the identification of productive relationships linking the two economies.

The objective of the aggregation procedure was not to eliminate productive relationships with third countries but rather to isolate the bilateral transmission mechanisms between Brazil and the European Union. Transactions involving other economies remain embedded in the productive structure captured by the original ICIO database and are reflected in sectoral production requirements through imported inputs. However, these economies are not explicitly represented as separate regions in the interregional system and therefore fall outside the scope of the bilateral analysis developed in this study.

The resulting interregional input–output system contains 100 productive activities, distributed as 50 sectors representing Brazil and 50 sectors representing the European Union. The intermediate transaction matrix was organized into four blocks, as presented in Equation (1):

$$Z = \begin{bmatrix} Z^{BB} & Z^{BE} \\ Z^{EB} & Z^{EE} \end{bmatrix} \quad (1)$$

Where Z^{BB} represents intermediate transactions within Brazil; Z^{EE} represents intermediate transactions within the European Union; Z^{BE} represents Brazilian inputs used by European sectors and Z^{EB} represents European inputs used by Brazilian sectors.

This block structure makes it possible to distinguish domestic production effects from interregional transmission effects, allowing the identification of spillovers generated through productive linkages between Brazil and the European Union. Final-demand components, value added, taxes less subsidies on products, and total output were aggregated according to the same regional structure, resulting in a complete interregional input–output system suitable for the estimation of production, value-added, and tax multipliers.

3.3 Technical Coefficients and Leontief Inverse

The matrix of technical coefficients was obtained by dividing each intermediate transaction by the corresponding sectoral gross output. The technical coefficient represents the amount of input from sector (i) required to produce one monetary unit of output in sector (j) and was calculated as follows:

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

Where a_{ij} is the technical coefficient; z_{ij} represents the intermediate transaction from sector (i) to sector (j) and x_j denotes total output of sector (j).

The matrix of technical coefficients forms the matrix (A), which summarizes the productive structure of the interregional economy. Based on this matrix, the Leontief inverse matrix was calculated as:

$$L = (I - A)^{-1} \quad (3)$$

where (I) is the identity matrix.

The Leontief inverse captures the direct and indirect production requirements generated throughout the economic system following a unit increase in final demand. Within the context of the Brazil–European Union interregional system, the Leontief inverse provides the basis for identifying how economic effects propagate through domestic and cross-border production networks. Consequently, it constitutes the fundamental analytical tool for estimating production, value-added, and tax multipliers, as well as the spillover effects examined in this study.

3.4 Production, Value-Added and Tax Multipliers

Production multipliers were estimated from the column sums of the Leontief inverse



matrix:

$$MP_j = \sum_i l_{ij} \quad (4)$$

where MP_j represents the production multiplier of sector (j) and l_{ij} are the elements of the Leontief inverse matrix.

Production multipliers indicate the total increase in output throughout the interregional economy resulting from a one-unit increase in final demand for a given sector. Because they incorporate both direct and indirect effects, these multipliers provide a measure of the productive interconnectedness of sectors within the Brazil–European Union production system.

To evaluate productive integration between Brazil and the European Union, production multipliers were decomposed into domestic effects and interregional spillover effects. Domestic effects correspond to impacts generated within the same region where the demand shock originates, whereas spillover effects measure production generated in the partner region through cross-border production linkages.

For the estimation of value-added and tax multipliers, sectoral coefficients were first calculated by dividing each indicator by gross output:

$$v_j = \frac{V_j}{X_j} \quad (5)$$

Where V_j denotes value of each indicator by sector (j) (value added generated by sector or taxes less subsidies on products) and X_j corresponds to gross output.

Value-added and tax multipliers were then obtained by multiplying the Leontief inverse coefficients by the respective sectoral coefficients:

$$GV_j = \sum_i l_{ij} v_i \quad (6)$$

where GV_j represents the total value-added or tax effect associated with a one-unit increase in final demand for sector (j).

Value-added multipliers measure the amount of income generated throughout the production system, whereas tax multipliers measure the generation of taxes less subsidies on products associated with productive expansion, following the definition adopted in the OECD ICIO database. Accordingly, the fiscal effects reported in this study refer exclusively to this component of indirect taxation and should not be interpreted as total government revenue.

As in the case of production multipliers, value-added and tax multipliers were decomposed into domestic and interregional components. This procedure makes it possible to identify the proportion of income generation and fiscal revenues retained within the originating region and the proportion transmitted to the partner region through international production networks.

Examining production, value-added, and tax multipliers simultaneously provides a multidimensional assessment of productive integration. While production multipliers capture



output generation, value-added multipliers reflect income retention, and tax multipliers measure the generation of taxes less subsidies on products. Comparing these indicators allows the identification of sectors that not only stimulate production but also retain a larger share of the associated economic benefits within the domestic economy.

3.5 Interregional Spillovers and Retention Indicators

To evaluate the degree of productive integration between Brazil and the European Union, the estimated multipliers were decomposed into domestic and interregional components. Domestic effects correspond to impacts generated within the region where the initial final-demand shock occurs, whereas interregional effects capture the impacts transmitted to the partner region through cross-border production linkages.

For each sector, spillover indicators were calculated as the proportion of total multiplier effects generated outside the region in which final demand originates. These indicators were estimated separately for production, value added, and taxes, allowing the identification of differences in the transmission of economic effects across dimensions.

Formally, the spillover indicator measures the share of total multiplier effects occurring in the partner region, while the complementary share corresponds to the retention rate. Consequently, the retention indicator represents the proportion of production, income generation, or tax revenues that remains within the originating economy following an increase in final demand.

Sectors characterized by high spillover rates exhibit stronger integration into international production networks because a larger share of their economic impacts is transmitted across borders. Conversely, sectors with high retention rates display a greater capacity to internalize the benefits associated with productive expansion, retaining a larger proportion of production, income, and fiscal effects within the domestic economy.

From a development perspective, retention indicators are particularly relevant because they provide information on the extent to which economic gains generated by productive activity remain within the originating economy rather than being transmitted abroad through global value chains. While productive integration may stimulate economic activity, the developmental implications of integration depend not only on production growth but also on the capacity of sectors to retain the associated economic benefits.

The simultaneous analysis of spillover and retention indicators therefore makes it possible to distinguish sectors that primarily generate production expansion from those that effectively retain the resulting income and fiscal gains. This distinction is especially important in the context of global value chains, where participation in international production networks does not necessarily imply proportional domestic capture of value creation.

4. Results

4.1 Productive Integration and Production Spillovers

The results indicate that productive integration between Brazil and the European Union is concentrated in a relatively small group of manufacturing and transport-related activities. While most sectors remain predominantly domestic in their productive structure, several industries exhibit stronger cross-border transmission mechanisms, reflecting their integration into international production networks.

Table 1 – Brazilian Production Multipliers and Spillovers

N	Sector	Production Multiplier	Production Spillover (%)
Highest Production Multipliers			
34	Air Transport	2.74	4.79
13	Manufacture of Refined Petroleum	2.66	2.56
9	Manufacture of Food Products	2.62	2.12
24	Manufacture of Motor Vehicles	2.60	4.72
14	Manufacture of chemical products	2.51	4.10
19	Manufacture of basic precious and other non-ferrous	2.36	2.56
20	Manufacture of fabricated metal products	2.35	2.77
22	Manufacture of electrical equipment	2.35	4.25
16	Manufacture of rubber and plastic products	2.35	4.27
Highest Production Spillovers			
26	Other Transport Equipment	2.00	11.23
25	Shipbuilding	1.84	7.27
33	Water transport	1.94	7.11

Source: Prepared by the author.

Among the sectors with the largest production multipliers, Air Transport (34), Manufacture of Refined Petroleum Products (13), Manufacture of Food Products (9), Manufacture of Motor Vehicles (24), and Manufacture of Chemical Products (14) stand out, with multiplier values exceeding 2.5. These results indicate strong backward linkages and a substantial capacity to stimulate production throughout the Brazil–European Union production system.

A different pattern emerges when attention is directed to interregional spillovers. The highest spillover effects were observed in Other Transport Equipment (26), Shipbuilding (25), and Water Transport (33), with spillover rates ranging from approximately 7% to 11%. Although these sectors do not display the largest production multipliers, they constitute the principal channels through which production effects are transmitted to European supply chains. Nevertheless, even in the most internationally integrated sector, nearly 89% of the total production effects remain within Brazil, indicating that domestic productive linkages continue to predominate.

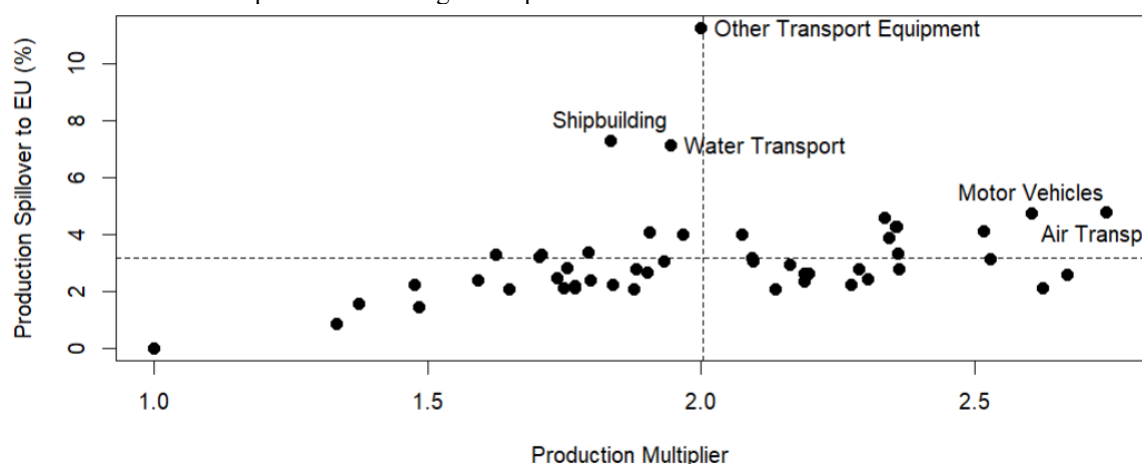
Other Transport Equipment is particularly noteworthy. Despite a production multiplier lower than those observed in Air Transport and Refined Petroleum Products, the sector recorded the highest spillover effect, with 11.23% of total production impacts associated with Brazilian final

demand occurring within the European Union. This result reflects the sector's strong dependence on imported components, specialized technologies, and cross-border production arrangements, while the majority of production effects (88.77%) continues to be retained domestically.

The concentration of spillovers in transport equipment industries and transportation services is consistent with the structure of contemporary global value chains, in which production processes are fragmented across multiple countries and connected through complex supply networks.

Figure 1 confirms that sectors with the highest production multipliers are not necessarily those exhibiting the strongest international spillovers. While Air Transport and Motor Vehicles generate the largest production effects, Other Transport Equipment, Shipbuilding, and Water Transport display the highest levels of productive integration with the European Union.

Figure 1 – Production Multipliers and Interregional Spillovers



Source: Prepared by the author.

Overall, the results suggest that productive expansion and international integration represent distinct dimensions of economic activity. Some sectors generate substantial domestic production effects, whereas others function as key transmission channels linking Brazilian and European production systems.

4.2 Value-Added Multipliers and Income Spillovers

The results reveal important differences between sectors that generate domestic income and those that transmit value-added effects to the European Union. While some activities retain most of the income generated within the Brazilian economy, others display stronger integration into international production networks, resulting in larger cross-border income spillovers.

Among the sectors with the highest value-added multipliers, Activities of Households (50), Real Estate Activities (42), Education (46), Forestry and Logging (2), and Financial and Insurance Activities (41) stand out. These sectors generated between 0.92 and 1.00 monetary units of value

added for each additional monetary unit of final demand, indicating a strong capacity to retain income within the domestic economy.

Table 2 – Brazilian Value-Added Multipliers and Spillovers

N	Sector	Value-added Multiplier	Value-added Spillover (%)
Highest Value-added Multipliers			
50	Activities of households	1.00	0.00
42	Real estate activities	0.96	0.49
46	Education	0.94	0.97
2	Forestry and logging	0.93	0.90
41	Financial and insurance activities	0.92	1.62
Highest Value-added Spillovers			
26	Other Transport Equipment	0.58	13.16
25	Shipbuilding	0.52	8.61
34	Air Transport	0.70	6.85
24	Manufacture of Motor Vehicles	0.69	6.33
23	Manufacture of machinery and equipment	0.73	5.25

Source: Prepared by the author.

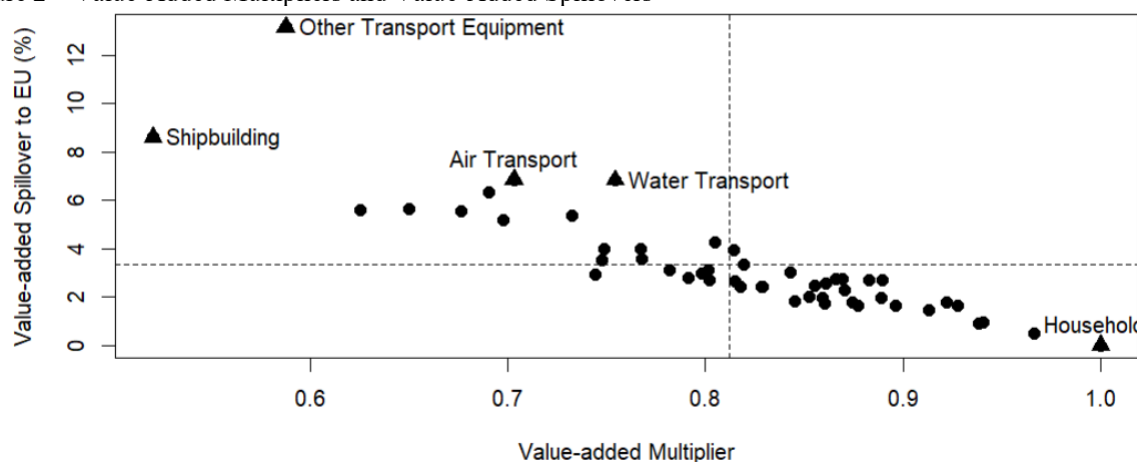
In contrast, the largest value-added spillovers were observed in Other Transport Equipment (26), Shipbuilding (25), Air Transport (34), Manufacture of Motor Vehicles (24), and Manufacture of Machinery and Equipment (23). Spillover rates ranged from approximately 5% to 13%, indicating that, although most of the income generated by Brazilian final demand remains within the domestic economy, a measurable share is transmitted to productive activities located within the European Union.

Other Transport Equipment presents the clearest example of this pattern. Although its value-added multiplier is substantially lower than those observed in Real Estate, Education, and Financial Services, the sector recorded the highest value-added spillover (13.16%). Similar results are observed for Shipbuilding, Air Transport, and Motor Vehicles, highlighting the importance of international production networks in shaping the distribution of income generated by economic activity.

The concentration of income spillovers in transport equipment industries and technologically intensive manufacturing sectors is consistent with their dependence on imported technologies, specialized components, engineering services, and other knowledge-intensive inputs supplied through global value chains.

Figure 2 illustrates the relationship between value-added multipliers and value-added spillovers. Most sectors are concentrated in the central region of the distribution, combining moderate levels of income generation with relatively limited international leakages. By contrast, Other Transport Equipment, Shipbuilding, Air Transport, Motor Vehicles, and Machinery and Equipment occupy the upper portion of the figure due to their stronger integration with European production chains. Activities of Households represent the opposite extreme, combining the highest value-added multiplier with the complete absence of international spillovers.

Figure 2 – Value-Added Multipliers and Value-Added Spillovers



Source: Prepared by the author.

Overall, the results indicate that productive expansion does not necessarily translate into proportional domestic income retention. While service-oriented activities retain most of the value generated by economic activity within Brazil, sectors more deeply integrated into global value chains exhibit larger value-added leakages toward the European Union.

4.3 Tax multipliers and fiscal spillovers

Tax multipliers provide an additional perspective on productive integration by capturing the fiscal revenues associated with increases in final demand. While production multipliers measure output generation and value-added multipliers reflect income creation, tax multipliers indicate the extent to which economic activity contributes to tax collection throughout the production system.

Among the sectors with the highest tax multipliers, Manufacture of Rubber and Plastic Products (16), Manufacture of Motor Vehicles (24), Manufacture of Textiles (10), Manufacture of Electrical Equipment (22), Manufacture of Paper and Paper Products (12), and Land Transport (32) stand out. These sectors generated between 0.09 and 0.10 monetary units of tax revenue for each additional monetary unit of final demand, indicating a relatively strong capacity to generate fiscal revenues throughout the economy.

Table 3 – Brazilian Tax Multipliers and Spillovers

N	Sector	Tax Multiplier	Tax Spillover (%)
Highest Tax Multipliers			
16	Manufacture of rubber and plastic products	0.10	1.73
24	Manufacture of Motor Vehicles	0.09	2.57
10	Manufacture of textiles	0.09	1.11
22	Manufacture of electrical equipment	0.09	2.02
12	Manufacture of paper and paper products	0.09	1.58
32	Land transport	0.09	1.16
Highest Tax Spillovers			
26	Other Transport Equipment	0.08	8.45
25	Shipbuilding	0.03	7.32

33	Water transport	0.03	6.79
34	Air transport	0.05	4.35
14	Manufacture of chemicals	0.06	2.97

Source: Prepared by the author.

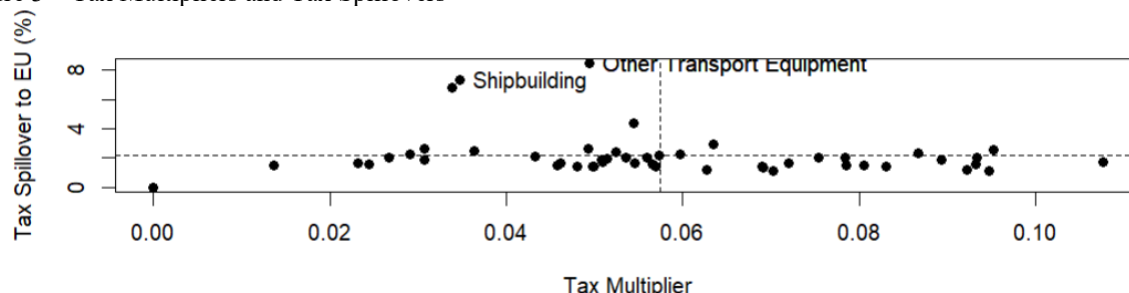
The largest tax spillovers were observed in Other Transport Equipment (26), Shipbuilding (25), Water Transport (33), Air Transport (34), and Manufacture of Chemicals (14). In these sectors, between approximately 3% and 8% of the tax revenues generated by Brazilian final demand were associated with productive activities located within the European Union.

Other Transport Equipment again represents the most internationally integrated sector, recording the highest tax spillover (8.45%). Similar patterns are observed in Shipbuilding and Water Transport, reinforcing the importance of cross-border production networks in shaping the distribution of fiscal effects. Nevertheless, more than 90% of the tax effects generated by Brazilian final demand remain within the domestic economy, indicating that fiscal retention continues to predominate even in the most internationally integrated sectors. However, tax spillovers are systematically smaller than production and value-added spillovers. For example, Other Transport Equipment generated production and value-added spillovers of 11.23% and 13.16%, respectively, compared with a tax spillover of 8.45%.

This pattern suggests that fiscal effects tend to be retained more strongly within the domestic economy than production and income effects. As a result, greater participation in international production networks does not necessarily imply proportional fiscal leakages.

Figure 3 confirms that sectors generating larger tax revenues are not necessarily those exhibiting stronger international fiscal transmission effects. Most sectors remain concentrated at relatively low spillover levels, while Other Transport Equipment and Shipbuilding stand out as the principal channels through which fiscal effects are transmitted to the European Union.

Figure 3 – Tax Multipliers and Tax Spillovers



Source: Prepared by the author.

Taken together, the results indicate that fiscal generation and fiscal transmission represent distinct dimensions of economic integration. While sectors such as Rubber and Plastic Products, Motor Vehicles, and Electrical Equipment display a strong capacity to generate tax revenues



domestically, transport-related industries exhibit the highest levels of fiscal spillovers. These findings reinforce the importance of evaluating production, income, and fiscal effects simultaneously when assessing the consequences of international productive integration.

4.4 Patterns of productive integration between Brazil and the European Union

The combined analysis of production, value-added, and tax multipliers reveals important structural characteristics of productive integration between Brazil and the European Union. Although all three indicators originate from the same interregional production system, they capture distinct dimensions of economic activity and therefore provide complementary insights into how economic gains are generated and distributed across regions.

A first pattern concerns the distinction between sectors with strong domestic multiplier effects and sectors exhibiting stronger international transmission mechanisms. Air Transport, Refined Petroleum Products, Food Products, and Motor Vehicles displayed some of the highest production multipliers, indicating a substantial capacity to stimulate economic activity throughout the production system. However, these sectors do not necessarily generate the highest levels of value added or fiscal revenues, nor do they always exhibit the strongest international spillovers. This finding suggests that production expansion alone provides only a partial picture of the economic consequences of international integration.

A second pattern emerges from the comparison between multiplier intensity and spillover intensity. Several sectors characterized by relatively moderate production, value-added, or tax multipliers recorded some of the highest spillover effects. This is particularly evident in Other Transport Equipment and Shipbuilding, which consistently appear among the sectors with the strongest production, income, and fiscal transmission effects toward the European Union. These findings indicate that the degree of international integration is not determined solely by the magnitude of domestic economic impacts but also by the extent to which productive activities depend on cross-border supply chains and imported intermediate inputs.

The results further reveal a clear sectoral divide between domestically oriented activities and sectors strongly integrated into global value chains. Real Estate Activities, Education, Forestry, Financial Services, and Household Activities generated high levels of domestic value added while exhibiting limited international spillovers. These activities depend primarily on domestic inputs and therefore retain a large share of the economic gains generated by final demand within Brazil. In contrast, transport equipment industries, transportation services, chemicals, machinery, and other technologically intensive manufacturing sectors displayed the highest spillover levels across all three dimensions examined.

This distinction is consistent with the global value chain literature. According to Gereffi,



Humphrey, and Sturgeon (2005), economic gains tend to be distributed unevenly across production networks, with higher-value activities often concentrated in specific segments of the chain. Similarly, Timmer et al. (2014) argue that countries may participate extensively in international production systems while specializing in stages associated with different levels of value capture. The evidence presented here suggests that sectors more deeply integrated into European production networks also exhibit greater leakages of production, income, and fiscal effects beyond national borders.

The results also reinforce the distinction between participation and value capture emphasized by Johnson and Noguera (2012) and Koopman, Wang, and Wei (2014). While productive integration increases economic interdependence and expands production opportunities, it does not necessarily imply proportional retention of the associated economic gains. In several sectors, particularly transport equipment and technologically intensive manufacturing industries, a significant share of the benefits generated by Brazilian final demand is transmitted to production activities located within the European Union.

An additional finding concerns the relationship between production, value-added, and tax spillovers. Although tax spillovers are systematically smaller than both production and value-added spillovers, their sectoral distribution closely mirrors the pattern observed for the other indicators. Sectors exhibiting strong productive integration with the European Union also tend to generate stronger cross-border fiscal effects. The correlation between production and tax spillovers exceeds 0.90, while the correlation between value-added and tax spillovers is above 0.84, suggesting that sectors generating stronger productive and income spillovers also tend to generate stronger fiscal spillovers.

At the same time, the magnitude of tax spillovers remains comparatively lower across most sectors. This finding suggests that fiscal effects are retained more strongly within domestic economies than production and income effects. Consequently, although participation in international production networks increases cross-border economic transmission, the associated fiscal benefits remain relatively more concentrated within national territories.

These results are broadly consistent with recent studies on Brazil's position in global value chains. Gonçalves Junior et al. (2024) emphasize that participation in international production networks does not automatically translate into proportional domestic value capture, while Dulcich (2023) highlights the importance of European production linkages in technologically intensive industries, particularly within transport-related sectors. The evidence presented here complements these studies by showing that similar patterns emerge not only for value added but also for production and fiscal effects.

Taken as a whole, the findings indicate that productive integration between Brazil and the



European Union is characterized by heterogeneous patterns across sectors. While service activities and primary sectors remain predominantly domestic in their economic effects, technologically intensive manufacturing industries and transportation-related activities constitute the principal channels connecting the productive structures of the two regions. These sectors therefore play a central role in shaping how production, income, and fiscal effects are distributed within contemporary global value chains.

5. Conclusions

This study examined productive integration between Brazil and the European Union through an interregional input–output framework derived from the OECD Inter-Country Input–Output (ICIO) database for 2022. By estimating production, value-added, and tax multipliers and decomposing these effects into domestic and interregional components, the analysis identified the sectors that play the most important roles in transmitting economic effects between the two regions.

The results reveal that productive integration between Brazil and the European Union is highly heterogeneous across sectors. While most activities remain predominantly domestic in their economic impacts, a relatively small group of manufacturing industries and transport-related activities exhibits stronger cross-border transmission effects. Even in these more integrated sectors, however, the majority of production, value-added, and tax effects remains within the Brazilian economy. In particular, Other Transport Equipment, Shipbuilding, Air Transport, Water Transport, Motor Vehicles, Chemicals, and Machinery and Equipment emerged as the sectors most strongly connected to European production networks.

The analysis also demonstrates that productive integration cannot be adequately assessed through production effects alone. Sectors displaying the largest production multipliers are not necessarily those generating the highest levels of value added or fiscal revenues, nor are they always the sectors exhibiting the strongest international spillovers. The distinction between production generation, income retention, and fiscal retention therefore represents an important dimension of international economic integration.

A central finding concerns the contrast between participation in international production networks and the domestic capture of economic gains. Service-oriented activities such as Real Estate, Education, Financial Services, and Household Activities displayed high value-added retention and limited spillover effects, indicating a strong capacity to internalize the benefits generated by economic activity. In contrast, transport equipment industries and technologically intensive manufacturing sectors recorded the highest production, value-added, and tax spillovers, reflecting their greater dependence on cross-border supply chains and imported intermediate



inputs.

These findings contribute to the growing literature on global value chains by providing evidence that productive integration and value retention are distinct phenomena. Greater participation in international production networks may expand production opportunities and strengthen economic interdependence, but it does not necessarily imply proportional retention of income and fiscal benefits within the domestic economy. From a development perspective, this distinction is particularly relevant because the long-term benefits of integration depend not only on the expansion of economic activity but also on the capacity to retain and internalize the gains generated along production chains.

The study also contributes to the literature on Brazil–European Union economic relations by complementing traditional analyses based on trade flows and computable general equilibrium models. By focusing on intersectoral and interregional linkages, the input–output approach makes it possible to identify the structural mechanisms through which production, income, and fiscal effects are transmitted between regions. In this sense, the results provide new evidence on the role of global value chains in shaping the distribution of economic gains between Brazil and the European Union.

Some limitations should be acknowledged. The analysis is based on a static input–output framework and therefore does not incorporate price adjustments, substitution effects, technological change, or behavioral responses that may occur over time. In addition, the results reflect the productive structure observed in 2022 and should be interpreted as structural relationships rather than forecasts of future developments. Furthermore, the aggregation of the 27 European Union member states into a single regional block does not allow the identification of the individual European economies that capture the observed spillover effects, limiting country-specific interpretations.

Future research may extend the analysis by incorporating dynamic approaches, evaluating alternative trade policy scenarios, or examining the potential implications of the Mercosur–European Union Agreement for productive integration, value-added generation, and fiscal retention. Such extensions would contribute to a broader understanding of how international production networks influence development trajectories and the distribution of economic gains across regions.

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Annex A: OECD ICIO Sectoral Classification

N.	Code	Economic activity	ISIC Rev.4
1	A01	Agriculture and hunting	01
2	A02	Forestry and logging	02
3	A03	Fishing and aquaculture	03
4	B05	Mining of coal and lignite	05
5	B06	Extraction of crude petroleum and natural gas	06
6	B07	Mining of metal ores	07
7	B08	Other mining and quarrying	08
8	B09	Mining support service activities	09
9	C10T12	Manufacture of food products; beverages and tobacco products	10, 11, 12
10	C13T15	Manufacture of textiles, wearing apparel, leather and related products	13, 14, 15
11	C16	Manufacture of wood and of products of wood and cork	16
12	C17_18	Manufacture of paper and paper products; Printing and reproduction of recorded media	17, 18
13	C19	Manufacture of coke and refined petroleum products	19
14	C20	Manufacture of chemicals and chemical products	20
15	C21	Manufacture of basic pharmaceutical products and pharmaceutical preparations	21
16	C22	Manufacture of rubber and plastic products	22
17	C23	Manufacture of other non-metallic mineral products	23
18	C24A	Manufacture of basic iron and steel	241,2431
19	C24B	Manufacture of basic precious and other non-ferrous metals	242,2432
20	C25	Manufacture of fabricated metal products	25
21	C26	Manufacture of computer, electronic and optical products	26
22	C27	Manufacture of electrical equipment	27
23	C28	Manufacture of machinery and equipment n.e.c.	28
24	C29	Manufacture of motor vehicles, trailers and semi-trailers	29
25	C301	Building of ships and boats	301
26	C302T309	Manufacture of other transport equipment	302 to 309
27	C31T33	Manufacture of furniture and other manufacturing	31, 32, 33
28	D	Electricity, gas, steam and air conditioning supply	35
29	E	Water supply; sewerage, waste management and remediation activities	36, 37, 38, 39
30	F	Construction	41, 42, 43



31	G	Wholesale and retail trade; repair of motor vehicles and motorcycles	45, 46, 47
32	H49	Land transport and transport via pipelines	49
33	H50	Water transport	50
34	H51	Air transport	51
35	H52	Warehousing and support activities for transportation	52
36	H53	Postal and courier activities	53
37	I	Accommodation and food service activities	55, 56
38	J58T60	Publishing, Motion picture, video, television programme production and broadcasting activities	58, 59, 60
39	J61	Telecommunications	61
40	J62 63	Computer programming and information service activities	62, 63
41	K	Financial and insurance activities	64, 65, 66
42	L	Real estate activities	68
43	M	Professional, scientific and technical activities	69 to 75
44	N	Administrative and support service activities	77 to 82
45	O	Public administration and defence; compulsory social security	84
46	P	Education	85
47	Q	Human health and social work activities	86, 87, 88
48	R	Arts, entertainment and recreation activities	90, 91, 92, 93
49	S	Other service activities	94,95, 96
50	T	Activities of households as employers; undifferentiated goods- and services-producing activities of households for own use	