Economic analysis based on **input-output tables**

Definitions, indicators and applications for Latin America

José E. Durán Lima
Santacruz Banacloche

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Nomenclature

CGE	Computable General Equilibrium
GVC	Global Value Chains
LAC	Latin America and the Caribbean
IOT	Input-Output Table
IOT LAC	Input-Output Table for Latin America and the Caribbean
IOT SA	Input-Output Table for South America
MRIO	Multi Regional Input-Output
MRIOT	Multi-Regional Input-Output Table
RIOT	Regional Input-Output Table
SAM	Social Accounting Matrix
SRIO	Single Regional Input-Output
SRIOT	Single Regional (National or Domestic) Input-Output Tables
A	*NxN* matrix of technical coefficients
A^M	*NxN* matrix of imported technical coefficients
BL	Backward linkages
Ce	CO_2 emissions coefficient
CE	Coefficient of use
E	CO_2 emissions factor
REB	Balance of Responsibilities
$EV1_p$	Direct imported content in the exports of a country *p*
$EV2_p$	Total imported inputs incorporated in the exports of a country *p*
EVi_p	Indirect imported content in a country's exports *p*
F	Factor
C	Final Consumption
FL	Forward linkages (forward linkages)
G	Inverse Ghosh matrix or technical distribution coefficients matrix
GCF	Gross Capital Formation
GVA	Gross Value Added
GVP	Gross Value of Production
I	*NxN* identity matrix
$IGDP_p$	Imported inputs over GDP
L	Inverse Leontief matrix of dimensions *NxN*
MCE	Employment multiplier

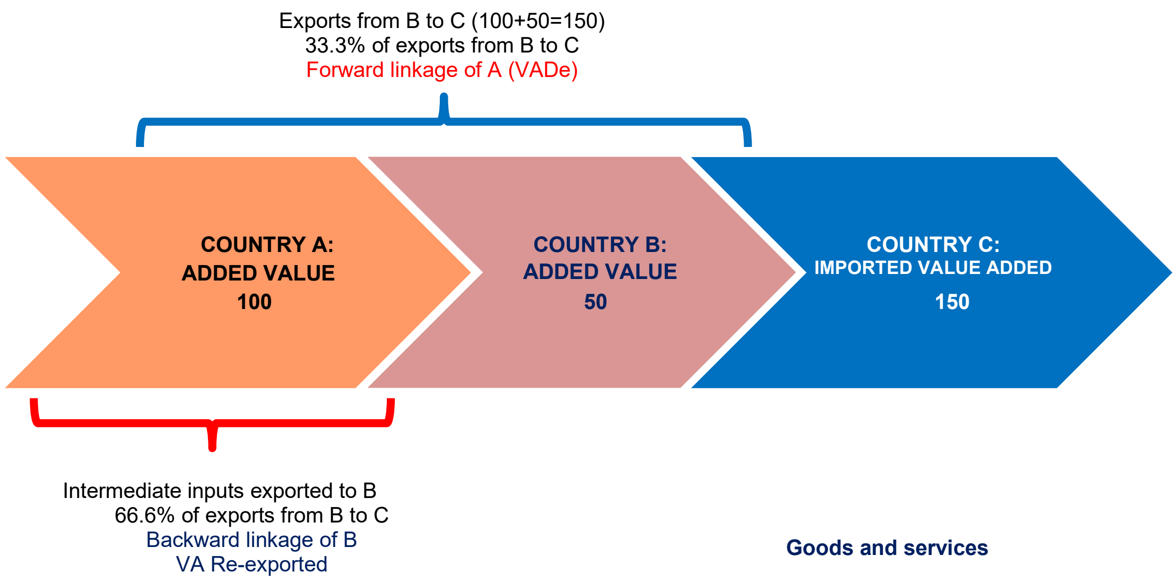
ME	CO_2 emissions multiplier
MF	Factor multiplier, in the form of a matrix *NxN*
N	Employment factor
RC	Responsibility of Consumers
RII_p	Ratio of imported inputs to domestic inputs in the country *p*
RC	Responsibility of Producers
V	Vector *1xN* of Value Added per product unit
$VADDe_p$	Direct domestic value added contained in a country's exports *p*
$VADIe_p$	Indirect domestic value added contained in a country's exports *p*
$VADTe_p$	Total value added contained in a country's exports *p*
$VADTe_p^f$	Total domestic value added contained in final imports
$VADTe_p^{int}$	Total domestic value-added contained in intermediate imports
$VAET_e^p$	Total foreign value added contained in a country's exports *p*
Y	Final Demand
Z	*NxN* matrix of intermediate inputs (by default domestic)
Z^D	*NxN* matrix of domestic intermediate inputs
Z^M	*NxN* Matrix of imported intermediate inputs
Z^T	*NxN* Matrix of total intermediate inputs
a_{ij}	Technical coefficients of sector branch *i* required by sector column *j*
$\hat{e}$	Total exports, diagonalized vector of dimensions *NxN*
f	Factor coefficient
x	1xN row vector of the *GVP*

Introduction

The economic growth of recent decades, together with the boom in international trade resulting from globalization, has generated a gradual geographic fragmentation of production processes. Thus, as an illustrative example, a product consumed in Chile may have been generated with primary inputs from Peru, which were subsequently manufactured in Ecuador, and then assembled and distributed as a final product by Colombia. It is estimated that trade in intermediate goods exceeds 50% of total exports in the world (Miroudot et al., 2009). The offshoring of economic activities at different stages of production generates a series of complex international linkages that are difficult to measure with conventional statistics. The proliferation of so-called Global Value Chains (GVC) is the result of this type of productive and commercial networks that are generated, giving rise to a combination of goods and services imported and processed domestically, which are subsequently exported for intermediate uses in subsequent stages of production or as products for final use or consumption (OECD, 2012; ADB, 2015). Despite the "global" denomination, many authors have analyzed the rather regional nature of these chains, organized into three major factories: "factory America", "factory Europe" and "factory Asia" (World Bank, 2017). Thus, trade in intermediate goods is much more important between nearby countries, while trade in final goods has a more global structure (Lalanne, 2020).

Understanding how the linkages between countries and sectors are structured is really useful, not only to analyze an economy's dependence on the world, the drag effect of key sectors, or how countries contribute to generating the value added of traded goods and services in global production networks, but also for companies, sectors and political decision-makers in developing countries, who wish to integrate and benefit from these linkages (Gereffi and Kaplinsky, 2001). To this end, measuring this type of international linkages is paramount. Unfortunately, traditional international trade statistics record gross flows of cross-border goods and services, without capturing the value added of each country. As an example, a country A produces and exports a good valued at 100 monetary units to country B, which in turn transforms this product and exports it to country C for 150 monetary units. This measurement can lead to erroneous conclusions about the contribution of trade to economic growth and income, as it incurs a double counting problem (Miroudot and Yamano, 2013; De Backer and Miroudot, 2014), since it does not take into account the incurred costs of a country in requiring imported intermediate inputs during its production process. This problem is solved when a measurement is made in terms of value added (VA) generated. Country A contributes by generating 100 units of value added. Country B, on imports from country A, adds 50 more units to its exports to country C, generating in this process a total of 150 monetary units.

Diagram 1
Simplified example of GVC



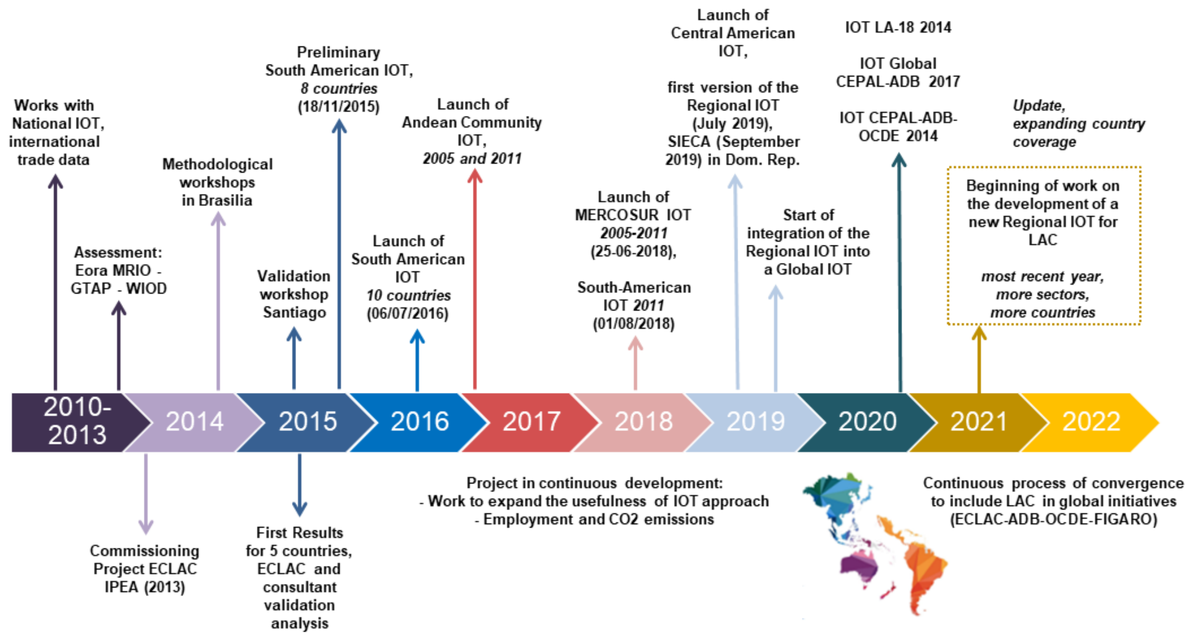
Source: Own elaboration.

For this reason, it is necessary to use the input-output methodology. Multiregional input-output tables (MRIOT) allow identifying the origin and destination of the value flowing through GVC, being able to define the roles of countries and industries that play a determining role in supply chains and sources of competitiveness (Jones, Powers and Ubee, 2013). Unfortunately, the provision of MRIOT is limited, since its assembly depends mainly on the quality and robustness of National Accounts and other statistics of the countries involved. Many developing countries lack institutions that can collect the necessary information for the compilation of Supply and Use Tables, the starting point for the creation of Input-Output Tables (IOT). As we will see in this handbook, not only the measurement of GVC is possible on the basis of IOT, as certain indicators are informative regarding other measures.

Given the limited MRIOT currently available, and aware that they do not contemplate a large number of Latin American and Caribbean countries, in recent years, the Integration Unit of the International Trade and Integration Division of the Economic Commission for Latin America and the Caribbean (ECLAC) has made substantial progress towards the assembly of multi-country (IOT) for the region, which allow the study of productive linkages and trade-based value added in Latin America. In 2016, the South American Input-Output Table (hereafter IOT SA) was launched, the region's first proprietary IOT capturing South America's regional linkages for the year 2005 (ECLAC, 2016). As a result of the effort made, and with the desire to deepen the productive relations of Latin America and the Caribbean, the Division has continued to expand and update these tools (see Diagram 2), with the creation of the Andean Community IOT (CAN IOT) and the MERCOSUR IOT for 2011, the update of the IOT SA to 2011 and 2014, and finally the creation of the Latin American Input-Output Table (LA IOT) for 2011 and 2014. This is a process of several years of work, in which several national teams participated.

As a culmination, in 2020 ECLAC has been part of the ECLAC-ESCAP-ADB/OECD working group, carrying out an intensive exercise of methodological homogenization in continuous development for the inclusion of Latin American countries in global multiregional IOT. At the time of publication of this handbook, this collaborative initiative is in full swing.

Diagram 2
Process followed for the assembly of the IOT



Source: Own elaboration.

Thus, a powerful set of publicly available IOT is now provided that is a milestone for both regional and multi-regional economic analyses. In addition, all kinds of activities have been carried out: technical assistance, IOT dissemination, training, etc. The present handbook is a further contribution to this process, whose time horizon, in addition to the launching of a LA IOT, which also included Mexico and Central American countries in addition to South America, has been extended to the launching of a (global) IOT that includes the countries of the region in a global multi-country input-output model.

The main purpose of this work is to offer a basic methodological guide for the calculation of indicators for trade and productive integration, with which to analyze Latin America's position in the world, as well as its main productive linkages and the value added it generates. It is of particular interest to deepen the analysis of the links between production and trade, especially in the area of regional integration, an area in which there are still spaces for the promotion of intra-industrial links between several countries in the region. The use of a homogeneous basis such as that presented by the South American IOT and the Latin American IOT makes it possible to analyze the productive interconnection between the various countries of the region. Specifically, the handbook at hand goes beyond the calculation of national indicators. It focuses on concepts and tools applicable to South American and Latin American IOT, through quantitative measures or indicators that users (government officials, academics, and the general public) can apply to generate calculations and interpret results that serve to define the productive and trade linkages of the countries of the region at the national, bilateral or Latin American level. These indicators can be extrapolated to any national IOT. In addition, some empirical results of the application of this methodology in Latin America are presented and analyzed. Although this document focuses on IOT, other complementary indicators on trade are available in other handbooks developed by ECLAC (Durán and Alvarez, 2011; updated in Durán, Alvarez and Cracau, 2016). In short, the major contribution of this handbook is to be able to apply indicators extensively discussed in the literature, adapted to the case of ECLAC's IOT, offering results for the region.

This handbook provides foreign trade and industry officials with reference tools for the development of their daily work in the evaluation of international trade and its role in the productive structure of a country or region. We hope that all those interested in the measurement of trade indicators can rely on this compilation of indicators, which in turn complements the methodological handbook of the South American IOT (ECLAC, 2016), and above all, that they can interpret the results correctly in order to lay the foundations for information that will enable the development of public policies that facilitate trade and promote dynamic trade relations in key sectors for regional integration. ECLAC has constantly emphasized the need to promote modern industrial and productive development policies, with a clear cross-border orientation (ECLAC, 2014a, 2014b). This goes beyond national objectives. We hope that the use of the methodologies described here will provide new tools to accompany the design of public policy, through the identification of sectors with greater impetus and potential for shared production that will generate greater economic growth.

Section I will present the multi-country IOT for Latin America as a tool for economic analysis, commenting on the peculiarities of the methodology, its limitations and possible applications. Successive sections will focus on the development of the definition, the mathematical formulation and the results offered by the different groups of indicators: Section II will present intersectoral economic indicators showing the productive linkages of the economies under study; Section III deals with the so-called Vertical Specialization, understood as the imported content of a country's exports, a relevant indicator in the GVC measure; Section IV focuses on Value Added indicators, which facilitate the understanding of GVC by reflecting the true participation of countries in the production processes without incurring in the error of double counting; finally, Section V deals with environmental and socioeconomic extensions of the model. The handbook concludes with brief conclusions on the methodology, results and objectives achieved.

I. The Input-Output Table as a tool for economic analysis

Input-Output Tables (IOT) are a statistical tool of economic analysis that allows measuring and describing productive relationships in one or several economies in a particular year, including linkages arising from trade. Studying production and trade through the framework of input-output analysis is essential in an economic era, where cross-border production processes are the norm, with more than half of international trade being intermediate inputs (ADB, 2015). The origins of input-output analysis date back to the first half of the twentieth century, with the contribution of Wassily Leontief (1936).

Currently, the input-output model is one of the most relevant methodological tools in economic analysis and its use has spread across different areas. Depending on the construction of these tables, a large amount of information can be extracted from the share of total exports of any industry in a country's GDP, or the imported content of the agricultural sector that a country requires to be able to export food products to the rest of the world, to the study of the fragmentation of production in GVC. IOT are also the starting point for the use of more complex models such as the *Social Accounting Matrix* (SAM), a tool that incorporates information on economic agents, allowing the construction of multipliers and the development of macroeconomic models. The SAM is also the main source of information for working with the so-called computable general equilibrium (CGE) models, which capture the main interdependencies between sectors and the behavior of the different economic agents, making it possible to evaluate alternative scenarios resulting from shocks affecting an economy.

If we take into account the introduction of IOT in other areas of the economy such as the content of productive factors in trade (Trefler and Zhu, 2010), business cycles (Acemoglu et al. 2012), the employment footprint (Alsamawi et al., 2014) and its applications in environmental issues (Lenzen et al., 2012; Peters et al., 2010), it is clear that the input-output methodology is consolidated as a tool of proven relevance and widespread use. In the region, this tool has also been used from an economic and social perspective, calculating for example the employment associated with exports from Ecuador to the European Union (Durán and Castresana, 2016), as well as from an environmental perspective, contextualizing Latin America in its position regarding the Paris Agreement (Durán and Banacloche, 2018). In ECLAC-ILO (2016), a particular analysis of the productive impulse generated at the sectoral level by intra-regional purchases is carried out. Other studies developed from the Regional IOT Project include productive integration in the Andean Community, analyzing value chains between Colombia and Ecuador (Durán, Cracau and Saeteros, 2018), productive integration between Argentina and Brazil (Amar and García-Díaz, 2018), possible economic and social effects of the deepening of the Customs Union between Guatemala and Honduras (ECLAC, 2017b), evaluation of economic and social impacts of possible trade negotiations between Jamaica and Central America, Mexico and northern Caribbean countries (ECLAC, 2018), or the potential dynamizing effect of exports in Central America and the Dominican Republic (Minzer and Orozco, 2018).

The input-output methodology is based on various sources (economic censuses and household income and expenditure surveys, among others), while the main source is the National Accounts of each country. From these, three tables are generated: the Supply Table, the Use Table and the so-called Symmetric Tables (the IOT itself). The first two tables have been extensively discussed in various handbooks (European Commission, 2008; Schuschny, 2005) and will be omitted due to the choice of symmetric tables to work on the proposed indicators. The latter are constructed from the first two, so they are not obtained directly, but allow the input-output methodology to be used more directly, since the symmetric tables connect the branches (also called sectors or industries) of homogeneous production, trough eliminating the secondary productions that are incorporated in other branches, where they are the main production. Thus, the symmetric tables of an economy have *NxN* sectors, as many sectors by rows as by columns. The elimination of secondary products requires two assumptions (industry technology and product technology), which we will not discuss in this handbook. Symmetric tables are the most used ones for input-output analysis, since the calculation of technical coefficients, multipliers and the use of indicators for GVC analysis is immediate.

The IOT is a double-entry matrix that provides by columns the composition of gross value of production from the expenditure perspective, and by rows from the income perspective. It can be divided into three main matrices (see Diagram 3): the intermediate input matrix (*Z*), the final demand matrix (*y*) and the value-added matrix (*GVA*). The total output, Gross Value of Production (GVP) or total supply (*total resources*) is the sum by columns of *Z*, imports of intermediate inputs Z^M (not to be confused with imports of final goods) and *GVA* by industrial sector, shown in the row *1xN* vector, the total demand (*total employment*) by sector is the sum by rows of the sectors, which include the intermediate inputs and the final demand offered by a column *Nx1* vector, fulfilling the accounting identity whereby total resources are equal to total employment. For the following calculations we will call *x* the *1xN* vector of the GVP.

Diagram 3
Simplified structure of a national symmetrical IOT

	Sectors *j* **1 2 3 … N**	**Final demand**			**Total employment**
		C	FBC	e	
Sectors *i* **1 2 3 ⋮ N**	*Intermediate demand:* Intermediate inputs, intermediate consumption or use (Z)	y			Gross Value of Production (GVP)
Imports	Imported intermediate inputs (Z^M)				
Value added (GVA)	Compensation of employees				
	Gross operating surplus				
	Taxes minus subsidies				
Total resources	Gross Value of Production (GVP)				

Source: Own elaboration.

The production structure is composed of sectors that produce and require intermediate inputs to produce. The intermediate input matrix (already noted as *Z*) thus captures the bi-sectoral transactions (and also bilateral ones in the case of MRIOT and regional matrices such as the IOT SA) in intermediate inputs, which are products used in the production of other products; where Z_{ij} are the domestic intermediate inputs of sector row *i* destined to sector column *j*. This is a square matrix, where the number of sectors is the same for rows and columns. As a rule, domestic matrices only have a *1xN* vector of imported intermediate inputs that includes the total of inputs that each domestic sector imports without declaring the sector of origin of the inputs. However, in the case of regional matrices such as the ECLAC and multi-regional IOT, the intermediate input matrix can be subdivided into domestic (Z^D) and imported (Z^M) intermediate inputs by country and sector if the input-output table has disaggregated them.

The value-added matrix (already noted as *GVA*) shows the remuneration of the factors of production (compensation of employees for the labor factor and gross operating surplus for capital). In other words, the value-added matrix details the share of primary inputs (labor and capital) in the output of a sector. Note that the gross operating surplus usually includes mixed income, which in turn aggregates the profits of public companies, intervened companies, private companies, interest collected by government and households, and rents received or imputed.

Final demand (*y*) is composed of Final Consumption (*C*), which in turn can be divided into private consumption and public consumption/expenditure, Gross Capital Formation (*GCF*) and Exports (*e*). In the case of national tables (SRIO) the exports capturing final demand are total sums; MRIOT and regional input-output tables (RIOT) that capture trade in intermediate goods and services such as the IOT SA, final demand captures final exports. Intermediate exports are transferred to the intermediate input matrix (see Diagram 4). When working with national matrices from the IOT SA, this fact must be taken into account, since information on intermediate and final exports will be combined. Finally, by accounting identity, total employment equals total resources, reflecting the GVP or total production of an economy, by sector.

Diagram 4
Regional and Multiregional Input-Output Table Structure
(Simplified version)

RIOT

	Intermediate consumption				Final demand				
	Country A	Country B	Country C	RoW	Country A	Country B	Country C	RoW	Output total
Country A	$Z^{A,A}$	$Z^{A,B}$	$Z^{A,C}$		$Y^{A,A}$	$Y^{A,B}$	$Y^{A,C}$	$R^{A, RoW}$	Output ^{A}
Country B	$Z^{B,A}$	$Z^{B,B}$	$Z^{B,C}$		$Y^{B,A}$	$Y^{B,B}$	$Y^{B,C}$	$R^{B, RoW}$	Output ^{B}
Country C	$Z^{C,A}$	$Z^{C,B}$	$Z^{C,C}$		$Y^{C,A}$	$Y^{C,B}$	$Y^{C,C}$	$R^{C, RoW}$	Output ^{C}
Rest of World (RoW)	$Z^{RoW,A}$	$Z^{RoW,B}$	$Z^{RoW,C}$						
Freight and insurance	FI^{A}	FI^{B}	FI^{C}						
Total intermediate consumption	TI^{A}	TI^{B}	TI^{C}						
Value added (basic prices)	VA^{A}	VA^{B}	VA^{C}						
Output total	Output ^{A}	Output ^{B}	Output ^{C}						

Satellite accounts	s^{A}	s^{B}	s^{C}

Diagram 4 (concluded)

MRIOT

	Intermediate consumption				Final demand				
	Country A	Country B	Country C	RoW	Country A	Country B	Country C	RoW	Output total
Country A	$Z^{A,A}$	$Z^{A,B}$	$Z^{A,C}$	$Z^{A,RoW}$	$Y^{A,A}$	$Y^{A,B}$	$Y^{A,C}$	$Y^{A, RoW}$	Output ^{A}
Country B	$Z^{B,A}$	$Z^{B,B}$	$Z^{B,C}$	$Z^{B,RoW}$	$Y^{B,A}$	$Y^{B,B}$	$Y^{B,C}$	$Y^{B, RoW}$	Output ^{B}
Country C	$Z^{C,A}$	$Z^{C,B}$	$Z^{C,C}$	$Z^{C,RoW}$	$Y^{C,A}$	$Y^{C,B}$	$Y^{C,C}$	$Y^{C, RoW}$	Output ^{C}
Rest of World (RoW)	$Z^{RoW,A}$	$Z^{RoW,B}$	$Z^{RoW,C}$	$Z^{RoW,RoW}$	$Y^{RoW,A}$	$Y^{RoW,B}$	$Y^{RoW,C}$	$Y^{RoW,RoW}$	Output ^{RoW}
Freight and insurance	FI^{A}	FI^{B}	FI^{C}	FI^{RoW}					
Total intermediate consumption	TI^{A}	TI^{B}	TI^{C}	TI^{RoW}					
Value added (basic prices)	VA^{A}	VA^{B}	VA^{C}	VA^{RoW}					
	Output ^{A}	Output ^{B}	Output ^{C}	Output ^{RoW}					
Satellite accounts	s^{A}	s^{B}	s^{C}	s^{D}					

Source: Own elaboration based on the IOT SA (ECLAC, 2016).

From the information provided by the intermediate input matrix *Z*, the technical coefficients can be obtained, which will be used to calculate the inverse Leontief matrix, the fundamental axis of the input-output analysis. The technical coefficients (a_{ij}) indicate the quantity of input of branch *i* (first subscript - row) necessary to produce one unit of output of sector *j* (second subscript - column).

$$a_{ij} = \frac{Z_{ij}}{x_j} \tag{1}$$

To understand the logic behind this methodology and to develop the indicators proposed here, basic knowledge of matrix algebra is necessary, which is taken for granted in this handbook. In matrix form, let' s assume an economy composed of three sectors:

$$A = Z\hat{x}^{-1} = \begin{bmatrix} Z_{11} & Z_{12} & Z_{13} \\ Z_{21} & Z_{22} & Z_{23} \\ Z_{31} & Z_{32} & Z_{33} \end{bmatrix} \begin{bmatrix} \frac{1}{x_1} & 0 & 0 \\ 0 & \frac{1}{x_2} & 0 \\ 0 & 0 & \frac{1}{x_3} \end{bmatrix} = \begin{bmatrix} \frac{Z_{11}}{x_1} & \frac{Z_{12}}{x_2} & \frac{Z_{13}}{x_3} \\ \frac{Z_{21}}{x_1} & \frac{Z_{22}}{x_2} & \frac{Z_{23}}{x_3} \\ \frac{Z_{31}}{x_1} & \frac{Z_{32}}{x_2} & \frac{Z_{33}}{x_3} \end{bmatrix} = \begin{bmatrix} a_{11} & a_{12} & a_{13} \\ a_{21} & a_{22} & a_{23} \\ a_{31} & a_{32} & a_{33} \end{bmatrix}, \tag{2}$$

where *Z* is the matrix of domestic intermediate inputs, $\hat{x}^{-1}$ is the diagonalized and inverted Gross Value of Production vector, and *A* is the *NxN* matrix of domestic technical coefficients, referring to the direct requirements of an economy per unit of output produced. Derived from the intermediate input matrix, the elements of *A* show the direct contribution of a sector *i* in the production of a given output of a sector *j*. Thus, a row reading indicates the intermediate inputs of the head of row sector (first subscript) that are used in all other sectors *j* of the economy per unit of sector *j* output. A column-wise reading indicates the intermediate inputs of the remaining sectors *i* of the economy that the column-header sector (second subscript) *j* uses to produce one unit of output. Note that, to produce a product, a sector may require inputs from within the sector itself. As a general rule, unless otherwise specified, *A* will be domestic technical coefficients A^D. In the case of having RIOT and MRIOT, to calculate the imported technical coefficients A^M we proceed to the same calculation as in Equation (2)using the matrix of imported intermediate inputs Z^M.

Once the technical coefficients have been obtained, the inverse Leontief matrix $(I - A)^{-1}$, a key element of the input-output analysis, is calculated:

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

Although *A* includes the direct requirements, in a national model, $(I - A)^{-1}$ includes the total domestic requirements, direct and indirect, of the different sectors that are necessary to satisfy one monetary unit destined to the final demand (see Equation (3)). An example for 3 sectors would be:

$$L = \begin{bmatrix} l_{11} & l_{12} & l_{13} \\ l_{21} & l_{22} & l_{23} \\ l_{31} & l_{32} & l_{33} \end{bmatrix} \tag{4}$$

The idea behind the Leontief inverse is that the inputs required by one sector in turn needed inputs from this and other sectors to produce, and so on, in the different rounds of production. In this case, *I* is the identity matrix, a square diagonal matrix whose dimensions coincide with those of the technical coefficients.

The key equation of the input-output analysis is captured in equation (5), which uses the Leontief inverse. This is the so-called Leontief Open Model (Miller and Blair, 2009), where *x* is the total output, which is equal to the Leontief inverse $(I - A)^{-1}$ times a vector of final demand, *y*. It reflects how the output of a country or region depends on final (exogenous) demand:

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

From the above expression one can calculate the increase in output (Δx) that would result from an increase in final demand (Δy) in the economy (Equation(6)). Practical examples are given later on (see Section II.F):

$$\Delta x = (I - A)^{-1} \Delta y \tag{6}$$

The Leontief inverse matrix $(I - A)^{-1}$ is a multiplier that reports how much the production of the whole economy has to increase to meet a given increase in final demand. Thus, in matrix form the generic element of the Leontief inverse matrix l_{ij} captures the total requirements from sector *i* (first subscript) to produce one unit of output of sector *j* (second subscript) that can go to final demand. Equation (7) is an illustrative example of a three-sector economy:

$$x = (I - A)^{-1} y = \begin{bmatrix} l_{11} & l_{12} & l_{13} \\ l_{21} & l_{22} & l_{23} \\ l_{31} & l_{32} & l_{33} \end{bmatrix} \begin{bmatrix} y_1 \\ y_2 \\ y_3 \end{bmatrix} = \begin{bmatrix} x_1 \\ x_2 \\ x_3 \end{bmatrix} \tag{7}$$

Specifically, a columnar reading of the Leontief inverse reports the total direct and indirect effect on output of the exogenous increase of one unit of final demand in a sector. That is, it considers vertically integrated sectors (Pasinetti, 1973). A row reading refers to the observable sectors, i.e. the transfers of inputs that a sector *i* provides to the rest of the economy. The significance of the Leontief inverse is that it considers *(i)* the unit increase in final demand, *(ii)* the inputs directly needed to produce that unit of final output, *(iii)* the inputs needed at the previous stage of production to produce the direct inputs, and so on.

A. Regional Input-Output Tables: Latin America's IOT

Every input-output table includes international trade. National IOT (SRIOT) include the intermediate imports necessary for a region's domestic production, as well as total exports (see Diagram 3, Z^M and *e*). Here, trade is understood as an exogenous variable, not included in inter-industry relations. To explain Leontief's logic, we have started from a model catalogued as SRIO (*Single Regional Input-Output*) that considers a single economy or region (Miller and Blair, 2009), given that historically this tool was mainly intended for the analysis of national economic structures. However, the IOT prepared by ECLAC are regional IOT (*regional input-output table*, RIOT), which together with the *multi-regional* ones (MRIOT) endogenize part or all of the international trade in intermediate goods and services, respectively, capturing interregional intersectoral relations. Any regional input-output table, when considering international trade between regions and/or countries, requires three main sources: *i)* the National Accounts statistics of each country involved (Supply and Use Tables or IOT), *ii)* bilateral trade data, *iii)* information or assumptions about the origin of international trade in intermediate goods. The Leontief logic is maintained: regardless of the tables used, the matrix algebra is the same, although national, regional or global Leontief inverses are obtained depending on which matrix is used. In this document we will calculate indicators on the RIOT prepared by ECLAC, as well as with the MRIOT, carrying out calculations oriented to all levels: national, regional and global or multiregional.

For this paper we have used the data from the *Regional Input-Output Table of South America* (IOT SA) for 2005, published by ECLAC and the Institute of Applied Economic Research of Brazil (IPEA) in 2016, as well as additional work developed by ECLAC to update the IOT of South America from 2005 to 2011 and 2014, and to expand the coverage of countries that comprise it. The current Latin American IOT includes, in addition to the IOT of the ten original South American countries, the IOT of Mexico, the Dominican Republic, and a set of Central American countries (Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, and Panama). All the IOT available for the countries and subregions of Latin America offer useful data for the analysis of regional production chains in a region where no multi-country IOT previously existed. The set of IOT that ECLAC has produced (national, subregional and the Latin American IOT) are publicly available and can be downloaded, together with the methodological handbook, from the ECLAC Trade and Integration Division website.

The South American IOT (2005 and 2011) shows the productive and trade relations between 10 countries in the region: Argentina, Bolivia (P.S)., Brazil, Chile, Colombia, Ecuador, Paraguay, Peru, Uruguay and Venezuela (B.R.), while the Latin American IOT, shows relation between 18 countries.[1] All IOT have a structure of 40 sectors with transactions valued in basic prices and openness of intermediate inputs (intermediate utilization) in total domestic and imported value (both intraregional and extraregional intermediate inputs), as well as vectors of final exports by country and region.

The results of this handbook present examples of indicators calculated with the South American IOT for 2005, 2011 and 2014, as well as the Latin American IOT, or national IOT available for more recent years. Throughout the handbook, specific examples will be given depending on the case of the indicator being explained.

Diagram 4 illustrates the structure of Latin America's regional IOT (Andean Community IOT, MERCOSUR IOT, Pacific Alliance IOT, and South American IOT). The reading of this table is similar to the example presented above (seeDiagram 3). In this case, the main diagonal of the intermediate demand matrix *Z* provides the domestic intermediate inputs ($Z^{A,A}$ $Z^{B,B}$ $Z^{C,C}$), matrices of *NxN* sectors similar to the SRIOT with which the domestic technical coefficients of each country are calculated, as

[1] The countries considered are: Argentina, Bolivia (P.S.), Brazil, Colombia, Costa Rica, Chile, Dominican Republic, Ecuador, El Salvador, Guatemala, Honduras, Mexico, Nicaragua, Panama, Paraguay, Peru, Uruguay, and Venezuela (B.R.).

reflected in Equation (2). Outside the main diagonal are reflected the imported inputs both from South American countries and from the rest of the world (Rdm). Thus, in the example of Diagram 4, Country A imports inputs from countries B and C of the region and inputs from the rest of the world ($Z^{B,A}$ $Z^{C,A}$ $Z^{Rdm,A}$). Recall that for both subscripts (generally sectors) and superscripts (countries or regions), the first element reports the origin and the second the destination of the transactions. In this sense, $Z^{B,A}$ are inputs coming from country B (exported) that are received (imported) by country A. This nomenclature applies to the entire document except for Section IV, paragraph C.

For example, from the expenditure perspective, sector 2 of Country A uses outputs from sector 1 of its own economy as inputs to its production process $Z_{1,2}^{A,A,}$ employing labor and capital, captured by the value added GVA_2^{A} to produce an output valued at GVP_2^{A}. From the income perspective, the output produced can be destined to satisfy the intermediate demand of the same country ($Z^{A,A}$) or others ($Z^{A,B}$ $Z^{A,C}$) or satisfy final demand, either being consumed by domestic demand ($Y^{A,A}$=C+GCF) or exported to the world ($Y^{A,B}$ $Y^{A,C}$ $R^{A,Rdm}$, with Y being final exports and R total exports), and therefore not used in the production process. Another example focusing on the regional IOT, the footwear sector of the Argentine economy (ARG) imports Brazilian products (BRA) as intermediate inputs, for example from the $Z_{textile,footwear}^{BRA,ARG}$, which transforms or improves using labor and/or capital factor by value $GVA_{footwear}^{ARG}$ and produces an output valued at $GVP_{footwear}^{ARG}$. These properties of the table make it possible to decompose the content of both domestic and imported value added, also distinguishing the origin of the inputs incorporated in production, and/or their destination.

In this document, "regional" refers to exports, imports or value added that refer to the countries of the regional input-output table, while "foreign" or "extra-zone" refers to the rest. The RIOT does not make all interregional transactions endogenous (see Diagram 4). Lacking information on the intermediate consumption that the region exports to the "rest of the world", as well as extra-regional intermediate consumption and regional imported final demand from abroad (from outside the region), the table is halfway between a national and a multi-regional IOT. Analyses on trade indicators (imported inputs over GDP, vertical specialization) can be developed from the national or SRIO perspective, with the advantage of having additional information on countries in the region and the rest of the world, with which to expand the typical indicators of SRIO analysis. This type of RIOT can be seen in examples such as the one developed by the Asia Development Bank (ADB, 2015), the *Institute of Developing Economies, Japan External Organization* (IDE-JETRO, 2005), *China 30-Province Inter-Regional Input-Output Table (*Liu et. al, 2014) or the Economic Commission for Latin America and the Caribbean (ECLAC, 2016).

Notwithstanding the outstanding properties of the regional IOT and the set of national IOT linked to it, it is necessary to clarify that it is an incomplete MRIOT, since it is not closed to the world (see Diagram 4). Thus, the Latin American RIOT (IOT LA) could be defined as an open model of eighteen regions, or *Ten-Region Open Model (*Nakamura, 2009; Miller and Blair, 2009). Analyses on trade indicators can be developed from the national or SRIO perspective, with the advantage of having additional information on countries in the region and the rest of the world, with which to expand the typical indicators of SRIO analysis. Lalanne has developed an adaptation of measures or indicators for the case of RIOT, such as: measures of value added in exports, measures of the importance of production in regional value chains, measures to characterize bilateral exports, and measures to characterize the position of a country-sector in the chains (Lalanne, 2020). Together with MRIOT-oriented handbooks (Ahmad et al., 2017; Arto, I., et al. 2019), the reader will find indicators and methodological proposals to study GVC in their full breadth.

The exhaustive study of GVC in this IOT cannot be developed, due to the limitations previously explained. In order to overcome these limitations, ECLAC is currently working on a project whose main objective is to expand the coverage of the region's IOT and its link with other regions of the world, mainly Asia and the Pacific, the European Union, as well as a set of partners of interest beyond these sub-regions. To this end, the Latin American IOT is made compatible with the multi-country IOT of the

Asian Development Bank (ADB), as well as with the information of the Organization for Economic Cooperation and Development (OECD). The critical route to achieve that purpose consists of homogenizing the sectors of the various initiatives to reach the same set of sectors that will allow, after a process of validation of foreign trade figures, the reconciliation of statistics from all initiatives in a new global IOT. That one will have as its main virtue to allow broader analyses of value chains, and productive fragmentation for countries in both Latin America and Asia Pacific among themselves and with the world (Durán, 2019). However, the regional IOT, as well as the South American IOT and those of the main sub-regions (Andean Community, MERCOSUR, Central America, and the Pacific Alliance), offer two main advantages: *i)* the production and trade of these regions are defined by primary and extractive activities, although the main MRIO databases aggregate these sectors, in favor of a greater sectoral disaggregation into manufacturing and service activities. The assembly of all these IOT considered the specific characteristics of the region/subregions when making a representative sectoral disaggregation, with which more precise sectoral analyses can be established; *ii)* in addition, the rest of the IOT databases do not generally include most Latin American countries. Therefore, regional and subregional IOT are ideal for studying regional integration.

Finally, it should be noted that in addition to the construction of the regional IOT, ECLAC has compiled vectors of employment (by qualification and gender) and CO_2 emissions consistent with the production of each country in the region, and with the same openness as the main tables (40 sectors). In this way, it is possible to calculate employment linked to final demand and its components (consumption, investment and exports), as well as emissions embedded in production, covering topics related to social and environmental issues, i.e. sustainable development. These satellite accounts are in permanent development and are available to the public upon request to the International Trade and Integration Division of ECLAC.

B. Multi-Regional Input-Output Table (MRIOT) Databases

In addition to the 2005 South American IOT and the 2011 and 2014 Latin American IOT, this handbook considers as a complementary source analyses with multiregional and global IOT. Both types of IOT are the main source of the analyses presented in the following sections. Multiregional IOT are based on the input-output methodology as are regional ones, although each has its own particularities. The data sets of these matrices differ mainly in three aspects: *i)* the construction methodology and the primary sources used. Although the IOT are derived from the supply and use tables and the National Accounts, differences may arise between databases; *ii)* the methods and information available for allocating imported intermediate inputs to sectors that use them; and *iii)* the coverage of countries, sectors or products and years.

During the 2018-2020 triennium, the Economic Commission for Latin America and the Caribbean together with the Economic and Social Commission for Asia and the Pacific (ESCAP) developed the project "Development of value chains for deeper integration between Latin America and Asia Pacific". From this project, Global IOT (MRIOT) were constructed. These include the IOT previously developed by each institution: the multi-country IOT of the Asian Development Bank and the South American IOT assembled for 2005, as well as the IOT for Latin America and the Caribbean 2011 and 2014, assembled by ECLAC. The new IOT constitute a powerful tool for the development of public policies and the promotion of global and regional value chains. They disaggregate production for 20 sectors and include 71 economies, in addition to the Rest of Latin America and the Caribbean (ROLAC) and the Rest of the World, for the years 2007, 2011 and 2017. ROLAC in these matrices adds Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, Panama and Dominican Republic.

In addition, a IOT for 2011 has been released to the public that includes 25 sectors and 78 economies plus the Rest of the World. This IOT disaggregates all countries in the ROLAC group and is consistent with the new Asian Development Bank IOT covering 38 economic sectors. The files made public include a correlation table between the World Input-Output Database (WIOD), ECLAC and ADB initiatives.

The following is a schematic presentation of the main databases in force that include input-output tables at the multiregional level. The presence of some of the Western Hemisphere countries (Canada, the US, and Latin America and the Caribbean) stands out in these databases (see Table 1).

This table also presents all the IOT that have been produced by ECLAC as part of the projects: "Input-Output Table for Industrial Policy in Latin America and the Caribbean", and "Development of value chains for deeper integration between Latin America and Asia-Pacific". As a result of the first project, ECLAC extended the IOT from South America to the entire region, including Mexico, Central America and the Dominican Republic. Likewise, among the extra-regional partners, sixteen new Asia Pacific partners were opened: Australia, Brunei, Cambodia, Japan, China, Republic of Korea, Philippines, Indonesia, Japan, Laos, Malaysia, Thailand, Malaysia, Mongolia, New Zealand, Myanmar, Singapore, and Vietnam. To these partners are also added a set of partners of interest to Latin America, CARICOM, Cuba, United States, Canada, European Union 28, and Rest of Asia and Rest of the World, a set of partners that were already included in the first South American IOT (ECLAC, 2016).

These matrices can be used to calculate more advanced indicators with a higher degree of decomposition that present detailed information on the characteristics that define the phenomenon of the international fragmentation of production embodied in the GVC. In addition, the vast majority of the databases presented in Table 1 offer some form of satellite accounts, socioeconomic and environmental accounts, with vectors on employment, materials used, air emissions, land use, and other factors. Depending on the specific needs of the researcher, technician or official, these databases can serve as the main tool or as a complement for value chain analysis in Latin America and the Caribbean.

Table 1
Regional and Multi-Regional Databases of MRIO (Multi-Regional Input-Output)

Databases	Regions	Western Hemisphere Countries	Sectors	Years
World Input-Output Database (WIOD)	41 44	Canada, Brazil, United States, and Mexico	35 56	1995-2011 2000-2014
Inter-Country Input-Output Tables ICIO-OECD	61	Argentina, Brazil, Canada, Chile, Colombia, Costa Rica, Mexico, Peru and the United States	34	1995-2011
	64	Argentina, Brazil, Canada, Chile, Colombia, Costa Rica, Mexico, Peru and the United States	36	2005-2015
	66	Argentina, Brazil, Canada, Chile, Colombia, Costa Rica, Mexico, Peru and the United States	45	1995-2018
Full International and Global Accounts for Research in input-Output analysis (FIGARO) EUROSTAT	46	Argentina, Brazil, Canadá, México and the United States	64	2010-2019
UNCTAD-Eora GVC Database	189	All except Anguilla, Dominica, French Guiana, Grenada, French Guiana, Montserrat, St. Vincent and the Grenadines, St. Lucia, St. Kitts and Nevis, Turks and Caicos Islands, Virgin Islands (U.S.), St. Vincent and the Grenadines, St. Vincent and the Grenadines, St. Vincent and the Grenadines, St. Kitts and Nevis, U.S. Virgin Islands	26	1990-2016
GTAP 10	141	United States, Canada, Mexico; Central America except Belize; South America except Guyana, French Guiana, Suriname; Caribbean: Jamaica, Dominican Republic, Puerto Rico	65	2004, 2007, 2011 2014
Asian International Input-Output Table 2005 IDE-JETRO	10	United States	7 26 76	2005
EXIOBASE	44 48	Canada, United States, Brazil, Mexico	129 163	2000 1995-2011
MRIOT FEALAC (CEPAL-ADB-ESCAP)	83 71	Canada, United States, Mexico, Argentina, Bolivia (Plurinational State of), Brazil, Colombia, Chile, Costa Rica, Dominican Republic, Ecuador, El Salvador, Guatemala, Honduras, Nicaragua, Panama, Paraguay, Peru, Uruguay, and Venezuela (Bolivarian Rep. of.)	20 25	2007, 2011, 2017

Table 1 (concluded)

Databases	Regions	Western Hemisphere Countries	Sectors	Years
Input-Output Table for South America ECLAC-IPEA	10	Argentina, Bolivia (Plurinational State of), Brazil, Colombia, Chile, Ecuador, Paraguay, Peru, Uruguay, and Venezuela (Bolivarian Rep. of.)	40	2005, 2011 y 2014
Latin America Input-Output Table	18	Argentina, Bolivia (Plurinational State of), Brazil, Colombia, Chile, Costa Rica, Dominican Republic, Ecuador, El Salvador, Guatemala, Honduras, Mexico, Nicaragua, Panama, Paraguay, Peru, Uruguay, and Venezuela (Bolivarian Rep. of.)	40	2011, 2014
Multi-Country Table Asian Development Bank	62	Brazil, Mexico	35	2011-2017
Multi-Country Table Asian Development Bank	71	Argentina, Bolivia (Plurinational State of), Brazil, Colombia, Chile, Ecuador, Mexico, Paraguay, Peru, Uruguay, and Venezuela (Bolivarian Rep. of.)	35 38	2011-2017
MERCOSUR Input-Output Table	5	Argentina, Brazil, Paraguay, Uruguay, and Venezuela (Bolivarian Rep. of.)	40	2005 y 2011
Input-Output Table of the Andean Community	4	Bolivia (Plurinational State of), Colombia, Ecuador, and Peru	40	2005, 2011, 2014
BRICS international Input-Output Table 2005 IDE-JETRO	7	Brazil and the United States	7 25	2005

Source: Own elaboration based on Jones, Powers, and Ubee (2013) and information available in official sites of ECLAC, GTAP, IDE-JETRO; ADB; OECD; EXIOBASE, WIOD, among others.

C. Assumptions and Limitations of the Input-Output Model

Due to the simplicity of its structure, the input-output model has the advantage of easily providing direct information on intra- and inter-sectoral linkages, as well as on the effects derived on the economy from the use of the model's multipliers. With this consideration in mind, it should be noted that the input-output model is based on a series of assumptions or hypotheses that we will see below (Schuschny, 2005):

- *Sectoral homogeneity assumption*: in symmetric IOT, each input is supplied by only one production sector. By means of the assumptions of product technology or industry technology, secondary productions are relocalized in the sectors where they are the main production. In other words, each sector produces a single product with the same input structure (Lora, 2008).
- *Relative price invariance assumption*: to homogenize the measurement of aggregates, input and output prices will remain invariant to the prices of a base year.
- *Strict proportionality hypothesis*: the quantity of intermediate inputs varies in the same proportion as output. This implies that the composition of the products of each sector is fixed, so that the production function of the Leontief model is linear, with fixed technical coefficients and constant returns to scale.
- *Additivity hypothesis*: it is assumed that the total effect of production in an economy is equal to the sum of the effects on sectoral production.

These assumptions, which form the basis for the simplicity and usefulness of the model, bring with them several limitations:

- Symmetric IOT prevent the analysis of the intra-sectoral value chain by homogenizing products/sectors in specific industries. Moreover, there is no possibility of input substitution. Intermediate inputs from all aggregated sectors are consolidated in a single industry.
- Fixed technical coefficients impose the assumption that all firms have the same production technology and the same efficiency levels, making economies of scale impossible.

- It does not consider the incorporation of durable goods within the IOT: capital goods (buildings, machinery, vehicles, etc.) that make up gross fixed capital formation are included in final demand, as finished products instead of primary factors with the capacity to contribute productivity.
- The matrices valued in monetary terms assume flows equivalent to the physical flows of goods and services, so that the price system is perfectly homogeneous. This is not the case in practice.

Although these limitations are not negligible, the advantages of the input-output model outweigh its shortcomings. The level of sectoral disaggregation it offers, the measurement of intersectoral linkages, its extensions and applications (structural decomposition, impact analysis, value chains, environmental and socioeconomic impacts), and above all its simplicity make the model important and it is now widely used.

II. Basic indicators

In this section, we focus on domestic or national matrices, which are represented in the main diagonal of regional and multi-regional IOT (e.g. $Z^{A,A}$, $Z^{B,B}$, etc.). The following indicators derived from an IOT will serve as a guide for practitioners and policy makers to generate valuable information that can be used to carry out policies to promote trade, boost industrial activity, or respond to the effects of changes in final demand. The calculations can be developed using any type of mathematical software (MATLAB, Stata, SAS, R, etc.). Similarly, through a less automated process, calculations can be developed using Microsoft Excel or any other spreadsheet application. Hereinafter, in this and subsequent sections, the proposed methodology for calculating the indicators will be complemented with their particular formalization, and in some cases some graphical reference will be presented that allows some suggested analytical interpretation. The ultimate goal will always be to equip the users of the handbook to reproduce the presented calculations for their own purposes.

The structural indicators presented in this section provide an overview of production, trade and sectoral linkages for a particular country, or for the region as a whole if presented and analyzed together. With these calculations, we can obtain information on GDP by country and sector, the weight of imported inputs over domestic inputs and GDP, backward and forward linkages, and the Rasmussen and Hirschman index. Although all calculations are usually aggregated by country, the same procedures can be applied to study specific sectors of the economy. As already indicated, they are also useful for the comparative analysis of the various countries in the region, so that patterns and typologies of countries and/or subregions (MERCOSUR, Andean Community, for example) can be identified.

A. Calculation of GDP by country and sector

At a first glance, the IOT provide information on GDP by country and sector: it is directly captured by the vector *1xN* of Gross Value Added at basic prices (GVA), where *N* is the number of sectors. Both for the calculation of GDP and for future calculations related to value added, the Value Added per unit produced (*V*) is presented as the vector of gross value added (*GVA*) *1xN* divided by the gross value of production. Note that here, as *GVA* is a vector and not a matrix, the vector *x* does not have to be diagonalized like in the calculation of the technical coefficients. This is an example of a factor, as can also be the number of employees or the CO_2 emissions of the industrial sectors, which we will see in Chapter V and whose treatment is the same as the one presented here:

$$V = VABx^{-1} = \begin{bmatrix} \frac{VAB_1}{x_1} & \frac{VAB_2}{x_2} & \dots & \frac{VAB_N}{x_N} \end{bmatrix} \tag{8}$$

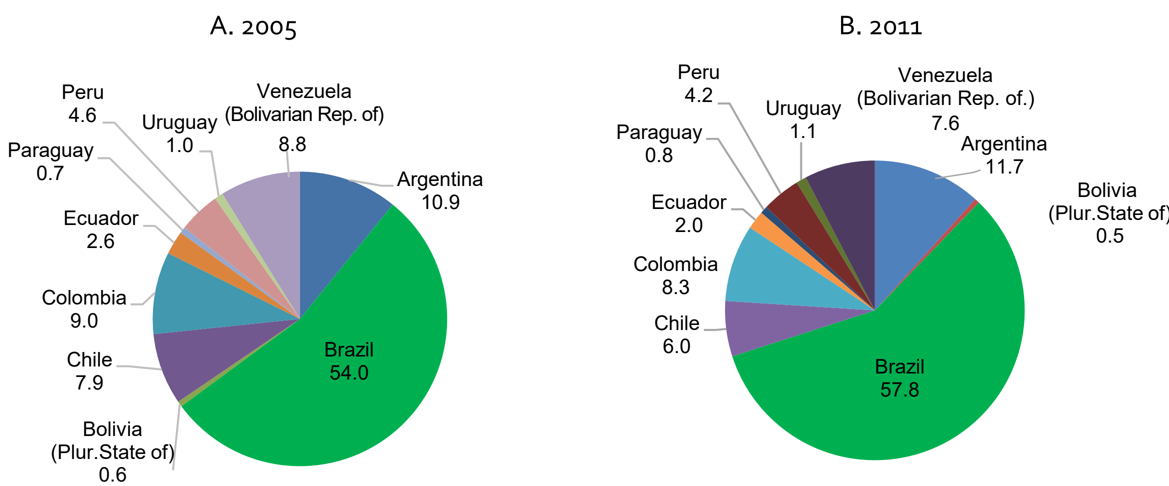
The sum of the GVA of the sectors gives the country's GDP. GVA encompasses the total contribution of factors in all branches of a country's or region's economy to the production of goods and services that will ultimately be consumed (both domestically and for foreign consumption). However, as a first exercise in approximating the input-output methodology, GDP is calculated as shown in the following table:

$$PIB_p = V(I-A)^{-1}y = [V_1 \quad V_2 \quad \dots \quad V_N] \begin{bmatrix} l_{11} & l_{12} & \cdots & l_{1N} \\ l_{21} & l_{22} & \cdots & l_{2N} \\ \vdots & \vdots & \ddots & \vdots \\ l_{N1} & l_{N2} & \cdots & l_{NN} \end{bmatrix} \begin{bmatrix} y_1 \\ y_2 \\ \vdots \\ y_N \end{bmatrix}, \tag{9}$$

where the GDP of a country is the result of pre-multiplying *V* of equation (8) by the domestic Leontief inverse, multiplied by the final demand *y*, of country *p*. As a reminder for the reading of the Leontief inverse, the element l_{1N} represents the total domestic requirements, direct and indirect, that sector *N* needs from sector 1 to produce a unit of final product that satisfies the final demand. Following the logic of matrix algebra and since in this case the value added coefficient *V* and the final demand *y* have not been diagonalized, the result of the equation is a single value representing the country's GDP.

Figure 1 shows the results of the GDP calculation by South American countries, with Brazil as the main economy in the region, followed by Argentina and Colombia. In 2005, these three countries accounted for 73.9% of South America's GDP. This relationship is maintained in 2011, with the particularity that there is an increase in the participation of Argentina and Brazil, and their closest neighbors, Paraguay and Uruguay, while the rest of the countries showed a reduction in participation.

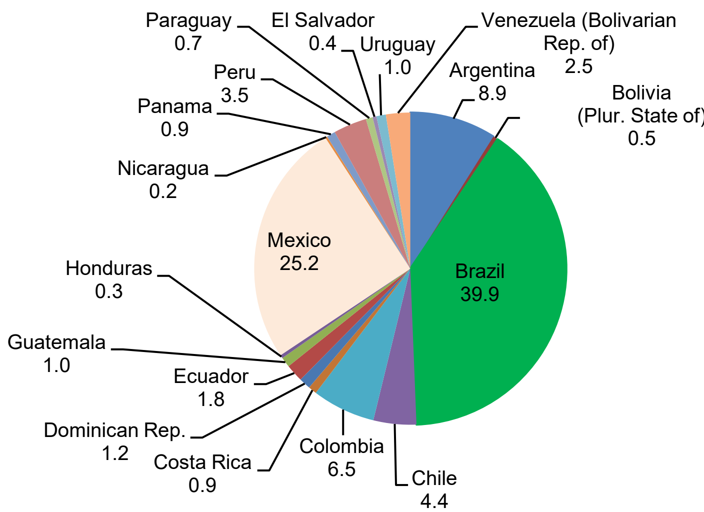
Figure 1
South America: GDP by country, 2005 and 2011
(Millions of dollars and percentages)



Source: Own elaboration based on IOT SA.

Figure 2 shows the GDP distribution of the eighteen countries in the region in 2014, including Mexico and Central America. There, Mexico accounts for 25% of Latin American GDP, and Brazil is the country with the largest share of the regional product (almost 40%). Argentina and Colombia follow with shares over 5% (8.9% and 6.5% of GDP, respectively). Among the Central American countries, Guatemala, Costa Rica, and Panama report a GDP of around 1%. The smallest countries in the region that are part of the regional IOT are Nicaragua, Honduras, and El Salvador, with GDP below 0.5% (see Figure 2).

Figure 2
Latin America: GDP by country, 2014
(Millions of dollars and percentages)



Source: Own elaboration based on IOT LA.

Equation (10) provides results at the sectoral level. The result is a vector *Nx1* that shows the contribution of each sector to the GDP of the economy. The matrix *V* this time has been diagonalized. The Leontief inverse shows no change with respect to Equation (3). This calculation is a useful comprehension exercise to understand the functioning of the IOT and the procedures arising from the successive indicators. Using the diagonalized final demand vector we would have an *NxN* matrix whose sum by rows would yield the same results.

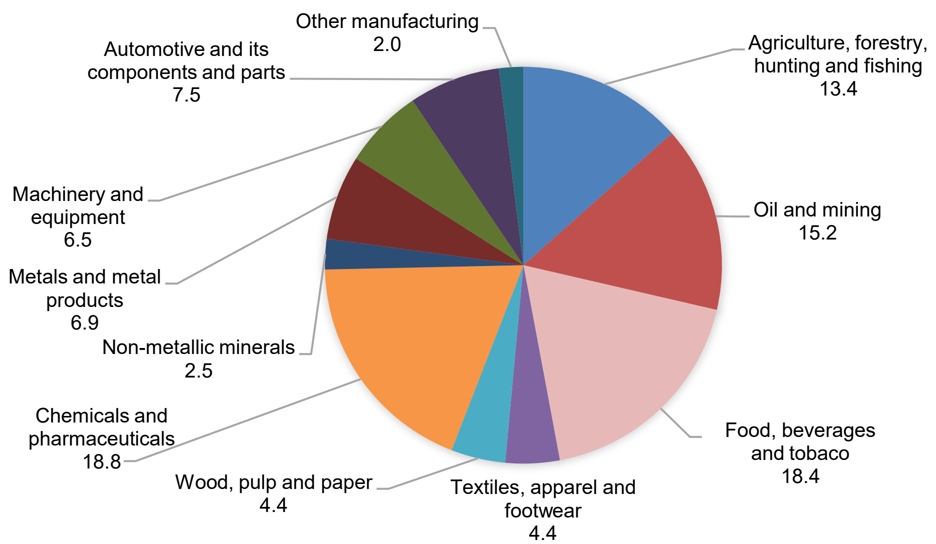
$$\begin{bmatrix} PIB_1 \\ PIB_2 \\ \vdots \\ PIB_N \end{bmatrix} = \begin{bmatrix} V_1 & 0 & \cdots & 0 \\ 0 & V_2 & \cdots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \cdots & V_N \end{bmatrix} \begin{bmatrix} l_{11} & l_{12} & \cdots & l_{1N} \\ l_{21} & l_{22} & \cdots & l_{2N} \\ \vdots & \vdots & \ddots & \vdots \\ l_{N1} & l_{N2} & \cdots & l_{NN} \end{bmatrix} \begin{bmatrix} y_1 \\ y_2 \\ \vdots \\ y_N \end{bmatrix} \quad (10)$$

At the sectoral level, Figure 3 shows the sectoral contribution to South American GDP in 2005 and 2014. For ease of graphical representation, and for illustrative purposes, this figure has aggregated the 40 IOT sectors into 12 broad categories, and the 7 service sectors are shown separately. Focusing attention on the example of Argentina, the country stands out for generating greater value added in services. Sixty-two percent of economic activity in the region comes from services related to tourism, business services, finance and insurance, transportation, construction, electricity and gas, and other services. In developed economies the weight of services ranges around 70% of GDP (Lanz and Maurer, 2015). The weight of primary and extractive sectors also defines the productive structure of the region: agriculture, livestock and fishing, food, beverages and tobacco, as well as mining, accounted for 17.8% and 15.1% of South American GDP in 2005 and 2014, respectively.

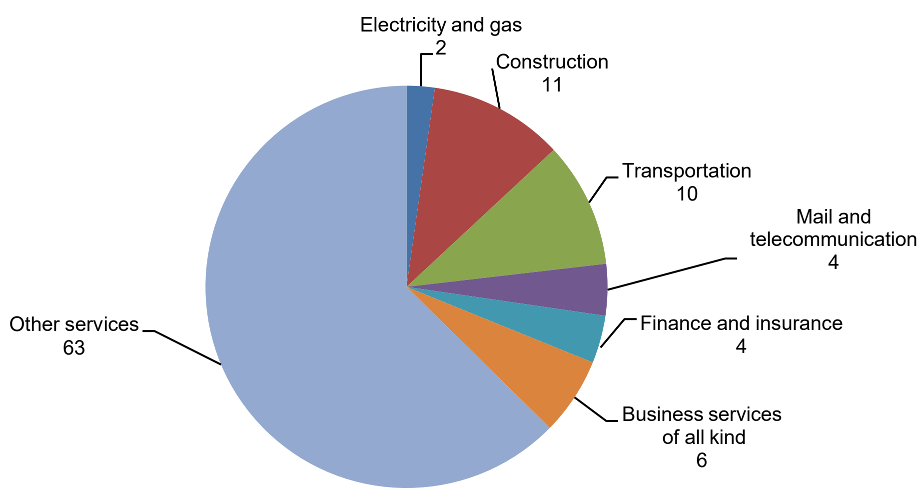
Figure 3
South America: GDP by sector
(Percentages)

A. 2005

Goods: 38%

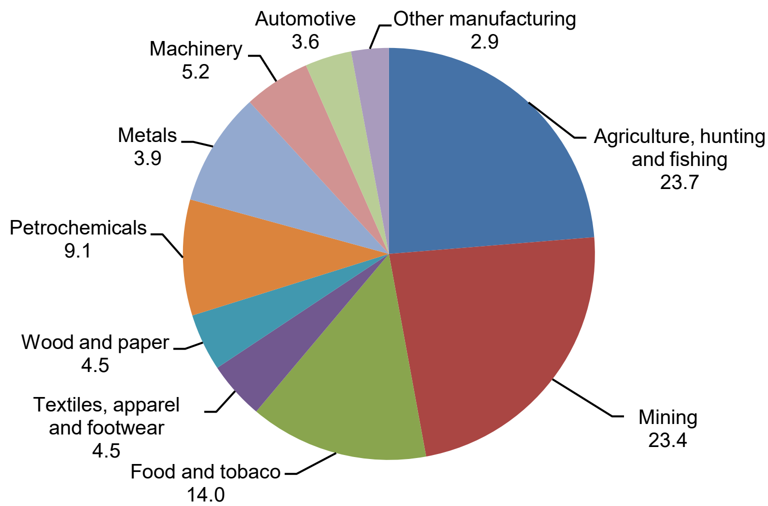


Services: 62%

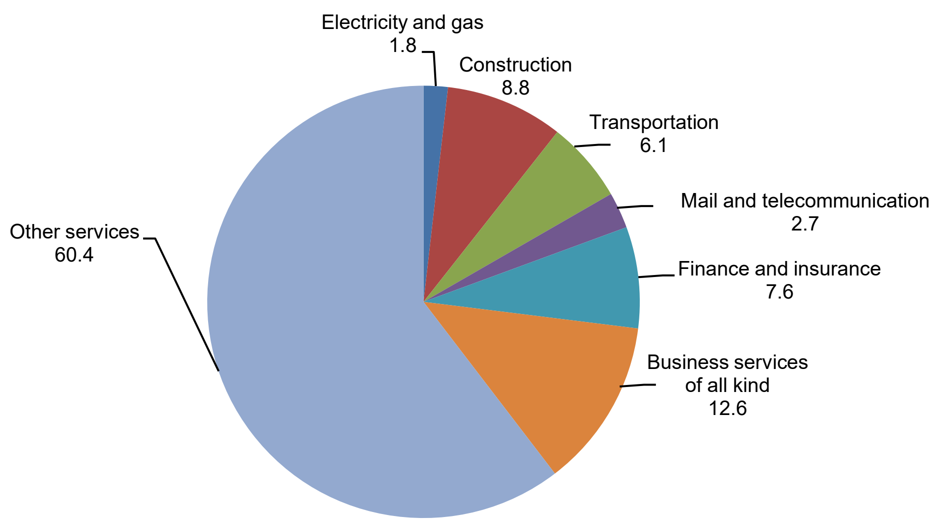


B. 2014

Goods: 25%



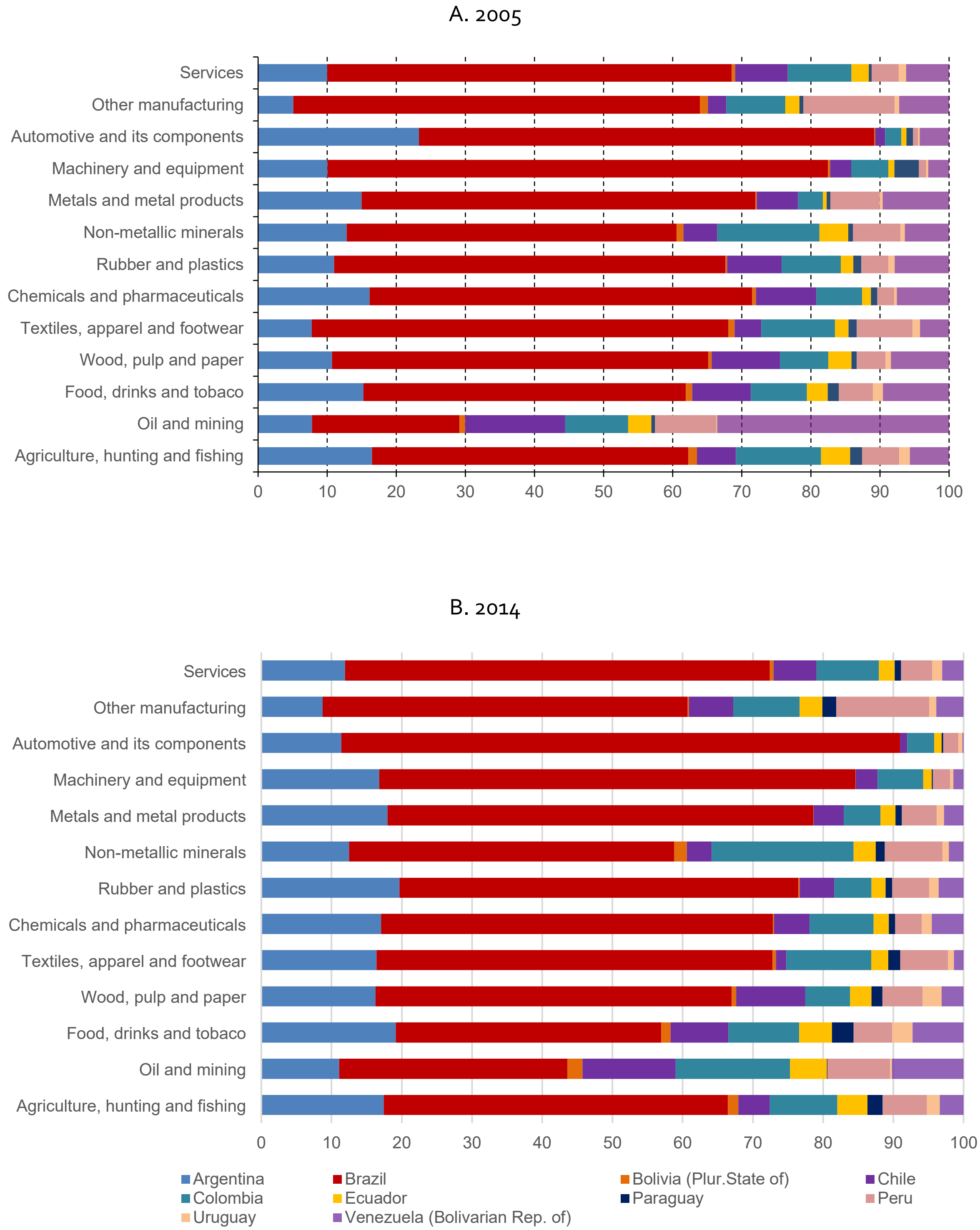
Services: 75%



Source: Own elaboration.

Brazil takes a predominant position in the South American economy when observing the participation of each country in thirteen large aggregate sectors (Figure 4). The 66% of the GDP generated by the Automotive and parts sector comes from the South American giant. Also noteworthy is the Brazilian participation in Textiles, clothing and footwear (60%), Services (59%) and Other manufacturing (59%). Brazil's smallest share is in the Oil and mining sector (21% of South American GDP). Venezuela (B.R.) (oil), as well as Chile, Peru (copper) and Colombia (coal and oil), together account for 66% of the sector's GDP in South America.

Figure 4
South America: sectoral share of GDP by country of origin, 2005 and 2014
(Percentages)



Source: Own elaboration based on IOT LA.

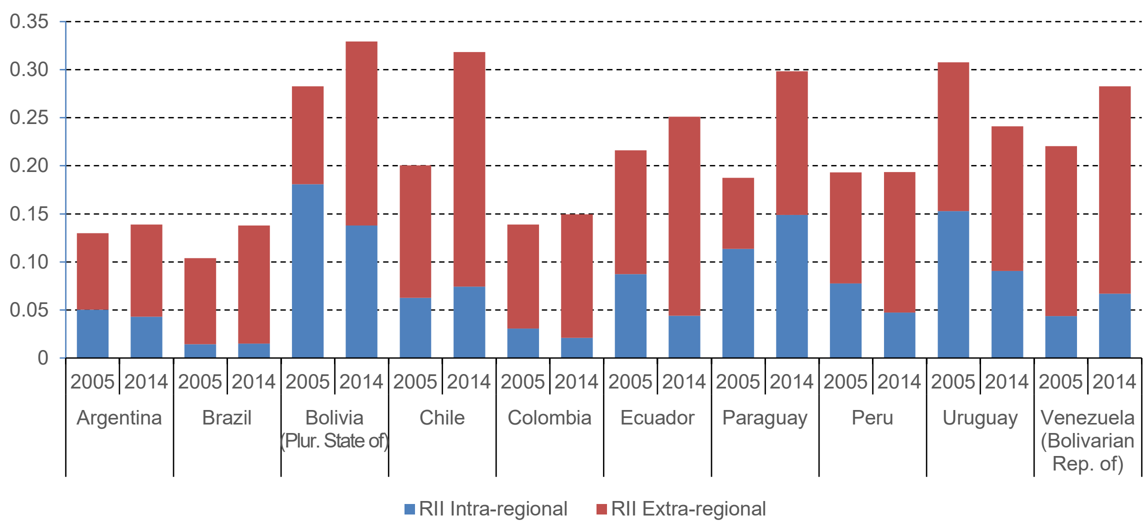
B. Ratio of imported inputs over domestic inputs

This indicator (RII) serves to compare the value of imported and domestic intermediate inputs used in the production of a country *p*. The inputs, both imported and domestic, are the direct requirements of a given economy, i.e. they do not take into account the indirect requirements that are also captured by the Inverse Leontief matrix. An *RII* result greater than one indicates that imported intermediate inputs have a higher share than domestic inputs in the total inputs of the country/sector, or vice versa, if the ratio is below one.

$$RII_p = \frac{\sum_{i=1}^{N}\sum_{j=1}^{N} z_{ij}^{M}}{\sum_{i=1}^{N}\sum_{j=1}^{N} z_{ij}^{D}}, \quad (11)$$

where the numerator is a value representing the sum total of the *NxN* matrix of imported intermediate inputs Z^M, where *i* and *j* are the row and column sectors, respectively. The denominator value is the sum of domestic inputs Z^D. Figure 5 shows the *RII* for the set of South American countries in 2005 and 2014, with an additional decomposition of the content of imported inputs of intraregional and extraregional origin, to determine the weight of the South American market as a source of imported inputs. Several insights can be drawn from the figure: i) in 2005, except for Uruguay, all South American countries have seen their dependence on imported inputs increase; ii) with the exception of Venezuela (B.R.), the share of extra-regional imported inputs in total imported inputs has increased considerably, reflecting possible shortcomings in regional integration. While already in 2005 countries such as Brazil and Colombia were importing extra-regional intermediate inputs, countries that seemed more integrated in 2005 such as Bolivia (P.S.) or Paraguay have shifted in 2014 to require a higher share of inputs from outside South America; iii) currently, Bolivia (P.S.), Chile and Paraguay are the South American countries that import more inputs per domestic input produced: between $0.3 and $0.33 of imported inputs are required for each dollar of domestic input required by these economies. The lowest dependence is observed in Brazil, Argentina, and Colombia. In these three countries, the ratio of extra-regional inputs is much higher than in the rest of the South American countries.

Figure 5
Ratio of imported inputs to domestic inputs in South American countries



Source: Own elaboration based on the IOT SA and IOT LA.

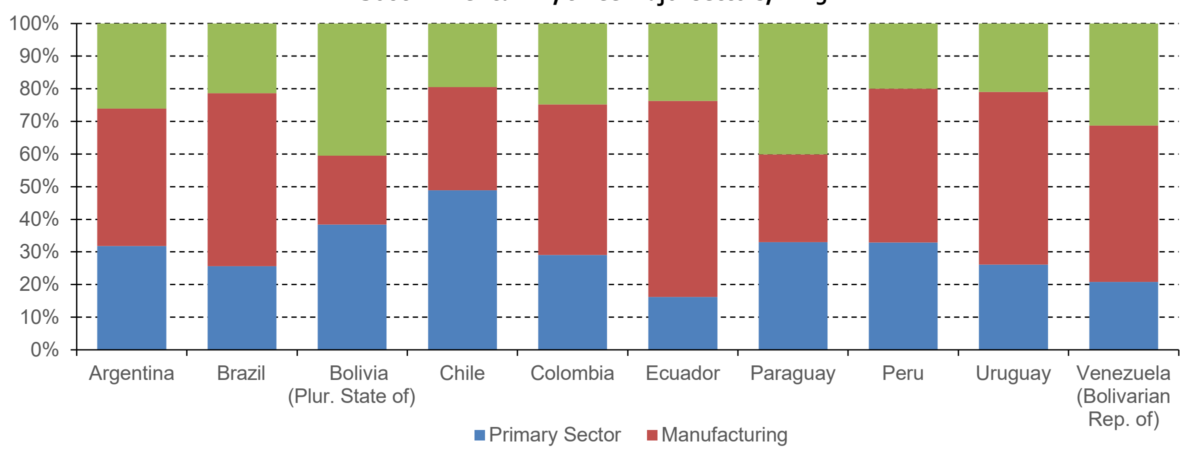
This indicator can also be used to measure dependence at the sectoral level, understood as the ratio of imported inputs over domestic inputs used by each industry (see Eq. (12):

$$rii_j = \frac{\sum_{i=1}^{N} z_{ij}^{M}}{\sum_{i=1}^{N} z_{ij}^{D}}, \tag{12}$$

where the result is a *1xN* vector that presents the ratio of imported to domestic inputs in each economy. This calculation establishes a column sum in each matrix *Z* and divides the *j* elements of the resulting *1xN* vector calculated for Z^M by those calculated for Z^D, obtaining a *1xN* vector that provides information for each sector. A value greater than 1 indicates that more imported inputs than domestic ones are needed in that sector.

Figure 6 shows the share of each major productive branch in imports of intermediate inputs over the use of domestic inputs, although it does not provide information on the sectoral origin of imports, i.e. which products from which sectors do the three major sectors import. The sector that requires the most imported inputs is Manufacturing. The Ecuadorian economy is heavily dependent on imports in this large sector, mainly in Machinery and equipment, Rubber and plastic products, and Motor vehicles. Transportation services in Bolivia (P.S.) and Paraguay are also very dependent. Colombia stands out for its dependence on imported inputs mainly in sectors such as vehicles (82% of its inputs are imported), office and computer machinery (79%), radio, television, and communications equipment (73%), basic chemicals (65%), and other transportation equipment (58%). In contrast, sectors such as mining, meat products and electricity do not exceed 4%.

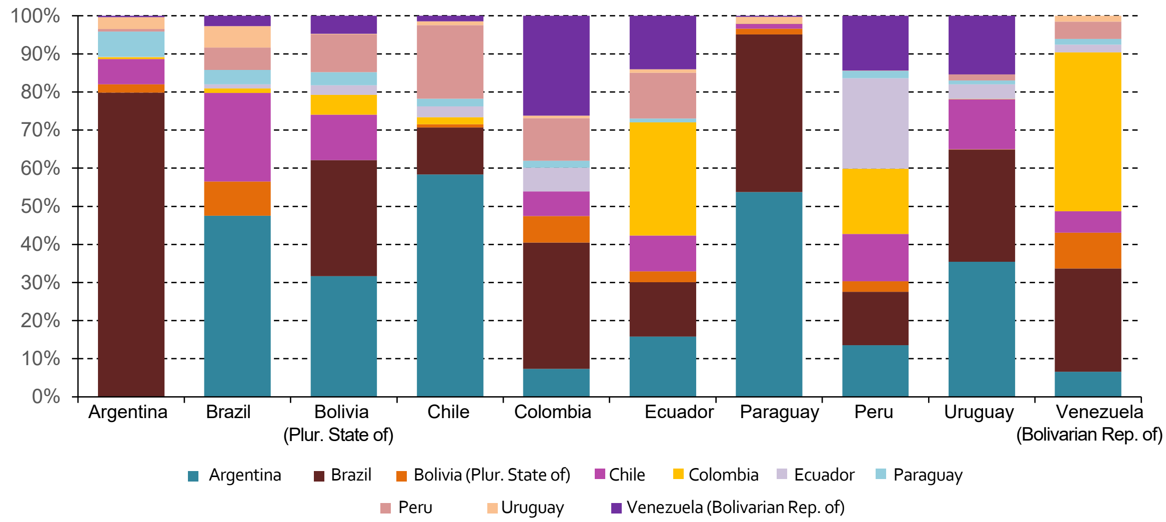
Figure 6
South America: IIR, three major sectors, 2005



Source: Own elaboration based on the IOT SA.

Regarding intra-regional trade in intermediate inputs, the integration between neighboring countries stands out. Also remarkable is the strong presence of Argentina and Brazil as the main suppliers of intermediate inputs among themselves. The same holds for the relation between them and the challenge of their partners within the Southern Common Market (MERCOSUR), mainly Paraguay and Uruguay. This is also the case of the strongest link between Ecuador, Colombia and Peru among the member countries of the Andean Community (see Figure 7).

Figure 7
South America: intra-regional imported intermediate inputs by country of origin, 2005

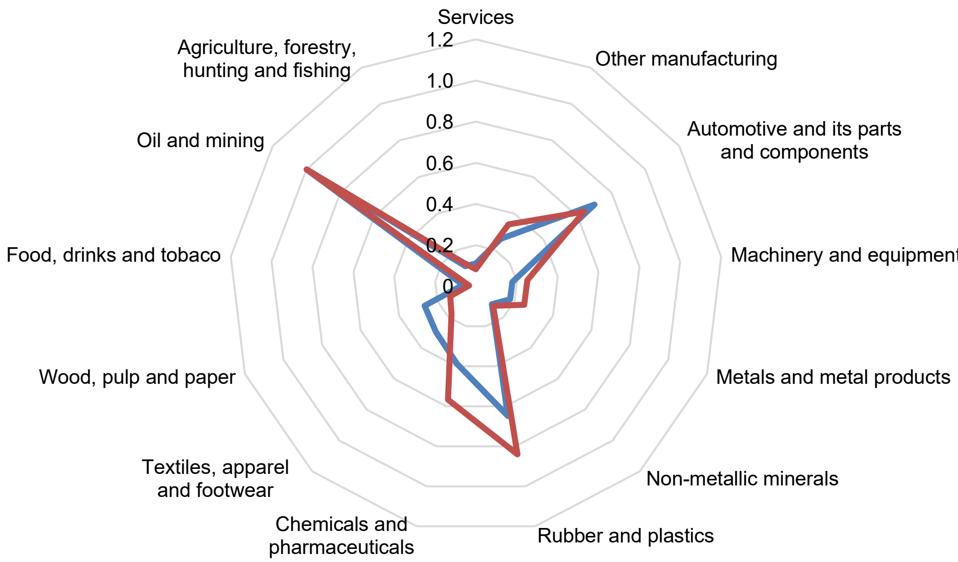


Source: Own elaboration based on the IOT SA.

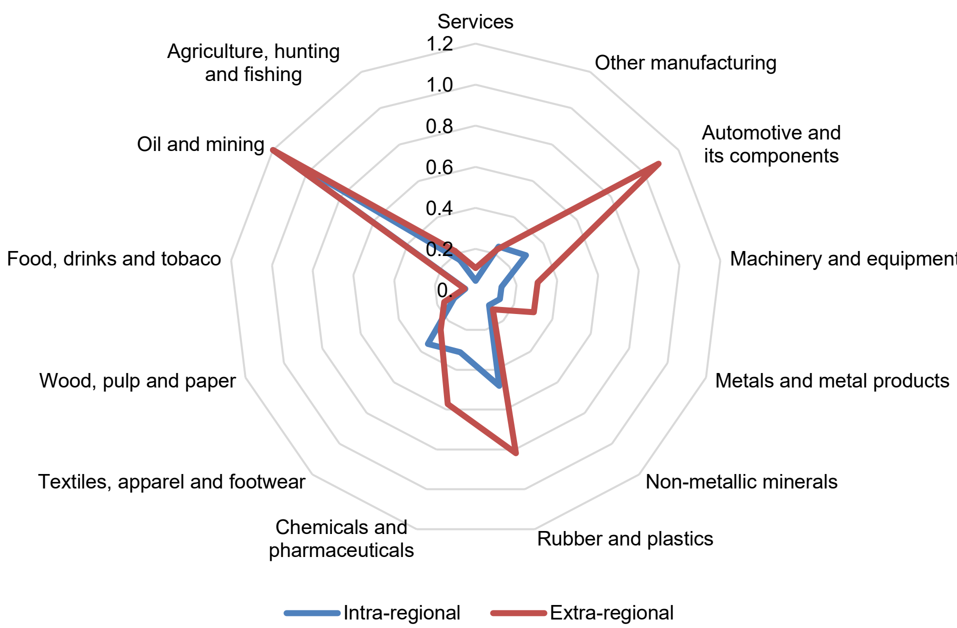
Figure 8 shows the ratio of imported inputs over domestic inputs for a particular country, Uruguay, the country that recorded the highest indicator in 2005 and which has seen its dependence decrease by 2014. The most foreign-dependent sectors in that country are Oil and mining which, in 2005, for each domestic intermediate input required 7.62 imported inputs from abroad, of which 35% came from South America. Dependence decreased by half, to only 3.8 in 2014. The country is dependent on products related to energy mining, used by the oil and mining sector, although this sector only accounts for 1% of the country's GDP. Especially noteworthy is a reduction in the dependence on regional intermediate inputs required in sectors such as Wood, cellulose, and paper or Automotive and its parts and pieces. Coming from the region itself in 2005, those needs have drastically decreased towards 2014. On the other hand, greater extra-regional dependence is observed in a wide range of sectors, except for those previously mentioned Wood, pulp and paper, and Oil and mining). This predominance of imported inputs over domestic inputs is much more noticeable in the Automotive and Machinery and equipment sectors. Moreover, the Food, beverages and tobacco sectors, together with Services, are the ones that are comparatively less dependent on foreign inputs in their productive process.

Figure 8
Uruguay: ratio of imported inputs over domestic inputs, main sectors

A. 2005



B. 2014



Source: Own elaboration based on the IOT SA and IOT LAC.
Note: The Oil and mining sector has an intra-regional *rii* ratio of 2.65 (2005) and 1.75 (2014) and extra-regional of 4.97 (2005) and 2.05 (2014).

Thanks to the sectoral openness offered by the IOT SA in the case of imported inputs, an *NxN* matrix of total intermediate inputs, Z^T, can be created (see Eq.(13)). In this case the reading would be different, as it would report the percentage of imported inputs over the total inputs required directly. A value close to zero would indicate the low share of imported intermediate inputs in the economy under study. Conversely, a value close to one would indicate a high dependence on foreign inputs.

$$Z^T = Z^D + Z^M \quad (13)$$

$$RII_p^* = \frac{\sum_{i=1}^{N}\sum_{j=1}^{N} Z_{ij}^M}{\sum_{i=1}^{N}\sum_{j=1}^{N} Z_{ij}^T} \quad (14)$$

An example of activities whose productive structure differs from domestic production and which are not usually captured by the input-output table databases is the case of the "free trade zones", also known as special export zones or *processing exports*. These activities focus their productive process on the assembly of imported inputs for subsequent export. Countries such as China or Mexico, whoseso-called *maquila* activity is remarkable, show inter-industrial linkages different from those seen in production to satisfy domestic consumption (Koopman et al., 2012). Finally, comparing these indicators at the sectoral level with GDP is necessary to understand the magnitude of the impact: high foreign dependence may not have a relevant impact on sectors with low participation in the economy.

C. Imported inputs required in production

Following the same logic as in the previous section, the weight of inputs directly required in an economy on the GDP can be calculated, which expresses the monetary value of the production of goods and services of final demand of the country under study. The calculations can be arranged in an aggregate form or by sectors, as *RII (*Eq. (11)) and *rii* (Eq. (12)), respectively, were calculated.

$$IGDP_p = \frac{\sum_{i=1}^{N}\sum_{j=1}^{N} Z_{ij}^M}{GDP_p} \quad (15)$$

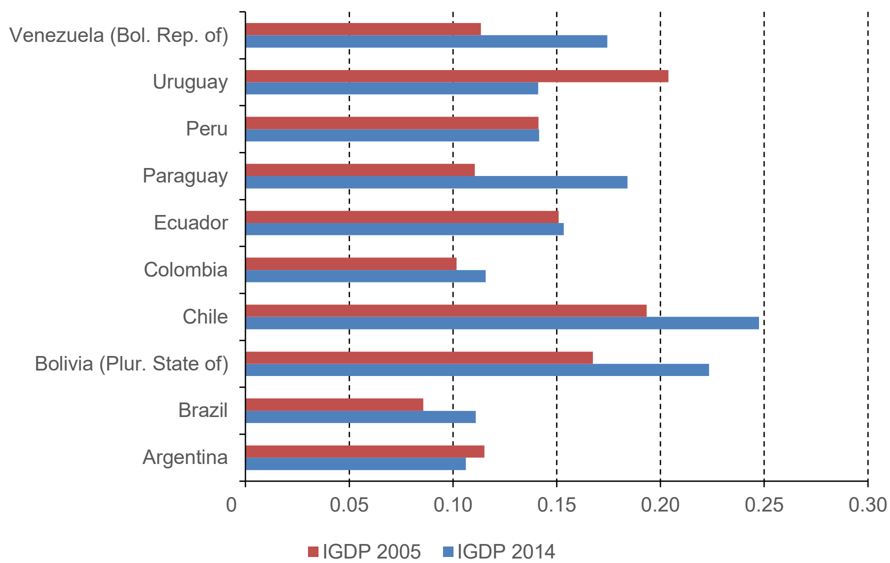
$$igdp_j = \frac{\sum_{i=1}^{N} Z_{ij}^M}{GVA_j} \quad (16)$$

As discussed in section A of this section, an economy's sectoral GDP (*GVA*) can be found directly by sector in the South American IOT (value added at basic prices), the sum of *GVA* being the country's total GDP. The reading of this indicator would be as follows: for each unit of final product, *IGDP* units of imported intermediate inputs are directly required. Equation (15) yields a single value that reports the total economy, where the denominator, *GDPp*, is the result of Eq. (9). On the other hand, Eq. (16) provides a *1xN* vector that refers to the sectors of that economy. The *Nx1* vector of Eq. (10) can be used as the denominator, but it must be transposed to generate a *1xN* vector that can be divided by the numerator.

Figure 9 shows the weight of imported inputs on GDP in South America. Given a number of imported inputs, the higher the value added (or intermediate consumption) a country generates, the lower the *IGDP* (or *RII*) ratio. The differences between the *RII* and *IGDP* ratios come from the denominator. Thus, the weight of domestic inputs relative to value added in Chile, Argentina and Brazil is close to each other. Bolivia (P.S.), Uruguay and Venezuela (B.R.), on the other hand, see a higher share of value added with respect to domestic inputs.

With a time series of IOT, the proposed *RII* and *IGDP* indicators can serve as a complement to analyze the degree of dependence of an economy over time, reflecting whether the economy increases or decreases its international dependence. A high dependence on imports at a given point in time can lead to a deepening of industrial linkages that promotes technological change. In the case of less mature economies such as those of Latin America and the Caribbean, it could be evaluated whether they have taken advantage in an initial phase of the transfer of technology incorporated in imported inputs to, in the next stage, expand the export of manufactured products of greater complexity, which require advanced production technologies and high-quality inputs. In addition, as reflected in Section I, one of the great virtues of IOT SA is the possibility of opening up some indicators by origin and destination. In this case, it is possible to know where the imported inputs that the ten countries of the region use in their production process come from.

Figure 9
Ratio of imported inputs to GDP in South American countries



Source: Own elaboration based on the IOT SA.

These indicators also offer clues about intra-regional dependency relationships, which would be greater if the ratio of the indicators increased over time. However, it should be noted that they do not provide information on the integration of countries into GVC, since the information obtained does not differentiate whether imported inputs are used for domestic production and consumption or for processing, value addition and subsequent export. These analyses can be completed by establishing a relationship between exports and imports of intermediate inputs, that is, the so-called Vertical Specialization, whose indicator will be discussed in the next section.

D. Production linkages, backward and forward linkages

Production chains provide information on the interdependence existing between the sectors of an economy. In their productive process, sectors play the role of both suppliers and demanders of intermediate inputs, although not all economic activities have the same capacity to induce multiplier impacts on others (Schuschny, 2005). Changes in final demand generate effects on production that vary according to the sector observed. This is where *backward* and *forward linkages* come in. The former ones attempt to describe which sectors influence the activity of other sectors by requiring their inputs to produce. The latter ones measure the relevance of a sector as a supplier of inputs for the productive activities of other sectors.

Such backward and forward linkages can be observed directly in the matrix *A* of technical coefficients (see Eq. (3) and the matrix of distribution coefficients *(B)*, respectively (Chenery and Watanabe, 1958)). A columnar reading of *A* shows the intermediate purchases of a sector relative to its actual output, or how sector *j* absorbs intermediate inputs from other sectors. To study forward linkages, it is first necessary to define the matrix of distribution coefficients:

$$B = \hat{x}^{-1}Z = \begin{bmatrix} \frac{1}{x_1} & 0 & 0 \\ 0 & \frac{1}{x_2} & 0 \\ 0 & 0 & \frac{1}{x_3} \end{bmatrix} \begin{bmatrix} Z_{11} & Z_{12} & Z_{13} \\ Z_{21} & Z_{22} & Z_{23} \\ Z_{31} & Z_{32} & Z_{33} \end{bmatrix} = \begin{bmatrix} \frac{Z_{11}}{x_1} & \frac{Z_{12}}{x_1} & \frac{Z_{13}}{x_1} \\ \frac{Z_{21}}{x_2} & \frac{Z_{22}}{x_2} & \frac{Z_{23}}{x_2} \\ \frac{Z_{31}}{x_3} & \frac{Z_{32}}{x_3} & \frac{Z_{33}}{x_3} \end{bmatrix} = \begin{bmatrix} b_{11} & b_{12} & b_{13} \\ b_{21} & b_{22} & b_{23} \\ b_{31} & b_{32} & b_{33} \end{bmatrix}, \tag{17}$$

where *B* is the matrix of direct product coefficients, or distribution coefficients. Recall that the reading of the technical coefficients studied in Eq. (3) by rows informs on the direct requirements that sector *i* transfers as inputs to the rest of the sectors of an economy so that they can satisfy final demand. In the case of the distribution coefficients, however, the effect of the diffusion of sector *i* in the economy under study is considered in terms of the production of that same sector (Eq.(17)). The elements of *B*, called b_{ij}, represent the intermediate consumption by sector *j* of sector *i*'s products per unit of sector *i*'s output. A row sum gives the direct forward linkages, the inputs that sector *i* transfers to the rest of the sectors of an economy, in terms of the total output of sector *i*.

Once the direct linkages have been presented, we can go a step further by analyzing the total linkages from the domestic Leontief inverse matrix (see Eq. (18)) and the Ghosh inverse (see Eq.(19)). Thus, results can be analyzed on the total requirements, direct and indirect, that the different sectors of the country need to satisfy the final demand. From here, the forward and backward linkages proposed by Rasmussen (1958) and Hirschman (1958) can be analyzed.

$$L_p = \begin{bmatrix} l_{11} & l_{12} & \cdots & l_{1N} \\ l_{21} & l_{22} & \cdots & l_{2N} \\ \vdots & \vdots & \ddots & \vdots \\ l_{N1} & l_{N2} & \cdots & l_{NN} \end{bmatrix}, \tag{18}$$

where *L* is the inverse Leontief matrix, and l_{ij} is the value of the total direct and indirect requirements that sector *i* transfers to sector *j* so that the latter can produce a unit of output to satisfy final demand. In other words, it reveals how the product of a given sector has been produced. Thus, l_{11} is the requirements that sector 1 needs from itself to produce. A columnar reading of *L* refers to the backward linkages (BL), which inform on the drag effect of the sector under study. Thus, a higher value in backward linkages means that the sector under study is important because of the drag effect it generates on itself and other sectors, on which it depends to produce and satisfy final demand. To measure backward linkages on other sectors, the elements of the main diagonal, l_{11}, l_{22}, ..., l_{NN}, are usually excluded.

To analyze forward linkages (FL), we use an alternative approach to the Leontief inverse, proposed by Ghosh (1958). This involves an improvement in the measurement of forward linkages, since it is constructed from the point of view of supply (see Eq. (17)).

$$\mathrm{G} = (\mathrm{I} - \mathrm{B})^{-1} = \begin{bmatrix} g_{11} & g_{12} & \cdots & g_{1N} \\ g_{21} & g_{22} & \cdots & g_{2N} \\ \vdots & \vdots & \ddots & \vdots \\ g_{N1} & g_{N2} & \cdots & g_{NN} \end{bmatrix}, \tag{19}$$

where *G* is the inverse of Ghosh. A reading by ranks refers to the so-called forward linkages, which provide information on the effect of the diffusion of a sector in the economy of the country under study. From this information it is possible to analyze which sectors are the ones that transfer the most to the rest of the sectors of an economy. In other words, which sectors diffuse their products most forward in the production process. In short, a specific row details the demand of the entire economy for the product of the sector under study.

In the following section, calculations are carried out based on domestic or national linkages, which capture the linkages generated in the domestic economy of a country *p*, net of imports. Although no results are provided in this handbook, regional and multi-regional IOT would also allow the calculation of linkages generated between sectors of an economy with the outside world. This is of interest in the case of countries and sectors with a greater dependence on the exterior. For this purpose, Eq. (18) and (19) would be the inverse of Leontief and Ghosh regional or global depending on the chosen IOT.

E. Rasmussen and Hirschman index

One of the most widely accepted forms in the literature for measuring production linkages is the Rasmussen and Hirschman Index, or RHI (Miller and Blair, 2009). They are also called dispersion power and dispersion sensitivity indices based on the contributions of Rasmussen (1958) and Hirschman (1958). These measures are related to backward and forward linkages, respectively. The Rasmussen-Hirschman indices distinguish between those backward and forward linkages. The former (BL_j) compare the capacity of a sector *j* to stimulate the rest of the sectors of an economy, with the average of the requirements of the set of sectors that make up that economy. A sector will have greater capacity and its BL will be greater, the more inputs it requires directly and indirectly to produce. The second (FL_i) measures how sector *i* transfers its products to the other sectors, which need to incorporate them as intermediate inputs for their production processes. In other words, the *LF* serves to evaluate the potential of a sector as an input supplier. Thus, the Rasmussen-Hirschman index, or dispersion power index for each sector *j* would measure backward linkages and is calculated as follows:

$$BL_j = \frac{\sum_{i=1}^{N} l_{ij}}{\frac{1}{N}\sum_{i=1}^{N}\sum_{j=1}^{N} l_{ij}}, \qquad (20)$$

where BL_j is the backward linkages indicator referring to sector column *j*, the numerator indicates the total production requirements coming from all sectors, which are necessary for sector *j to* satisfy one monetary unit of final demand. It is calculated as the sum of the l_i of sector *j*, i.e. the *i* elements of sector *j* chosen from the Leontief inverse matrix denoted as $L = (I - A)^{-1}$. The denominator is an average of the requirements of the set of sectors of the economy, a value that reflects the sum of all the elements of the matrix *L* divided by the number of sectors *N* in which the input-output table is structured.

On the other hand, the dispersion sensitivity index, or forward linkages (FL_i), is calculated from the so-called inverse matrix of technical distribution coefficients *G*. Thus, the dispersion sensitivity index of each sector *i* is given by the following expression:

$$FL_i = \frac{\sum_{j=1}^{N} g_{ij}}{\frac{1}{N}\sum_{i=1}^{N}\sum_{j=1}^{N} g_{ij}}, \qquad (21)$$

where FL_i is the forward linkages indicator referring to sector row *i*. The numerator is the sum of the *j* elements of sector *i* of matrix *G* (sum of row *i*); thus, a higher value of the numerator indicates a greater distribution of inputs of sector *i* with respect to its total production. The denominator is the average of the total distribution generated in the economy, calculated as the sum of all the elements of matrix *G* divided by the number of sectors *N* in which the input-output table is structured. Each g_{ij} can be interpreted as a measure of the total output generated in sector *j* per monetary unit of input of sector *i*.

Both linkages, BL and FL, evaluate the effect of a specific sector with respect to the average effect of the economy; therefore, a value above (below) one will indicate that the sector under study exerts a greater (lesser) pulling power (backward or forward) with respect to the average of the economy. Once both linkages have been calculated, there are four possible options, as shown in Diagram 5.

Diagram 5
Classification of economic sectors according to the Rasmussen-Hirschman indexes
(Most representative sectors)

	Backward linkages < 1	Backward linkages > 1
Forward linkages > 1	(II) **DRIVING** Sectors	(I) **KEY** Sectors
Forward linkages < 1	(III) **INDEPENDENT** Sectors	(IV) **DRIVEN** Sectors

Source: Prepared by the authors based on Miller and Blair (2009).

Quadrant I includes those sectors with high forward and backward linkages, which are called *key sectors*. These sectors stand out as demanders and suppliers of intermediate inputs, which gives them a greater capacity to influence the rest of the sectors of the economy.

Quadrant II presents those sectors with low backward linkages and high forward linkages, called *driven sectors*. These sectors are called that way because they stand out as suppliers of inputs to the rest of the sectors, i.e., they are driven by the demand of the rest of the sectors. Both key sectors and driven sectors can generate so-called bottlenecks in the face of demand shocks: in the event of an unexpected increase in consumption, investment or due to expansionary fiscal policies, these sectors can only respond slowly, slowing down a country's production process.

In **quadrant III** are the sectors located with low backward and forward linkages, called *independent sectors*. This means that these sectors, on the one hand, are not important suppliers of intermediate inputs, indicating that their production is mainly destined to satisfy final demand. On the other hand, they have a low carry-over effect, which means that they are not great dynamizers of the economy. An increase in the demand for products from this sector would not generate large increases in the supply of products from other sectors.

Finally, **quadrant IV** encompasses those sectors with high backward linkages and low forward linkages, called *driving sectors*. They exert a powerful drag effect, with the potential to dynamize the economy, but their supply mainly supplies final demand.

As an example, the Rasmussen-Hirschman indeces for Brazil (2005) are presented. Sectors such as Milling, bakery and pasta, Beverages or Basic chemical products, are key sectors in the Brazilian economy. They have the capacity to dynamize the economy due to their strong supply and demand for intermediate inputs. Mining is characterized as a driven sector, requiring few domestic intermediate inputs compared to the average of the Brazilian economy. On the other hand, the Construction sector or Pharmaceuticals are independent sectors, which allocate their production to final demand, without affecting or being affected by the drag effect of other sectors. Finally, sectors such as Sugar and confectionery products or Motor vehicles are drivers, which require many intermediate inputs and their supply is mainly aimed at satisfying final demand (see Table 2).

Table 2
Brazil: Rasmussen-Hirschman indexes

	Linkages backward < 1	Linkages backward > 1
	(*Driven Sectors*)	(*Key Sectors*)
Forward linkages > 1	1) Mining (non-energy) 2) Mail and telecommunications 3) Electricity and gas 4) Agriculture and forestry	1) Milling, bakery and pasta products 2) Beverages 3) Basic chemicals 4) Rubber and plastic products
	(*Independent Sectors*)	(*Driving Sectors*)
Forward linkages < 1	1) Office equipment 2) Construction 3) Other services 4) Pharmaceuticals	1) Sugar and sugar confectionery products 2) Motor vehicles 3) Other food products 4) Tobacco products

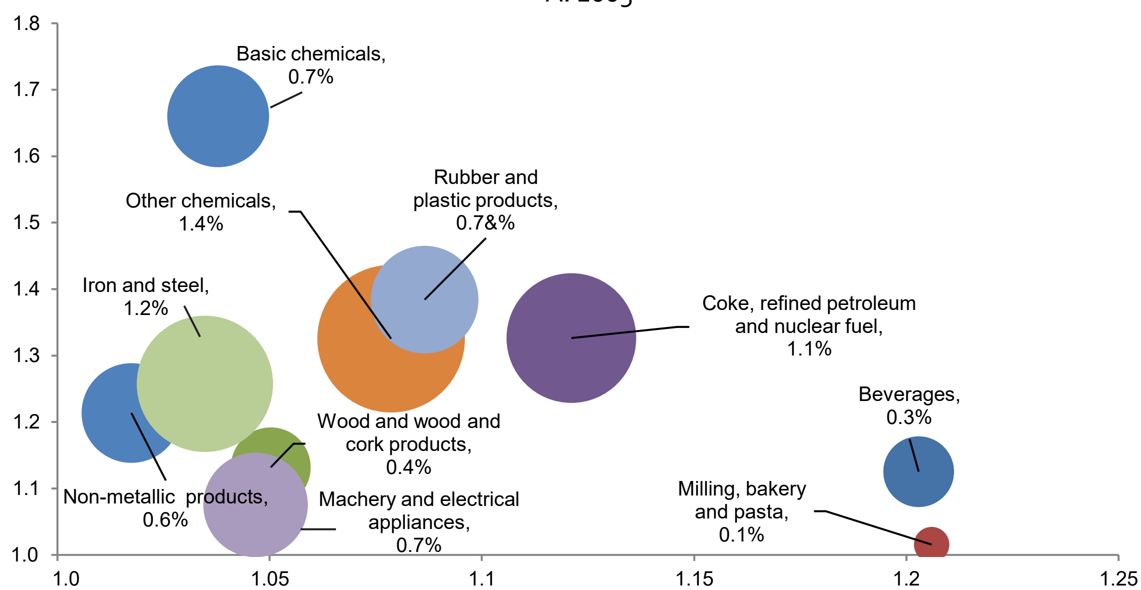
Source: Prepared by the authors based on the SA IOT.

According to Chenery and Watanabe (1958), who establish these measurements in direct terms, in a process of economic and productive development, countries would begin in a first stage with weak backward relationships. According to the *RHI*, this is the case of countries such as Bolivia (P.S.), Paraguay and Venezuela (B.R.). In a second stage, the sectors would show high forward and backward linkages. This is the case of Brazil, Uruguay and Chile. Finally, in the more developed economies, sectors with high backward and low forward ratios would predominate (Schuschny, 2005).

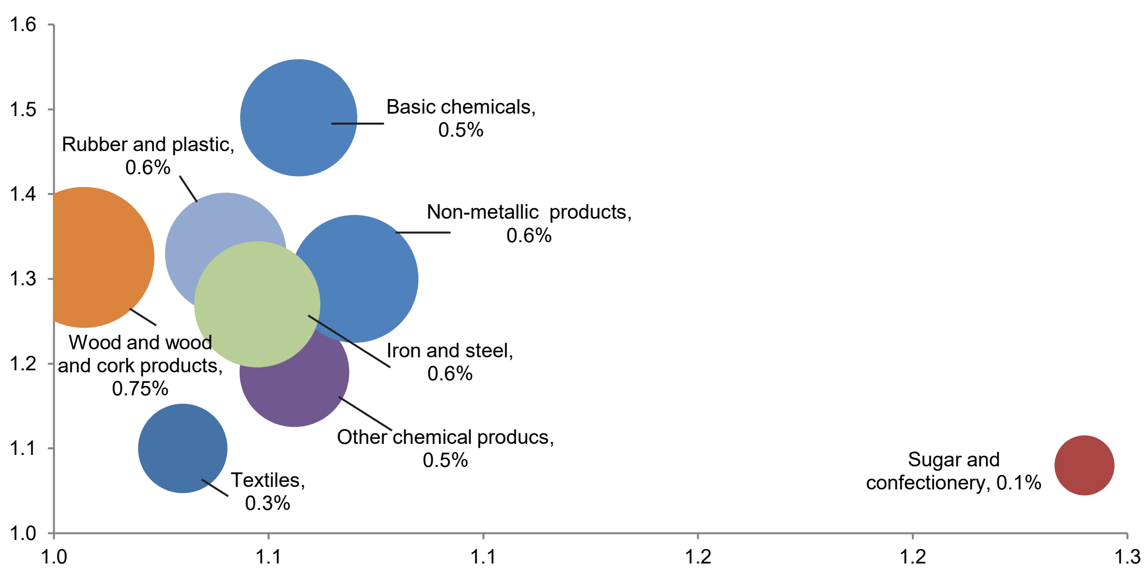
This form in which the indicators of productive linkages are presented is not unique and can be complemented by other studies that offer different methodologies for their measurement (Laumas, 1976; Dietzenbacher, van der Linden and Steenge, 1993; Lopes, Dias and Ferreira do Amaral, 2002), all of which have already been discussed in Schuschny (2005). These indicators in themselves provide information on the potential drag of industries, although a sector can be a key sector in an economy, with a high drag potential, as well as an input supplier to other sectors, but be a sector of little relevance in the economy, in terms of production and value added. It is therefore necessary to relate linkages to the relative participation of each sector in the level of activity of the economy under study. For example, in the case of Brazil (see Table 2), although the *Sugar and confectionery products* sector has a greater potential for linkages than the *Other food products* sector, the latter has a six times greater share in Brazilian GDP than the former. Figure 10 shows the *key sectors* of the Brazilian economy and their share in GDP for the years 2005 and 2014. The *Basic chemicals* sector has large forward linkages, so they provide inputs to the rest of the sectors. Its backward linkages, although not as remarkable, are above average. Nevertheless, the sector represents 0.7% of GDP. The carry-over effect is greater in sectors such as *Beverages* or *Milling, bakery and pasta*. However, the latter is the *key sector with the* smallest share in Brazil's GDP. Brazil's key sectors account for only 7.2% of the country's GDP, and their share decreased to 6.3% in 2014. *Basic chemicals*, *Rubber and plastic products*, *Non-metallic mineral products*, *Iron and steel*, and *Other chemical products* remain as *key sectors.* Sectors such as *Beverages* cease to be key in 2014, although those of *Wood pulp and paper* or *Sugar and confectionery products* now appear.

Figure 10
Brazil: key sectors according to the HRI and their share in GDP
(Percentage share)

A. 2005



B. 2014



Source: Own elaboration based on the SA IOT.
Note: *Backward linkages* on the abscissa axis, *forward linkages* on the ordinate axis.

It is worth mentioning that these calculations do not consider issues such as the relationship of one sector with the others, as well as the degree of concentration and dispersion of impacts. One sector may be key (with an above-average multiplier in forward and backward linkages) but affect very few sectors (with a high degree of concentration). To deal with this limitation, several studies and measures have been carried out, such as the power and sensitivity of dispersion (Rasmussen, 1963) or the graphical representation of the *multiplier product matrix* (MPM) (Sonis, Hewings and Guo, 1997).

Finally, to show sectoral linkages in relational terms, measures and methodologies have been developed such as Streit's coefficients (Streit, 1969) or the identification of industrial complexes or *clusters* that are located close to each other in space and linked by an intense exchange of goods and services (Domínguez Hidalgo and Prado Valle, 1999). Moreover, the combination of input-output studies with Network Analysis (RA) have been studied, which also considers the number of relationships and the position of sectors in the input-output structure (Noguera-Méndez et al., 2016), allowing the analysis of economic growth by relating the productive sectors of an economy and their interconnectivity (Kubo et al., 1986). This type of analysis makes it possible to focus attention on sectors that are not only key as demanders and suppliers of intermediate inputs. They also have an important weight in the economy of a country and are axes of the inter-industrial network, defined by a great complexity where product diffusion and diversification stand out.

Other types of analysis such as *structural decomposition* or the *dynamic input-output* model are also used based on the IOT. Both analyses are described in Schuschny (2005). Structural decomposition analysis is used as a predictive model that allows us to identify the causes that give rise to changes over time in the components of final demand (Schuschny, 2005). This analysis needs information from IOT elaborated in two consecutive periods, so, in the case of South America, it is possible to carry it out thanks to the update of the IOT SA to the year 2011 and 2014. On the other hand, the dynamic input-output model arises as a response to solve certain limitations of the original model, related to its static nature. The traditional input-output model does not consider any endogenous adjustment dynamics, being configured as a "macro-exercise" of comparative statics (Schuschny, 2005). There, i) the consumption patterns of economic agents do not attend to functions that include changes in prices, tastes, etc., ii) investment is considered exogenous or iii) the variation of inventories does not generate feedback effects on intermediate consumption. Thus, the dynamic input-output model offers solutions to one of the limitations of the model previously discussed (see Section I, Section A), where the measurement of durable goods is incorporated into the matrix. This in turn generates the so-called capital coefficient, to measure the inputs that contribute to the productive process and that are not immediately used in the productive process (buildings, machinery, vehicles, etc.).

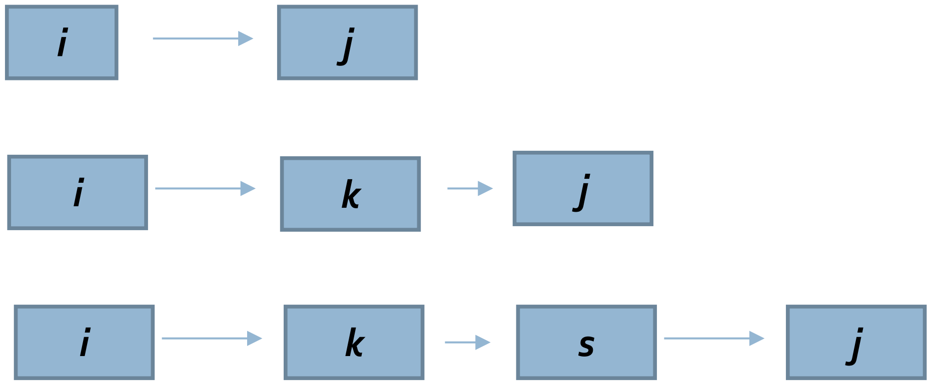
Modeling changes in final demand using IOT, however, has been criticized due to the limitations of the model. To this end, other methodologies, such as computable general equilibrium models, have proven to be more effective in performing realistic long-run analyses of changes in output and trade by allowing endogenous price estimation, solving non-linear problems and incorporating specific structural variables (O'Ryan et al., 2000).

F. Average propagation length

While the BL and FL indices measure the *strength of* the linkages, the average propagation length tells us about the distance of the linkages. It refers to the rounds of production necessary to connect two industrial sectors. We obtain the production relationship between industry *i* and *j* from the coefficient l_{ij} (what industry *j* requires from product *i*). Both industries are connected directly and in a straight, logical way with an immediate step of production.

But how are industry *i* and industry *j* indirectly connected? The answer is: through the coefficient $l_{ik}l_{kj}$, which shows us the requirements of industry *k* for industry *i*'s products. Then, in a future round, product *k* will be required by industry *j*. This is the connection in two steps.

Diagram 6
Steps required to connect sector *i* to sector *j*



Source: Own elaboration.

A compact way to measure the average propagation length is by constructing a matrix of bilateral coefficients, which we define as APL (*Average Propagation Lengths*). This matrix will allow us to find the economic distance between sectors. From this matrix, adding by row, we obtain the average backward propagation length, while by column we obtain the average forward propagation length. In both cases, the result indicates the number of steps required for an exogenous change to affect the value of output in another sector. The following Eqs. (22 to 24) define the methodology.

$$APL = \frac{L(L-I)}{(L-I)},$$

with the APL Matrix being $\begin{bmatrix} APL_{ij} & \dots & APL_{iN} \\ \dots & & \dots \\ APL_{Nj} & \dots & APL_{NN} \end{bmatrix}$, (22)

where APL_{ij} are the steps required to get from *i* to *j* in the case of a cost push, or alternatively, the steps required to get from *j* to *i* in the case of an increase in demand.

With a simple average, we are not incorporating the relative weight of the purchase of intermediate goods. Therefore, we will relativize it using the Z matrix.

$$APL_i^f = \frac{\sum_j APL_{ij} z_{ij}}{\sum_j Z_{ij}} \quad (23)$$

$$APL_j^b = \frac{\sum_i APL_{ij} z_{ij}}{\sum_i Z_{ij}} \quad (24)$$

APL_i^f informs us about the average number of steps needed to connect industry i with all sources of demand.

APL_j^b tells us the number of steps required by industry *j* to reach all industries in the economy.

G. Dependence on imported inputs

To determine the dependence on imported inputs, or in other words, the identification of the direct and indirect requirements of imported inputs by the country's economy, the input-output methodology was considered. It consists of using the imported intermediate utilization matrix of the country's input-output table to calculate the matrix of imported technical coefficients (Am), as follows:

$$Am = \left[a_{ij}^{m}\right] \tag{25}$$

where $a_{ij}^{m} = \frac{x_{ij}^{m}}{X_j}$; x_{ij}^{m} is the value of input *i* imported by sector *j*; and X_j is the GVP of sector *j.*

a_{ij}^{m} is the coefficient that measures the value of the import of input i by sector j for each monetary unit produced by this sector.

Post-multiplying the matrix of import coefficients by the Leontief inverse yields the matrix of total import requirements.

$$Q = A_{ij}^{M}L \tag{26}$$

The sum of column *j* of the matrix reports the total import content required to produce one monetary unit of sector *j* domestically. This calculation makes it possible to determine the activities whose dependence on the rest of the world is relevant in terms of demand for imported inputs, i.e. which depend on the outside to increase their level of production.

The sum of row *i* of the matrix indicates the import of input *i* required if the production of all sectors increases by one monetary unit. This indicator shows the foreign sectors on which the economy is most dependent, i.e. those that are most present in the flow of imports when domestic production grows.

Comparing the indicators described above on an individual basis with their average values allows obtaining a sectoral classification; this in turn groups the economic sectors according to their behavior as demanding or being demanded regarding imported intermediate inputs. If, for example, as a demanding one, a sector obtains an indicator higher than 1, it is understood as evidence of being a more demanding sector of intermediate inputs than the average of the sectors of the economy. Likewise, a value higher than 1 for the demanded sectors is indicative of a greater economic impulse following increases in the country's domestic production in the face of expected shocks. For example, in the event of an increase in the construction of a large infrastructure project, the products of sectors linked to this sector will be in much greater demand (imports of iron and steel bars, pipes, as well as capital goods for the infrastructure project). To the extent that these goods can be supplied by local companies, instead of imported inputs, the impact on imports will be lower. On the contrary, in the absence of domestic products, imports will increase more than proportionally in the face of expected production increases due to the momentum of the sector in question.

In order to analyze the pattern of dependence on imported inputs, a stylized analytical typology is presented that identifies four possible options, reflected in Diagram 7.

Diagram 7
Classification of economic sectors according to the dependency indexes for the import matrix
Most representative sectors

	Demanding $Q_j > \sum_{j}^{n} \frac{Q_j}{n}$ $Q_j > 1$	Less Demanding $Q_j \leq \sum_{ij}^{n} \frac{Q_j}{n}$ $Q_j \leq 1$
Demanded $Q_i > \sum_{j}^{n} \frac{Q_i}{n}$ $Q_i > 1$	(II) Sectors of **HIGH DEPENDENCE**	(I) **Driven Sectors** **MEDIUM DEPENDENCE**
Less demanded $Q_i \leq \sum_{ij}^{n} \frac{Q_j}{n}$ $Q_j \leq 1$	(III) Sectors of **MEDIUM DEPENDENCE**	(IV) Sectors of **LITTLE DEPENDENCE ON IMPORTS**

Source: Own elaboration based on Miller and Blair (2009).

Type I sectors: Quadrant I includes those ***driven sectors*** that, when output expands, the total demand for imported inputs from these sectors increases above average. Moreover, when the output of these sectors increases, their demand for imported inputs is relatively small. The impulse on the demand for imported inputs from these sectors occurs only when there is an expansion of the total output of the economy and boosts their demand for imported inputs. This is not the case, when their total supply increases. Hence, these **sectors are moderately dependent**.

Type II sectors: In quadrant II are those sectors located that depend on above average imports of inputs to increase their production and, when the other sectors of the economy increase their production, the total import of inputs from these sectors also increases. Consequently, these are sectors that need imported inputs to produce and that serve the above-average domestic demand for inputs in the economy. For this reason, these are sectors that probably tend not to create many links in the national productive system and are rather **sectors that are highly dependent on imports**.

Type III sectors: Quadrant III includes those sectors that have a total demand for imported inputs above the economy's average. To increase their production, they necessarily depend on imports from the rest of the world much more than the rest of the sectors of the economy. Conversely, when the other sectors increase their output, the total demand for imported inputs from these sectors is lower than the economy's average. Like the type I sectors, these are **sectors with a medium dependence on imported inputs**, since, if the total demand of the whole economy increases, the impulse on their imports of imported inputs is less affected than the economy as a whole.

Finally, **quadrant IV** contains sectors with a low dependence on imports of inputs to increase their production, being sectors that are either poorly interlinked or dependent on domestic inputs. They are also sectors with low demand, so that when the economy's production increases, the total demand for imports of inputs from these sectors is lower than the average for all sectors. In conclusion, these sectors are **not very dependent on imports.**

To complement the analysis of import dependence, it is suggested to additionally calculate import dependence indices, constructed as vertical specialization indices, called EV2. Those consist of calculating the total import content incorporated in production, which can be broken down into direct and indirect production content. We will return to this concept of vertical specialization in the following section:

$$EV2_i = A_i^M (I - A)^{-1} \widehat{VBP_i} \quad (27)$$

The result of this calculation yields an NxN matrix whose column sum provides information on the imported content destined to the production of sector *j* in matrix form. This is what is known in the literature as vertical specialization of sectors *j*. The sum of all the elements of the matrix provides information on the vertical specialization of the economy. This indicator was popularized in the vertical specialization literature, defined by Hummels, Ishii and Yi (2001) as the use of foreign intermediate inputs in the production of final products that are exported. However, for the case at hand, since the imported content of production is of interest, exports are not considered, but rather the gross value of production.

The results of the methodology described here for import dependence and imported content in production are presented and analyzed below, using the case of Bolivia (P.S.) as an example. It should be noted that the regional matrix for Latin America and the Caribbean, developed by ECLAC for 2014, was used to calculate the indicators mentioned here.

The import intensity dependence indices calculated using the Leontief methodology show that by 2014, at least 84% of Bolivia (P.S.)'s GVP was made up of economic sectors with low import dependence. This is revealed considering the intensity of demand measured as a proportion of GDP as an indicator of the weight of dependence. In aggregate terms, the proportion of Bolivia (P.S.)'s GVP with lower import linkages than average is found in primary sectors, some sub-sectors of agroindustry (Meat, Milling, Sugar, and Beverages, Tobacco), Non-metallic minerals, Construction, and a wide range of services (Electricity and gas, Telecommunications and post, and Finance and insurance) aggregated in the category Other services (see quadrant 4 of Tab. 3).

The sectors with the highest import dependency rates are textiles, paper and wood, basic chemicals, other chemicals, rubber and plastics, vehicles, and machinery and equipment. All of these are sectors that have a double dependence, i.e. they are import-demanding above average demand. They also react by increasing import demand when total production increases. It can be said that they are sectors with a strong connection to the international market. At first sight, it could be said that this is where the search for potential sectors for an import substitution program should be focused. However, the relative weight of the sum of all the sectors in the same quadrant in the GVP barely reaches 1.3%. Nevertheless, the indicator in question warns of the high dependence on imports in all the industries listed.

Other sectors worth mentioning are those included in quadrant 2: Transportation, Fuels and refined petroleum products, Business services, and Iron and steel. These four sectors have a combined incidence of 13% in total GVP. They all have in common the fact that they are highly demanded by the rest of the sectors of the economy. If total demand increases, these sectors will see their demand for imported intermediate goods expand. Although these sectors have a low demand for intermediate imports, they all require imports of capital goods, mainly motor vehicles, machinery and equipment, as well as final consumer goods.

Table 3
Bolivia (Plur. State of): sectoral characterization by import dependency index, 2014
(As a percentage of gross production value)

	Demanding	Less demanding
Demanded	Textiles (0.22%), Paper and wood (0.42%), Basic Chemicals (0.018%), Other chemical products (0.27%), Pharmaceuticals (0.18%), Rubber and plastics (0.18%), Vehicles (0.01%), Machinery and equipment (0.13%) 1.3%	Fuels and refined petroleum (1.96%), Business services (1.95%), Iron and steel (0.20%), Transportation (9%) 13.1%
Less demanded	1.9% Apparel (0.44%). Footwear (0.50%), Non-ferrous metals (0.6%), Metal products (0.10%), Machinery and electrical equipment (0.03%), Other manufacturing (0.22%)	83.7% Mining (energy) (12.61%), Agriculture, hunting and fishing (9.31%), Mining (non-energy) (6.46%), Construction (5.03%), Meat and meat products (3.4%), Milling, bakery and pasta (2.48%), Sugar (0.62%), Other food products (3.47%), Beverages (2.59%), Tobaco products (0.13%), Non-metallic minerals (2.06%), Non-ferrous metals (0.6%), Other services (34.26%)

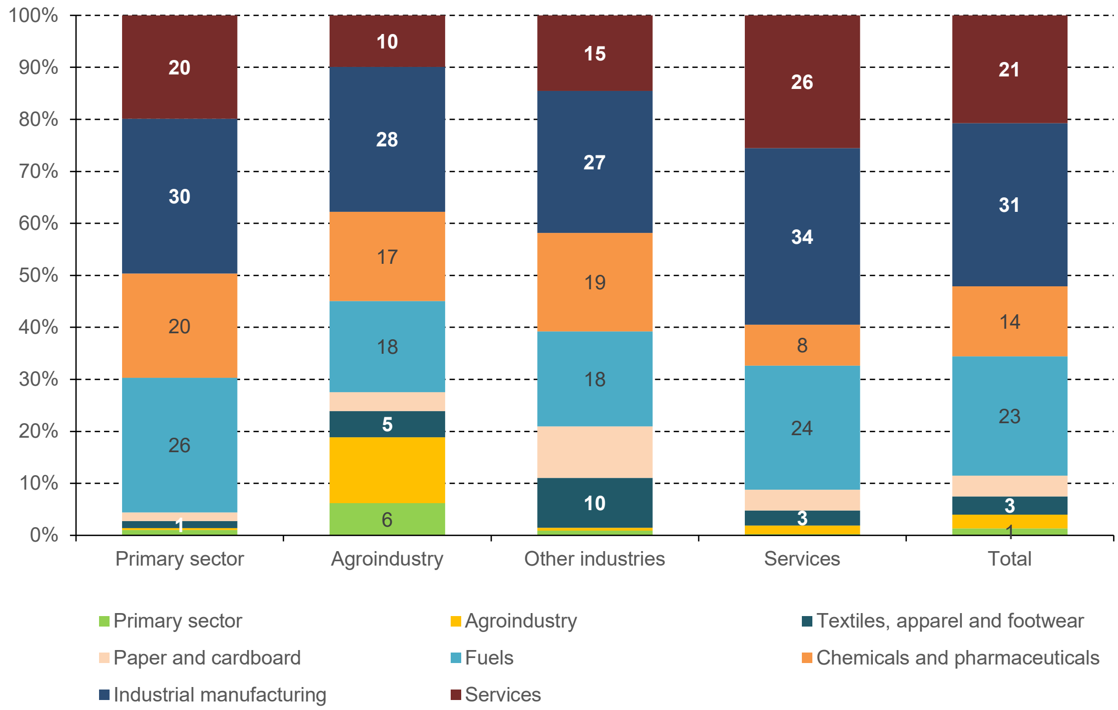
Source: Own elaboration based on Bolivia (P.S.)'s IOT estimated in the Latin American IOT.

With smaller shares, and no more than 2% together, there is a group of sectors that are little demanded by the rest of the economy. Rather, they are themselves demanders of intermediate inputs imported from the rest of the world. This group includes Clothing, Footwear, Non-ferrous metals, Fabricated metal products, Machinery and electrical equipment, as well as other manufactures.

The main limitation to progress in a process of import substitution lies in the fact that the productive structure of Bolivia (P.S.), i.e. the pattern of its productive structure, has as its backbone the agricultural, farming, mining and agro-industrial industries. All of them are highly dependent on imports of industrial goods in the categories of capital goods, as well as manufactures of medium and high technological content in general.

Aggregating the matrix of inter-sectoral imports of Bolivia (P.S.), for 4 major economic sectors (primary goods, agro-industrial, industrial and services), it was possible to verify that the greatest import demand in that country was concentrated in 4 categories: fuels (23%); industrial goods of various types (31%), that is (Iron and steel, Machinery and equipment, Cars, Electrical and telecommunications equipment, etc.), as well as services (21%). This pattern is reproduced in all sectors. Figure 11 shows that, in all cases, the 4 sectors accounted for more than 85% of the imported inputs of each sector, with smaller shares for Primary goods, Paper and cardboard and Agro-industrial products.

Figure 11
Bolivia (Plur. State of): structure of imported inputs of the production function of large economic sectors, by sector of origin, 2014
(As a percentage of total imports)



Source: Own elaboration based on Bolivia (P.S.)'s IOT estimated in the Latin American IOT.

III. Vertical specialization

The trend in international trade observed worldwide is marked by the phenomenon of globalization and the geographic fragmentation of production. Trade in intermediate inputs accounted for 56% and 73% of trade in goods and services in OECD countries, respectively (Miroudot et al., 2009). Efforts to boost international trade by reducing tariff barriers, trade facilitation and other instruments have helped in the offshoring of production. Companies move stages of their production processes across borders, taking advantage of the benefits offered by other countries (lower labor costs, access to certain markets, etc.). Phenomena such as outsourcing, offshoring, nearshoring and GVC illustrate the importance of this process (Grossman and Hansberg, 2006; Shamis et al., 2005). In this sense, vertical specialization is an indicator that captures information on the fragmentation of production, relating it to exports (Cadarso et al., 2008).

Vertical specialization is defined by Hummels, Ishii and Yi (2001) as the use of foreign intermediate inputs in the production of final products that are exported. It should be remarked that in this way the production stages of a given product can be determined, i.e. it is concluded which countries become part of a single production chain (Backer and Yamano, 2012). At least three countries are involved sequentially: the imported content coming from a country A, incorporated in the finished product of a country B, which is exported to a third country C. The last one receiving that product to satisfy the domestic demand of its economy. The examples discussed in this section correspond to national IOT but can be used with regional and multi-regional IOT, where the possible combinations are greater, since it is possible to calculate the imported content by origin that is necessary to export by destination. Vertical specialization indicators, together with value-added indicators (presented in the subsequent Section IV), are one of the main pillars of international trade analysis using the input-output methodology.

A. Direct imported content on exports (EV1)

This indicator, called *EV1* here, is the basic measure of vertical specialization (VS) that considers the direct imported content in the exports of a country *p* with a matrix example of three sectors:

$$EV1_p = \sum_{i,j=1}^{N} (A_{ij}^{M} \hat{e}_{ij}) =$$

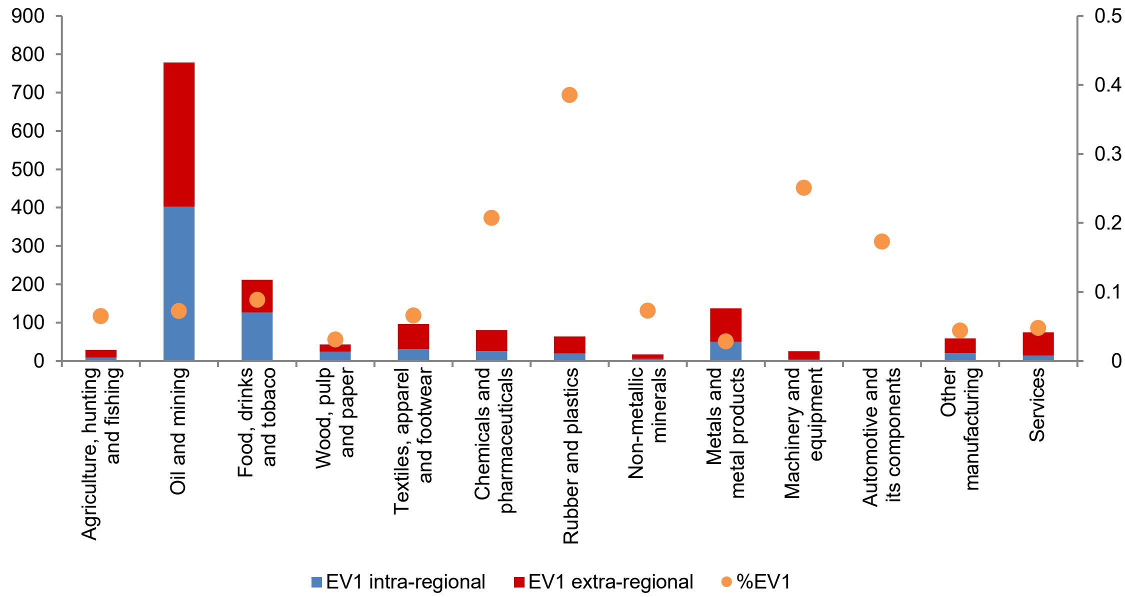
$$\sum_{i,j=1}^{N} \left(\begin{bmatrix} a_{11}^m & a_{12}^m & a_{13}^m \\ a_{21}^m & a_{22}^m & a_{23}^m \\ a_{31}^m & a_{32}^m & a_{33}^m \end{bmatrix} \begin{bmatrix} e_1 & 0 & 0 \\ 0 & e_2 & 0 \\ 0 & 0 & e_3 \end{bmatrix} \right) =$$

$$\sum_{i,j=1}^{N} \begin{bmatrix} a_{11}^m e_1 & a_{12}^m e_2 & a_{13}^m e_3 \\ a_{21}^m e_1 & a_{22}^m e_2 & a_{23}^m e_3 \\ a_{31}^m e_1 & a_{32}^m e_2 & a_{33}^m e_3 \end{bmatrix} \quad (28)$$

EV1 can be calculated by directly multiplying the matrices A^M and ê, where A^M is the *NxN* matrix of technical coefficients imported by country *p* and ê is the *Nx1* vector of diagonalized gross (total) exports of country *p.* This generates a new matrix, whose sum of all its values yields a value referring to the monetary units of direct imported content in the exports of country *p.* This indicator is usually referred to in terms of share in total exports (see Figure 12). A column sum gives the vertical specialization by sector in monetary units. A comparison at the sectoral level provides much more detailed information on which sectors need the most imported content to export, and analyses can be made relating the relevance of the sector in the economy (share in GDP, Rasmussen-Hirschman index), its share in gross exports, and the level of productive fragmentation.

Figure 12 shows the direct imported content of Peru's exports in absolute terms (left axis), and in terms of imported inputs per unit produced (right axis). In absolute terms, exports from the Oil and mining sector stand out, which also proves to be a driving sector, with backward linkages above the country's average. This sector not only exerts a drag effect on the domestic economy, but also participates to a large extent in the country's exports. To export, this sector imports inputs mainly from the region (52%). Although this sector alone, together with Food, beverages and tobacco and Wood, pulp and paper, has a higher share of intra-regional imported inputs, together they account for 57.5% of the country's total exports. In terms of extra-regional participation, there is the Machinery and equipment sector and Services, although these are sectors whose participation in exports is not relevant. In terms of imported inputs per unit of output produced, the Rubber and plastics sector (0.38 imported units per exported unit), together with Machinery and equipment (0.25) and Automotive and its parts (0.17), are the sectors that require the most imported inputs to export. However, these are sectors whose share in exports does not exceed 1.1%. In contrast, the Oil and mining sector requires 0.07 units of imported intermediate inputs per exported unit. A high ratio of imported inputs per unit produced, together with a high share of exports of a sector, informs about the productive specialization of that sector in GVC. This is a fact that is not seen in Peru. In short, Peru does not appear to be part of the GVC, since it does not participate in productive fragmentation. The most important exporting sectors do not process large quantities of imported intermediate inputs.

Figure 12
Peru: direct import content (by origin) over exports (EV1), 13 major categories, 2005
(Millions of dollars and percentages)



Source: Own elaboration based on the SA IOT.

The regional IOT also provide imported inputs by sector and country of origin and gross exports by country of destination for the 10 countries of the region. That way, *EV1* can also be computed considering bilateral exports. Three equations covering all possible combinations are presented below. In all cases the equations yield a single value. For a sectoral analysis, proceed as previously explained in Eq. (29), summing by columns:

$$EV1_A = \sum_{i,j=1}^{N} (A_{ij}^{M} \hat{e}_{ij}^{A,B})$$

$$EV1_B = \sum_{i,j=1}^{N} (A_{ij}^{C,B}\ \hat{e}_{ij})$$

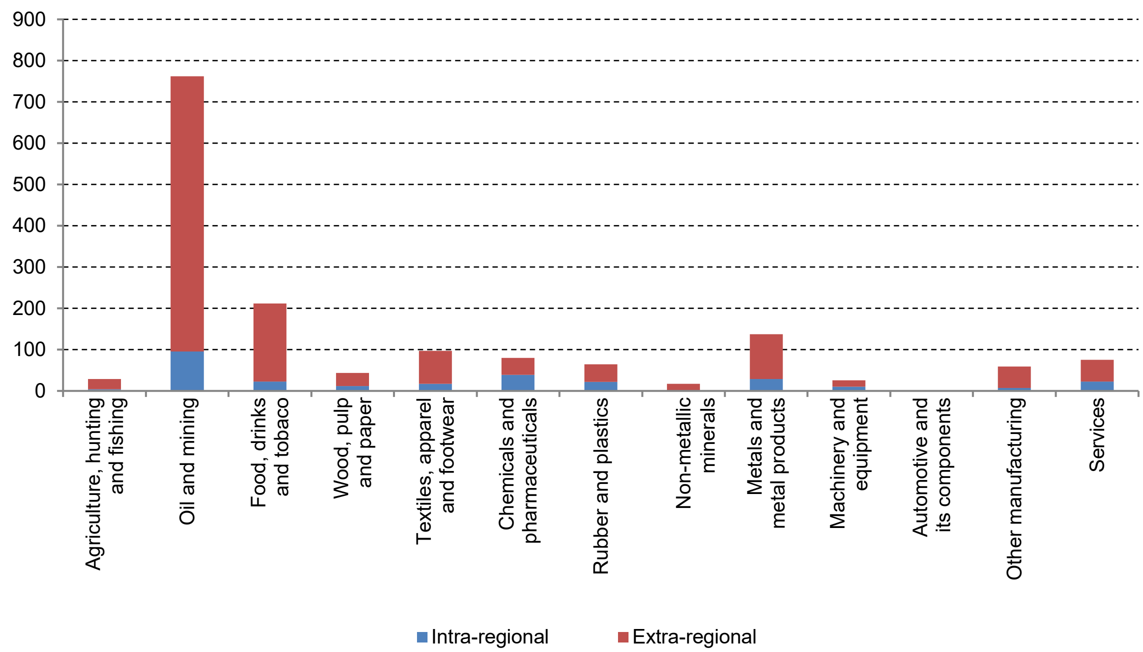
$$EV1_C = \sum_{i,j=1}^{N} (A_{ij}^{A,C} \hat{e}_{ij}^{C,B}) \quad (29)$$

In this case, $EV1_A$ measures the vertical specialization of country A by reporting the total imported content in the gross exports from country A to country B. The calculations are exactly the same as in Eq. (28), with the difference of being able to combine imported inputs A^M by origin and gross exports *e* by destination country. $EV1_B$ is the content that country B imports from C, to satisfy its gross exports. Again, recall that the first superscript reports the country of origin of the inputs and the second the destination. The first example focuses on the destination of the imported content of a country's exports, i.e. where the final product exported by the country under study (country A in this case) is going. The second example focuses on the origin of imports that are necessary for the country under study (country B in this case) to satisfy foreign demand. $EV1_C$ measures the imported content of country A in country C's exports to country B. This last example focuses both on the origin of the imports that are necessary from country A so that the country under study (country C in this case) can satisfy the final demand of country B.

Normally this type of analysis that includes origin and destination cannot be performed by national IOT, which as a rule do not report the origin of intermediate imports and the destination of total exports. However, regional IOT do provide intermediate inputs by origin and total exports *and* by destination for the 10 countries of the region.

Figure 13 shows the destination of the direct requirements imported by Peru to satisfy foreign demand. The difference between the origin and destination of imported content in sectors such as Oil and mining stands out. The sector requires inputs imported mainly from South America, which are processed by the country and then exported mostly to the rest of the world.

Figure 13
Peru: direct import content of exports, by destination (EV1), 13 major categories, 2005
(In millions of dollars)



Source: Own elaboration based on the SA IOT.

The direct imported content of Peru's exports $EV1_{PER}$ using A^M from Chile and total exports to the European Union, shows an *EV1* equal to 12.3 million dollars and its reading is as follows: of the 4,484 million dollars that Peru exported in 2005 to the European Union, 12.3 million dollars are attributed to the direct imported requirements from Chile contained in exports to the European Union. In short, 0.3% of Peru's exports to the EU-27 come from inputs imported from Chile.

A limitation of this indicator is that it considers only the direct imported requirements of exports. It ignores indirect inter-industry linkages, which also contribute to vertical specialization. However, *EV1* is generally used in combination with another indicator, proposed by Hummels, Ishii and Yi (2001), presented below, which captures both imported inputs (direct and indirect) embodied in the exports of the country under study.

B. Total content (direct and indirect) imported over exports (EV2)

In the previous section we presented an indicator that measures the direct imported requirements in a country's exports. This ignores indirect inter-industry linkages, i.e, all the upstream stages or phases of production needed to produce direct inputs (the inputs needed to produce inputs, and so on). This implies an underestimation of the imported content in a country's exports. Therefore, to capture the total content, the *EV2* indicator is presented below, which incorporates the total direct and indirect imported inputs embodied in a country's exports.

$$EV2_p = A_p^M (I - A)^{-1} \hat{e}_p \, , \tag{30}$$

where $A_p^M(I - A)^{-1}\hat{e}_p$ is the total imported content in the domestic production of country *p* destined for exports, in matrix form. This is an *NxN* matrix whose column sum provides information on the vertical specialization of *j* sectors. The sum of all the elements of the matrix provides information on the vertical specialization of the economy. An example for 3 sectors is:

$$\sum_{i,j=1}^{N}\left(\begin{bmatrix} a_{11}^m & a_{12}^m & a_{13}^m \\ a_{21}^m & a_{22}^m & a_{23}^m \\ a_{31}^m & a_{32}^m & a_{33}^m \end{bmatrix}\begin{bmatrix} l_{11} & l_{12} & l_{13} \\ l_{21} & l_{22} & l_{23} \\ l_{31} & l_{32} & l_{33} \end{bmatrix}\begin{bmatrix} e_1 & 0 & 0 \\ 0 & e_2 & 0 \\ 0 & 0 & e_3 \end{bmatrix}\right) =$$

$$\sum_{i,j=1}^{N}\begin{bmatrix} a_{11}^m l_{11} e_1 + a_{12}^m l_{21} e_1 + a_{13}^m l_{31} e_1 & a_{11}^m l_{12} e_2 + a_{12}^m l_{22} e_2 + a_{13}^m l_{32} e_2 & a_{11}^m l_{13} e_3 + a_{12}^m l_{23} e_3 + a_{13}^m l_{33} e_3 \\ a_{21}^m l_{11} e_1 + a_{22}^m l_{21} e_1 + a_{23}^m l_{31} e_1 & a_{21}^m l_{12} e_2 + a_{22}^m l_{22} e_2 + a_{23}^m l_{32} e_2 & a_{21}^m l_{13} e_3 + a_{22}^m l_{23} e_3 + a_{23}^m l_{33} e_3 \\ a_{31}^m l_{11} e_1 + a_{32}^m l_{21} e_1 + a_{33}^m l_{31} e_1 & a_{31}^m l_{12} e_2 + a_{32}^m l_{22} e_2 + a_{33}^m l_{32} e_2 & a_{31}^m l_{13} e_3 + a_{32}^m l_{23} e_3 + a_{33}^m l_{33} e_3 \end{bmatrix}. \tag{31}$$

Considering the total direct and indirect value of the imported content of Colombia's exports, it can be seen that 10.3% of the products it exports come from imported inputs (see Figure 14). Specifically, US$ 2,264 million of imports were necessary to produce and satisfy Colombian exports, which amounted to US$ 22,055 million in 2005. Uruguay and Bolivia (P.S.) continue to have the highest values of vertical specialization, not only in direct but also in indirect terms. Venezuela (B.R.) offers the lowest value. This is one of the South American countries with the least fragmentation of production, since the main exports of Venezuela (B.R.) come from extractive sectors such as *Mining, coke and oil*. They do not require a large, imported content, since Venezuela (B.R.) has abundant natural resource endowments. However, to satisfy the final demand in a country whose economy is extractive in nature and which is defined by a weak participation of manufacturing in its GDP, Venezuela (B.R.) is one of the most foreign-dependent countries.

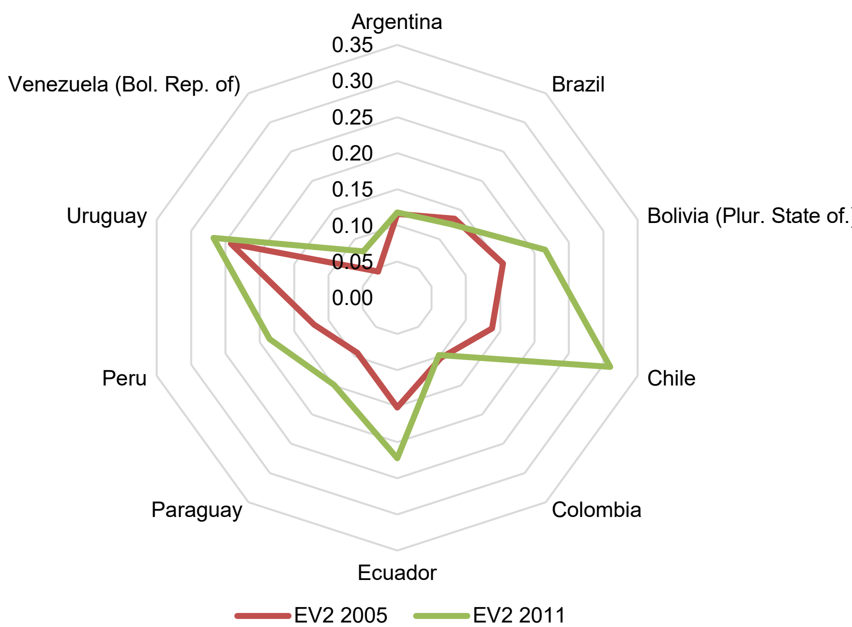
Using the IOT SA, this indicator can be opened by origin of the imported content and by destination of exports. The process is the same as in the case of Eq.(24), simply change the A^M imported technical coefficients according to origin, and/or the destination of exports. Equation (32) is shown as an illustrative example:

$$EV2_A = A^{B,A}(I - A)^{-1}\hat{e}^{A,C} \tag{32}$$

This Equation (32) presents the vertical specialization indicator for country A, which reports the total requirements from imported inputs from country B, necessary to satisfy the final demand of country C. Following the example of Peru, when considering the $EV2_{PER}$ with inputs imported from Chile and exports to the EU, the total imported content, direct and indirect, increases to US$22.85 million. A sectoral analysis (by columns) attributes more than $10 million of Chilean imported content to Peruvian exports to the EU-27 from the Mining (non-energy) sector, followed by $4.3 million of Other food products.

In addition, once the direct and total requirements have been calculated (Eq. (30) and (33)), the indirect imported content of a country's exports (*EVi*) can be calculated as the difference between *EV2* and *EV1*. In the case of Colombia, *EVi* is equal to 3.5%, compared to 6.8% for the direct imported content *EV1* and 10.3% for the total content *EV2*. The highest *EVi* values are observed in Uruguay and Chile, the lowest in Colombia, Paraguay, and Venezuela (B.R.). Figure 13 shows the importance of measuring total requirements, since in the region 45% of the imported content of exports is explained by the indirect requirements that *EV1* does not capture. In Colombia, the direct imported content of exports is 7%. In other words, for each unit exported, Colombia directly requires 0.07 imported units. This indicator is higher in countries such as Uruguay (15.7%), Bolivia (P.S.) (10.2%) and Ecuador (9.3%). The lowest weight of this indicator is observed in Venezuela (B.R.) (3.4%) and Chile (5.3%). The imported content of exports became even higher in 2011 in all countries except Brazil, Argentina, and Colombia. The change in Chile, Bolivia (P.S.), Ecuador and Peru stands out.

Figure 14
Vertical Specialization in South American Countries, 2005 and 2011



Source: Own elaboration based on the SA IOT.

Having obtained the total imported requirements needed to export *(EV2)* and knowing what a country's total exports are, we can also calculate by taking the difference the total domestic requirements embodied in a country's exports. This is understood as a proxy variable for the domestic value added embodied in exports *VADe*, which we will see in the next section.

$$\widehat{VADe}_p \approx \sum_{i,j=1}^{N}(\hat{e}_{ij}) - EV2_p\,, \tag{33}$$

where the value obtained is expressed in monetary units of country *p*. In the case of Colombia, the $VADe_p$ ≈ 22,055 - 2,264= US$19,791 million in relation to US$135,428 million being the total GVA of the Colombian economy. In this case, the domestic value added associated with exports is 14.6% over the total value added. This proxy will be compared with the value-added indicators shown in the following section.

This approximation Eq. (33) and the domestic value added in exports Eq. (30) do not usually provide identical results, since these indicators of vertical specialization assume that imports are entirely produced abroad. Hence, it is not possible to account for domestic value added that may be embodied in imported inputs. As an example, taking the case of Chile in the IOT SA, the Iron and steel sector imports Z^M intermediate inputs worth US$22.28 million, coming from the Fabricated metal products sector in Peru. These inputs imported by Chile may not be entirely from Peru, as their production may have required inputs from third countries, as well as from the importing country itself, Chile in this case. In contrast, an analysis on the value added captures the factors that have been employed by an economy to generate final products. The latter is therefore a more accurate approach to measure the representativeness of a country's production processes in international trade and the GVC.

Evidence suggests that, for many countries, at least at the aggregate level, EV indicators (also *EVi* and *VADe*) calculated using national IOT are very close to the equivalent estimates that would be derived using MRIOT. However, the relationship starts to become misaligned when the estimates are derived by partner and industry (Ahmad et al., 2017). This is because domestic matrices assume the same sectoral technological endowment of imports, and because it does not capture inter-country linkages that affect domestic requirements. Moreover, something that national IOT cannot do and MRIOT and RIOT can is that the latter allow decomposing the imported content of exports into exports of intermediate inputs and exports of final goods.

The vertical specialization indicators presented in this section provide valuable information on the fragmentation of production processes between countries. High values of these indicators show a greater insertion of the sectors in global value chains, which on the other hand can be understood as a greater dependence on the exterior. Thus, comparing the *RII* and *EV2* (Figure 5 and Figure 14, respectively), countries with greater dependence on the exterior, such as Uruguay, Bolivia (P.S.), Chile or Argentina, tend to be those that require more imported content to export. Low values may imply a low insertion in the GVC, as well as a lower dependence on foreign trade. This is the case of Paraguay. In the case of Venezuela (B.R.), since its export specialization is based on commodities and it does not have a developed industry that allows it to satisfy final demand, the country is an exception. Venezuela (B.R.) is highly dependent on the exterior but without participating in the process of productive fragmentation.

IV. Value Added Indicators

This section presents the main value-added indicators that can be obtained with national IOT. Together with vertical specialization, which yields results on productive fragmentation, value added indicators provide more precise information than conventional statistics on the role of countries and their weight in trade when determining a country's share in the value of a final product. Furthermore, the measurement and decomposition of these indicators into MRIOT make it possible to study the so-called Global Value Chains. Those are the networks formed by linking the different stages of production of goods and services at the international level, and where imported and domestically produced inputs are combined to produce products that are then exported as intermediate inputs (for subsequent stages of production) or as finished products (for final consumption). Although the possibilities of MRIOT for the analysis of value-added indicators are much greater than in national IOT, indicators are presented that provide aggregate information on the content that each country places on the products that pass through its borders. In this section, we study the different measurements of value added contained in the exports of South American countries offered by the IOT SA, being able to differentiate between direct, indirect, and total value added, as well as value added contained in intermediate exports or final exports. The foreign value added is also calculated by difference.

A. Domestic value added contained in exports

Just as A^M was used to evaluate the imported content in a country's production (Eq.(28)), the domestic value added contained in exports follows the same logic. This indicator can be disaggregated like Vertical Specialization, into *i)* direct value added and *ii)* total domestic value added (direct and indirect). One more component that cannot be measured with domestic IOT but can be measured with MRIOT is the so-called re-imported value added. This refers to the domestic value added that returns to the country of origin incorporated in intermediate imports that are used by the industry in question (Ahmad et al., 2017). From MRIOT, a country's exports can be disaggregated into these three categories, which in turn house three components, accounting for a total of nine components of gross exports (Koopman et al., 2014). For this handbook, only the direct, indirect, and total domestic value added, and foreign value added of a country's exports are going to be calculated. Recall that the distinctive quality of the IOT SA is the fact that it can be opened by destination of exports. That said, for a three-sector economy, the direct domestic value added contained in a country's gross exports *p* is calculated as follows:

$$VADde_p = \sum_{i,j=1}^{N} \hat{V}_p \hat{e}_p$$

$$\sum_{i,j=1}^{N} \left(\begin{bmatrix} V_1 & 0 & 0 \\ 0 & V_2 & 0 \\ 0 & 0 & V_3 \end{bmatrix} \begin{bmatrix} e_1 & 0 & 0 \\ 0 & e_2 & 0 \\ 0 & 0 & e_3 \end{bmatrix} \right) = \sum_{i,j=1}^{N} \begin{bmatrix} V_1 e_1 & 0 & 0 \\ 0 & V_2 e_2 & 0 \\ 0 & 0 & V_3 e_3 \end{bmatrix} \quad (34)$$

The total direct and indirect domestic value added contained in the gross exports of a country *p is* expressed in the following formula:

$$VADe_p = \sum_{i,j=1}^{N} \hat{V}_p (I - A^D)^{-1} \hat{e}_p$$

$$\sum_{i,j=1}^{N} \left(\begin{bmatrix} V_1 & 0 & 0 \\ 0 & V_2 & 0 \\ 0 & 0 & V_3 \end{bmatrix} \begin{bmatrix} l_{11} & l_{12} & l_{13} \\ l_{21} & l_{22} & l_{23} \\ l_{31} & l_{32} & l_{33} \end{bmatrix} \begin{bmatrix} e_1 & 0 & 0 \\ 0 & e_2 & 0 \\ 0 & 0 & e_3 \end{bmatrix} \right) = \sum_{i,j=1}^{N} \begin{bmatrix} V_1 l_{11} e_1 & V_1 l_{12} e_2 & V_1 l_{13} e_3 \\ V_2 l_{21} e_1 & V_2 l_{22} e_2 & V_2 l_{23} e_3 \\ V_3 l_{31} e_1 & V_3 l_{32} e_2 & V_3 l_{33} e_3 \end{bmatrix}, \quad (35)$$

where $\hat{V}_p$ is a diagonalized vector of the value-added coefficients (Eq. (8)) of country *p* by industry of origin. The other components of the equation, the Leontief inverse matrix and the diagonalized export vector, have already been extensively discussed in the previous sections. Thus, equations (34) and (35) provide *NxN* matrices whose sum of all their elements yields the value in monetary units of *ADVde* and *ADVe* for economy *p*, respectively. To analyze the sectoral origin of value added, a row-wise reading is carried out. However, the most important results come from the sum by columns, since it relates to the value added generated in a country in terms of sector *j*, which is the exporter.

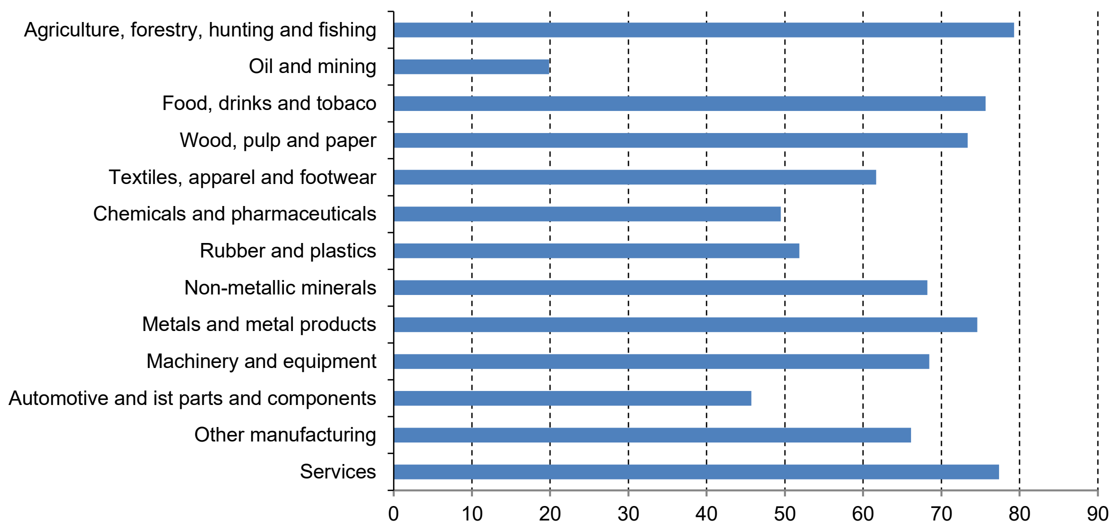
The *VADe* is the most complete indicator presented here to measure the domestic value added contained in exports. It can be used to measure the share of domestic value added embodied in the country's total exports:

$$\%VADe_p = \frac{VADe_p}{\sum_{i,j=1}^{N} (\hat{e}_{ij})_p} \cdot 100 \quad (36)$$

This indicator takes values between 0 and 100. The lower (higher) the indicator, the higher (lower) the foreign content of exports and hence the higher (lower) the importance of imports in exports. In addition to its direct implications, it also hints on the degree of "double counting" in trade statistics since it reflects more accurately a country's true contribution to exports.

Taking the case of Uruguay as an example, exports with the highest domestic value added come from service sectors such as Finance and insurance (91%), Post and telecommunications (89%), or Business services of all types (86%). On the other hand, the domestic component of exports related to Coke and refined petroleum (19%), Basic metal products (42%), or Motor vehicles (45%) is particularly low. Figure 15 shows the share of domestic value added in Uruguay's exports to the world, according to 13 major categories.

Figure 15
Uruguay: domestic value added in exports
(Percentages)



Source: Own elaboration based on the SA IOT.

Finally, the indirect domestic value added incorporated in gross exports (originating from domestic intermediate inputs) is calculated by the difference between $VADe_p$ and $VADde_p$ as follows:

$$VADie_p = VADe_p - VADde_p \quad (37)$$

The domestic value added contained in gross exports can be decomposed into the sum of value added exported to different destination countries (which can also be grouped into regions) by replacing the vector *e* in equations (34), (35) or (36) with an *NxN* matrix of gross exports from each origin industry to each destination country.

The main conclusions drawn from Figure 16 are: *i)* a high domestic value added contained in exports and *ii)* a high share of indirect domestic value added, captured by the Leontief inverse. Countries such as Brazil, Ecuador and Uruguay stand out in this regard, which implies a greater linkage of their productive structure. Uruguay is also the country with the lowest domestic value added in its exports, which indicates a greater insertion in the GVC if complemented with the Vertical Specialization indicator discussed in the previous section. The opposite case is that of Venezuela (B.R.), whose high value added in exports mainly comes directly. This is due to the nature of its production, extractive.

The characteristics of the IOT SA increase the descriptive possibilities of domestic value added in the region. Below are three examples that delve into the domestic value added of a country's exports: the domestic value added in the country's intermediate and final exports and the domestic value added of exports by country of destination.

1. Domestic value-added contained in intermediate and final exports

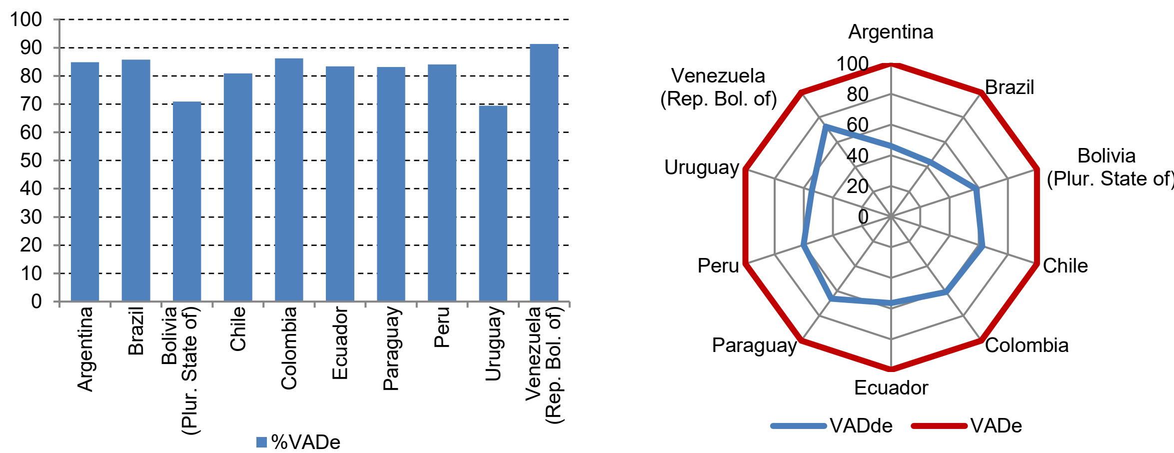
The domestic value added contained in the gross exports of the ten countries that make up the Latin American IOT can be decomposed into those that serve as intermediate foreign demand ($VADe_p^{int}$) and those exports that satisfy final demand ($VADe_p^{f}$):

$$VADe_p^{int} = \hat{V}_p (I - A^D)^{-1} \hat{e}_p^{int} \, , \quad (38)$$

$$VADe_p^f = \hat{V}_p(I - A^D)^{-1}\hat{e}_p^f \,, \quad (39)$$

where $\hat{e}_p^{int}$ is the matrix of gross intermediate exports of country *p* by industry of origin, generated by diagonalizing the vector provided by the IOT SA, and e_p^f is that of gross final exports of country *p* by industry of origin. This calculation is possible only if the matrix provides information on export openness, which differentiates exports by destination into intermediate and final. Figure 16 shows the share of total domestic value added contained in the exports of the ten countries in the region. The same *ADVe* disaggregation calculations carried out in Eq. (24) and (37) can be reproduced for Eq. (38) and (39), simply changing the vector of gross exports *e* for e_p^{int} or e_p^f as appropriate. These calculations can also be carried out at the sectoral level, following the same logic.

Figure 16
Domestic value-added contained in exports, 2005
(Percentages)



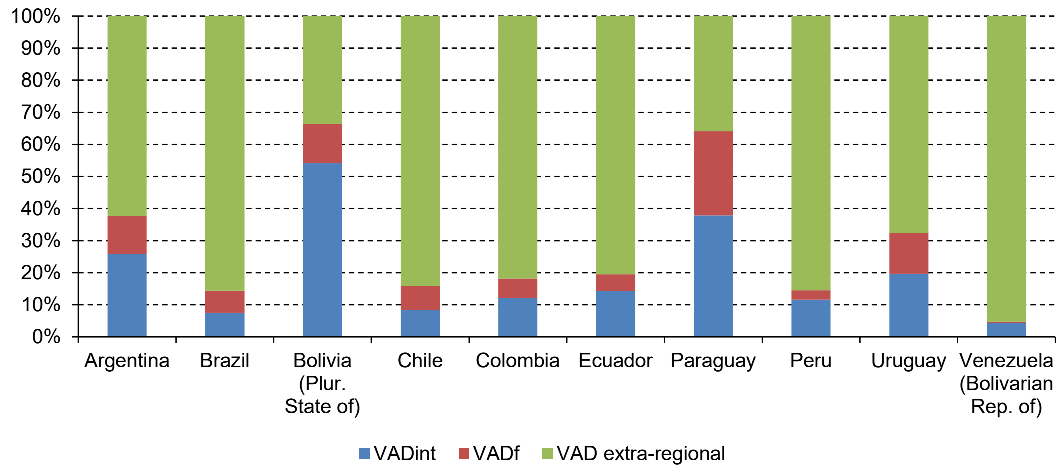
Source: Own elaboration based on the SA IOT.

A limitation of the differentiation of intermediate and final goods in national matrices is the treatment of intermediate goods. By having an e_p^{int} vector, this is treated as an exogenous variable, outside the limits of the Leontief inverse. This means assuming that the total direct and indirect requirements of the country of destination of the intermediate inputs have the same technological (cost) structure as the intermediate input exporting economy. In the case of multi-regional matrices, these interrelationships fall within the overall Leontief inverse, solving the problem.

In addition to being able to differentiate between intermediate and final exports, one of the most relevant measurements made possible by the IOT SA is the study of the share of intra-regional trade with respect to the total, in terms of value added. This allows to observe the degree of integration of countries and sectors in the region. Figure 17 shows the domestic value added contained in exports, differentiating, on the one hand, between intermediate and final intraregional exports and, on the other, regional exports.

The integration of South American countries is low, given the high share of domestic value added in extra-regional trade. Countries such as Bolivia (P.S.) and Paraguay are the most integrated in the region, given their characteristics. They are inland countries, without maritime access, which increases their transportation costs and reduces their possibilities of exporting outside the region. They are also small economies, which base their dependence and trade relations on neighboring countries. At the other extreme are countries such as Chile, Venezuela (B.R.) and Brazil, which specialize in primary and extractive goods destined for the world's large factories, developed economies and emerging powers. Another relevant fact is the importance of trade in intermediate goods. At the intraregional level, all the countries in the region generate more value added in trade in intermediate goods than in final goods.

Figure 17
Domestic value added contained in intra-regional exports, 2005

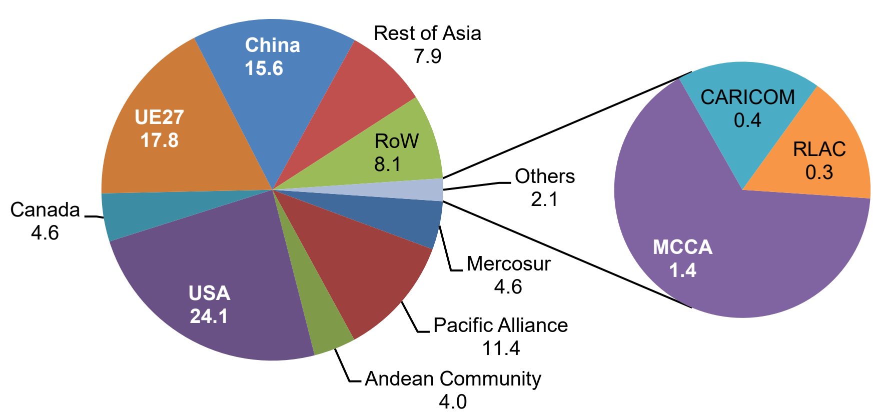


Source: Own elaboration based on the SA IOT.

2. Domestic value added in exports by country of destination

Figure 18 shows Peru's situation with its main trading partners. One of the most relevant measurements made possible by the IOT SA is the study of the share of intra-regional trade and its comparison with the rest of the world. Thus, Peru's value-added exports go mainly to the United States, the European Union of 27 and China. Within the region, its relations with the rest of the members of the Pacific Alliance stand out. Mainly driven by trade with neighboring Chile, in terms of value added, this regional integration initiative is the most important in Peru, ahead of the Andean Community.

Figure 18
Peru: domestic value added contained in exports
(Percentages)



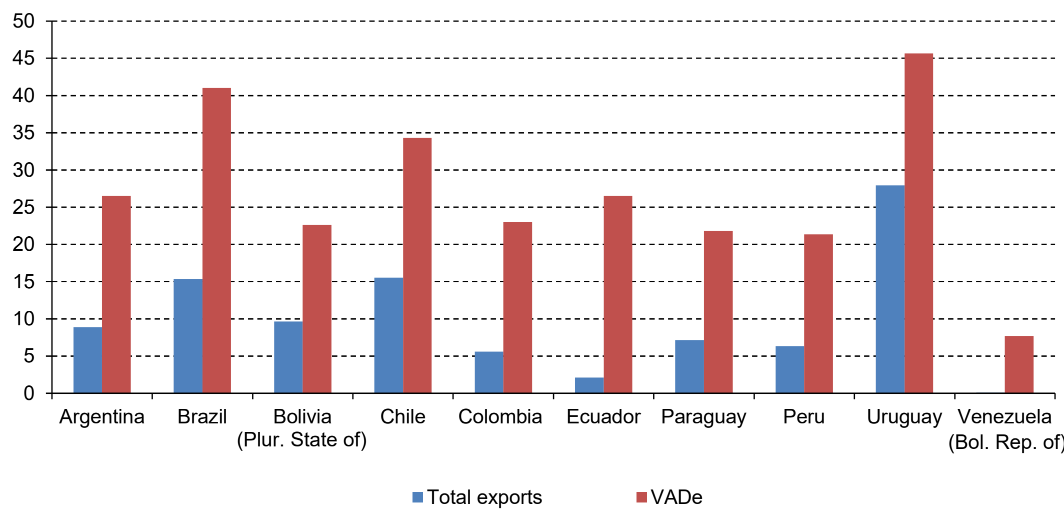
Source: Own elaboration based on the SA IOT.
Note: the domestic value added contained in exports to Colombia is included in both the Andean Community and the Pacific Alliance, this figure incurs double counting.

3. Domestic value added contained in services exports

The importance of services in developed and developing economies is undeniable in terms of their share of GDP and employment. However, trade in services was relegated to second place, overshadowed by the importance of goods flows, as well as by the difficulty of accounting for cross-border services transactions. Thus, conventional statistics (Balance of Payments) reflect a share of trade in services that does not exceed 20% of total trade flows (Lanz and Maurer, 2015). However, services are necessary for the rest of the sectors to carry out their activities (*servification* of manufacturing). To export products such as foodstuffs like soybean oil or rice milk, inputs from the agricultural sector are required, but also services such as electricity, transportation services, financial intermediation services, R&D services, etc. Therefore, given the increased demand for goods to be exported, part of the resulting employment generation will come from the service sectors, which have been required by the different manufacturing industries to be able to export. When trade in services is measured as a supplier of intermediate inputs in terms of value added, the share of services in exports increases considerably, reflecting the importance of this sector as the "glue" of any productive process.

Figure 19 shows a comparison of the weight of services in exports. In total terms, only Uruguay, Brazil and Chile exceed services share of 15%. When measuring the domestic value added of services incorporated in exports (Eq. (29)), the share of services in exports increases considerably in all cases. This calculation is carried out by the sum by ranks of the seven service sectors provided by the IOT SA (Banacloche, 2017).

Figure 19
Share of services in South America's exports
(Percentages)

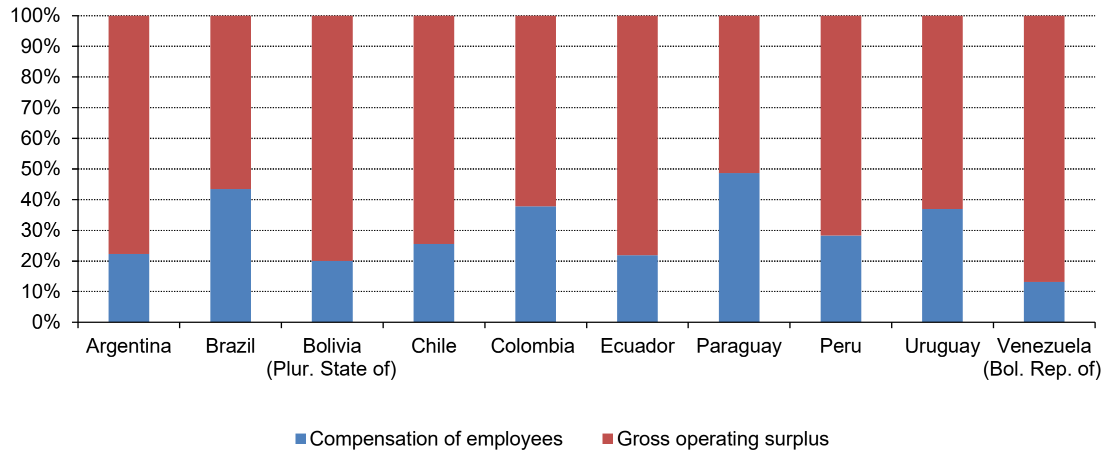


Source: Own eleboration based on the SA IOT.

4. Breakdown of *ADVe*: compensation of employees vs. gross operating surplus

Decomposing the payment to the factors of production in a country's productive process provides information on the distribution of income. In South America, payment to capital is higher than payment to labor in all countries (Fig. 20). Income redistribution policies focused on capital would be more effective in South America, although the gross operating surplus usually includes mixed income. Also informal employment in the region has an important weight. The two facts have an impact on the interpretation of the results.

Figure 20
Share of compensation of employees and gross operating surplus in total exports



Source: Own elaboration based on the SA IOT.

B. Foreign value added contained in exports

The foreign value added contained in exports (VAEe) can be calculated in the case of having domestic IOT as the difference between the total exports of the country under study and the domestic value added contained in those exports. In the case of MRIOT, where the value-added vectors of all countries/regions treated appear and where the matrix is closed, the MRIO analysis can be run disaggregating the value added to its full extent. In the case of national matrices, the *VAEe* ratio for country *p* is expressed as:

$$VAEe_p = \sum_{i,j=1}^{N} (\hat{e}_{ij})_p - VADe_p \tag{40}$$

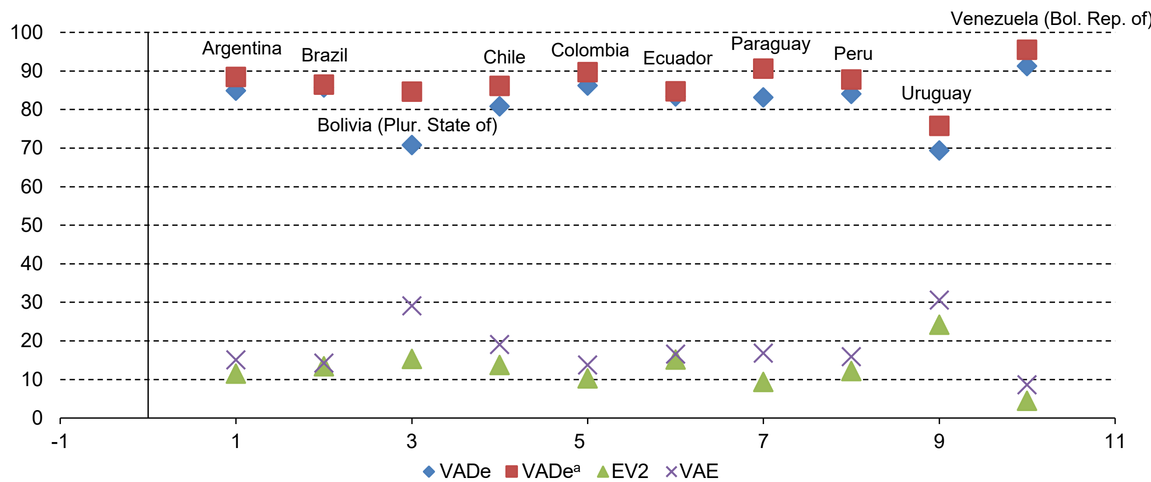
$$\%VAEe_p = 1 - \%VADe_p \tag{41}$$

This indicator yields values similar to those of *EV2*, since conceptually they are similar ratios. In the case of IOT SA, this ratio can also be differentiated by opening exports by industry of origin, country of destination, and/or type of demand served (final or intermediate). Equation (35) implies that the sum of domestic and foreign value-added content should be equal to the total exports of country *p*, both at the aggregate and sectoral levels.

There are several ways to measure a country's participation in GVC. However, open national or regional IOT such as IOT SA cannot calculate GVC in their full magnitude. Hence, the presented indicator and Vertical Specialization are the only approximations available to calculate the foreign value added contained in exports.[2] With MRIOT, this indicator can be calculated by origin and destination. For the analysis of MRIOT, specialized handbooks provide information in this regard for the calculation of GVC (Ahmad et al., 2017; ADB, 2015; Jones, Powers and Ubee, 2013).

[2] In the case of the IOT SA, the term *open* refers to the lack of information on intermediate inputs exported by the country or countries included in that IOT to the world as well as on final imports of the countries from the world.

Figure 21
Differences between main value-added indicators and vertical specialization
(Percentages)



Source: Own elaboration based on the SA IOT.
[a] Calculated according to equation 40.

The indicators presented here are useful to understand the participation of each country in international trade. Note that by measuring the domestic value added contained in final demand, results would be obtained for each country's GDP (see Section II. A).

C. Decomposition of value added in exports

The South American Input-Output Table (IOT SA) is an open regional matrix, whose structure does not include the intermediate inputs exported by the countries of the region to the rest of the world, nor the trade links between the rest of the world. Treating IOT SA as a multi-regional matrix implies accepting the distortion that occurs in Leontief's inverse, mainly because it assumes that South America does not export intermediate goods to the rest of the world. Moreover, the direct linkages themselves in the rest of the world modify the indirect linkages of a global Leontief inverse (Banacloche et al, 2020). Because of this, many value-added measures cannot be developed from RIOT without at least adapting the mathematical notation and narrowing the measures for the RIOT case like the ECLAC IOT (Lalanne, 2020). This adaptation has already been carried out by Álvaro Lalanne in his document on "The insertion of Uruguay in South American value chains", a reference document for understanding how to apply value-added measures in RIOT.

To complement the existing multi-country IOT in Latin America and Asia Pacific, the Economic Commission for Latin America and the Caribbean (ECLAC), together with the Economic and Social Commission for Asia and the Pacific (ESCAP) and the Asian Development Bank (ADB), constructed Global IOT (MRIOT). These include the IOT previously developed by each institution: the multi-country matrix of the Asian Development Bank and the South American Matrix assembled for 2005, as well as the IOT for Latin America and the Caribbean 2011 and 2014, assembled by ECLAC.

The new IOT are a powerful tool for the development of public policies and the promotion of global and regional value chains. They disaggregate production for 20 sectors and include 71 economies, in addition to the Rest of Latin America (ROLAC) and the Rest of the World, for the years 2007, 2011 and 2017. ROLAC in these matrices adds Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, Panama, and Dominican Republic.

In addition, an IOT for 2011 has been released to the public that includes 25 sectors and 78 economies plus the Rest of the World. This IOT disaggregates all countries in the ROLAC group and is consistent with the new Asian Development Bank IOT covering 38 economic sectors. The files made public include a correlation table between the World Input-Output Database (WIOD), ECLAC and ADB initiatives.

This new tool is intended to improve knowledge of interregional production chains, promote the development of value chains, and contribute to the formulation of policies for integration between the two regions. Students, academics, and public policy makers are invited to use the tool made available to the public in studies, technical analyses and the design of indicators to support decision-making.

Thanks to the creation of multi-regional IOT, in this section, we present the methodology and results of GVC analysis based on the proposal of Koopman, Wang and Wei (2014), also "KWW", which decomposes a country's gross exports into value-added components:

$$
\begin{aligned}
uE_{s*} = &\left\{\underbrace{V_s\sum_{r\neq s}^{G} B_{ss}Y_{sr}}_{1} + \underbrace{V_s\sum_{r\neq s}^{G} B_{sr}Y_{rr}}_{2} + \underbrace{V_s\sum_{r\neq s}^{G}\sum_{t\neq s,r}^{G} B_{sr}\,Y_{rt}}_{3}\right\} \\
&+\left\{V_s\sum_{r\neq s}^{G} B_{sr}Y_{rs} + \underbrace{V_s\sum_{r\neq s}^{G} B_{sr}A_{rs}(I-A_{ss})^{-1}Y_{ss}}_{4}\right\} \\
&+\underbrace{V_s\sum_{r\neq s}^{G} B_{sr}A_{rs}(I-A_{ss})^{-1}E_{s*}}_{5} \\
&+\left\{\underbrace{\sum_{t\neq s}^{G}\sum_{r\neq s}^{G} V_t\,B_{ts}Y_{sr}}_{6} + \underbrace{\sum_{t\neq s}^{G}\sum_{r\neq s}^{G} V_t\,B_{ts}A_{sr}\,(I-A_{rr})^{-1}Y_{rr}}_{7}\right\} \\
&+\underbrace{\sum_{t\neq s}^{G} V_tB_{ts}A_{sr}\sum_{r\neq s}^{G}(I-A_{rr})^{-1}\,E_{r*}}_{8}
\end{aligned}
\qquad (42)
$$

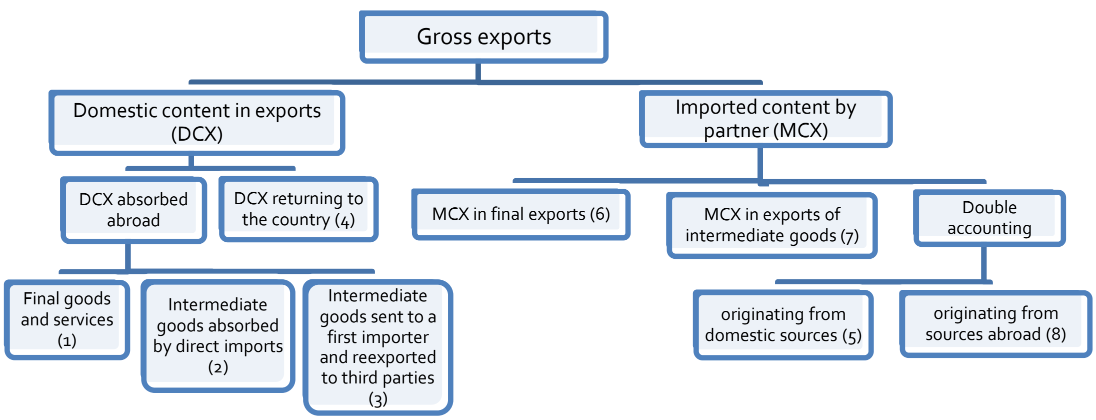
where $uE_{s*}$are the total exports of country *s*, omponent *u* is a $1xGN$ vector of ones, where N is the number of sectors and G is the number of countries, *V* is the diagonalized vector of value added by product, of dimensions $GNxGN$, *B is the* global Leontief inverse matrix of $GNxGN$, where B_{ss} is the part corresponding to the domestic part of this inverse, for country *s* (of dimension NxN). Recall that the first subscript indicates the country of origin and the second the country of destination. *A* are the technical coefficients and *Y* is the final demand. Finally, $(I - A_{ss})^{-1}$ refers to the domestic Leontief inverse calculated from a matrix of technical coefficients with elements only on the main diagonal, and $(I - A_{rr})^{-1}$ from technical coefficients with zeros on the main diagonal. The asterisk refers to all countries. For example, E_{s*} indicates the total exports of country *s*.

Diagram 8 captures the components of the decomposition shown in Eq.(36), mainly two basic components: domestic value added, and the imported content of exports. These are the elements that constitute the axis of a country's participation in global value chains either through the sale of its domestic production to the world (forward linkages), or the purchase of inputs required to enter its exportable production (backward linkages). Both components can approximate the productive integration of foreign trade at the bilateral, regional, and global levels. Their extent refers to the calculations made with the vector of bilateral exports, of a group of partners, for example, those of Latin America, or another subregional grouping, or total exports.

The domestic content corresponds to the value added incorporated in total exports, which can be absorbed abroad in the form of final consumer goods (1), or alternatively intermediate goods absorbed by productive sectors of the importing country (2), and in some cases, the domestic value added forms part of intermediate goods that are then re-exported (3), there being a proportion of value added, which having been included in the productive process of a third country, returns to the domestic productive process (4). An example of this is the export of products containing copper parts and pieces that were previously exported and returned to be incorporated in another final product exported by the same country. The four components make up the total value added exported by a given country and constitute the various levels of value added generation and international insertion of the country into global value chains.

The imported content of exports, also known as a measure of vertical integration, is the proportion of total exports that incorporate intermediate goods of foreign origin, which may be part of exports of final goods (6), or in turn of new intermediate goods (7), or alternatively be part of redundant imports that have some double counting, in the sense of incorporating imported content with domestic inputs included in imported products (5), or alternatively imported content with foreign inputs (8).

Diagram 8
Structure of gross exports according to domestic value added and imported inputs incorporated



Source: Own elaboration based on Koopman et al. (2016), Koopman, Wan, and Wei (2014), and Borin and Mancini (2020).

The decomposition of the gross value exported into various elements, including double counting has important implications for trade policy. Inomata (2017) cites as an example the anti-dumping measures that the European Commission imposed on footwear imports from China and Vietnam in 2006, which had a negative impact on EU service industries. The explanation for the injury was the fact that footwear imports from that origin incorporated value added originating in EU design and distribution sectors. Situations such as this could have been avoided if the sources of the imported value added, or alternatively the trade balance of the value-added component, were more clearly known. This could show different conclusions from the trade balances in gross terms.[3]

[3] Since accounting for value added in gross and net terms is perfectly compatible in terms of identity, a country's trade balance can be decomposed into gross and net terms. A demonstration of such identities can be found in Kuboniwa (2014a, 2014b).

Attending to the literature, the approach of Koopman et al. (2016), systematized above in Diagram 8, is conceived as the first unifying mathematical framework to formalize and decompose gross exports into value-added components. Moreover, among the virtues of this decomposition it stands out that it includes other GVC measures: for example, the value-added exports (VAX) ratio (Johnson and Noguera, 2012) in components 1 to 3, the GDP in exports (components 1 to 4), the domestic content in exports (components 1 to 5) as well as the so-called vertical specialization (components 6, 7 and 8) and the VS1 of Hummels et al. (2001) (components 3, 4 and 5). Finally, components 4, 5 and 8 show the value added that crosses national borders at least twice and are the result of multiple counting by official trade statistics. However, it should be noted that this methodology has its limitations: first, it cannot be used for bilateral trade. Second, it does not separate foreign value added and domestic content appropriately. And third, the expressions include gross exports as dependent and independent variables. New developments have emerged in recent years to deepen the GVC analysis, both for the calculation of bilateral exports (Borin and Mancini, 2019) and the limitations of KWW in terms of endogeneity (Arto et al, 2020).

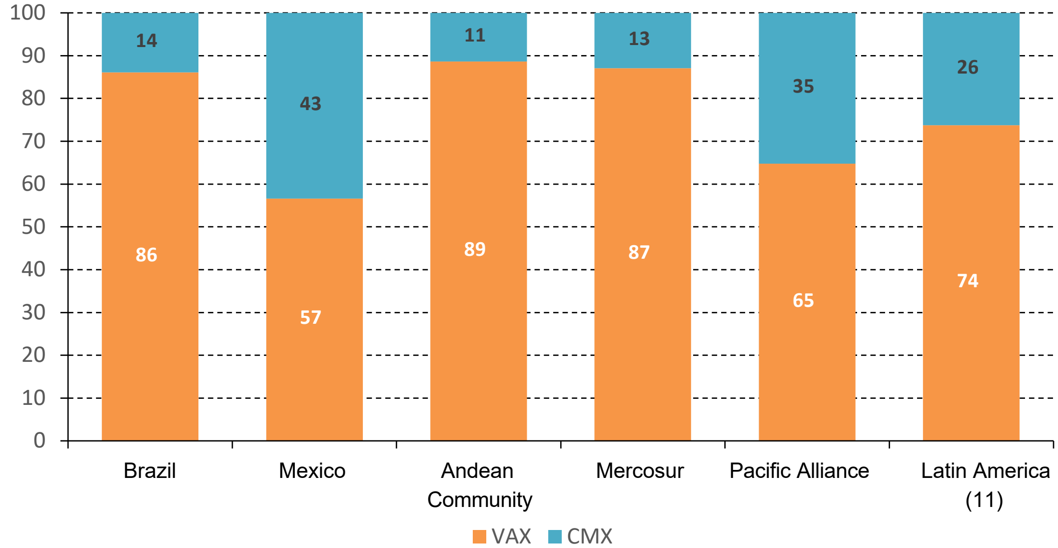
Table 4 presents the two main components of Latin America's total value-added exports in gross and relative terms. It shows that on average 72.9% of regional value-added exports are domestic inputs of the country itself, with the imported component accounting for 27%. Venezuela (B.R.) and Argentina are the countries with the highest domestic content (93.3% and 91%, respectively), and Mexico is the one with the highest vertical integration measured as the proportion of imports incorporated in exports of goods to the world. Bolivia (P.S.) and Chile are the next countries. At the sub-regional level, imports from the Pacific Alliance countries show greater vertical integration, influenced by the higher proportion of imported content from Mexico, mainly (see Fig. 22).

Table 4
Latin America (11) breakdown of gross exports by domestic value addedand imported inputs incorporated, 2017
(Millions of dollars and percentages of total)

Countries	Gross exports decomposition *(Millions of dollars)*			Vertical Integration Indicators *(Share of total)*		
	VAX	CMX	Exports	VAX	CMX	Exports
Argentina	64 620	6 766	71 386	90.5	9.5	100.0
Brazil	222 279	35 930	258 209	86.1	13.9	100.0
Paraguay	13 618	2 154	15 772	86.3	13.7	100.0
Uruguay	11 439	1 583	13 023	87.8	12.2	100.0
Venezuela (Bol. Rep. of)	13 930	982	14 912	93.4	6.6	100.0
Bolivia (Plur. State of)	7 889	1 640	9 529	82.8	17.2	100.0
Ecuador	18 895	2 983	21 877	86.4	13.6	100.0
Colombia	40 829	4 846	45 675	89.4	10.6	100.0
Peru	39 345	4 267	43 613	90.2	9.8	100.0
Chile	61 618	12 435	74 053	83.2	16.8	100.0
Mexico	250 184	191 562	441 746	56.6	43.4	100.0
Latin America (11)	744 647	265 148	1009 794	73.7	26.3	100.0

Source: Own elaboration based on the Global IOT constructed in the 2017 Latin America and East Asia Cooperation Forum project, ECLAC-Asian Development Bank and ESCAP.

Figure 22
Latin America (11) breakdown of gross exports by domestic value added and imported inputs incorporated, 2017
(Percentages)



Source: Own elaboration based on the Global IOT constructed in the 2017 Latin America and East Asia Cooperation Forum project, ECLAC-Asian Development Bank and ESCAP.

A broader look at all the components of exported value added (both domestic and imported) by looking at the breakdown of gross exports into the 8 components described in Diagram 1 can be seen from the calculation of these components at the country level. Tab. 4 presents the results in absolute values, while Tab. 5 presents the relative values of each component in relation to total exports.

A first analysis indicates that there are two main dominant components of domestic value added: firstly, value added absorbed abroad in intermediate goods (VAXig), and secondly, value added in final goods (VAXfg), shown in columns (2) and (1), respectively in Tab. 3. In the first case, exports of exported domestic value added have Mexico as the main exporter in the region, with 50%[4] of the total value added exported by the 11 countries considered. It is followed by Brazil and Chile with 27% and 6% of the total. The countries that export the least value added in final goods are Venezuela (B.R.) and Bolivia (P.S.), which are the countries with the lowest degree of industrialization in South America. In both cases, the manufacturing industry is oriented more to the domestic market than to the production of goods for export. In terms of the value added of intermediate goods, it is Brazil, with US$103.8 billion, that exports the highest density of inputs, followed by Mexico, which exported US$97.1 billion. Chile, Colombia, and Peru follow in order of importance. It should be noted that the products exported in this category include not only semi-industrial or industrial manufacturing products, but also basic raw materials such as iron ore, petroleum, copper, and minerals.

The exported value-added component of intermediate goods that are re-exported to a third country (VAXig-reex) is also dominated by Brazil, Mexico, and Chile.

[4] These percentages result from obtaining the percentage of the total value exported by each country in the category analyzed in the total value exported by the total number of countries considered in the analysis. For example, for column 1, 50% for Mexico is obtained by dividing 119,054 by 237,520 and multiplying by 100. The resulting percentage is 50.1%.

Table 5
Breakdown of gross exports by domestic value added and imported inputs incorporated, 2017
(In millions of dollars)

Country	Domestic value-added (DVA_G)				Vertical Specializations (VS)				Total exports
	DVA_FIN (1)	DVA_INT (2)	DVA_INTrex (3)	RDV_G (4)	DDC (5)	FVA_FIN (6)	FVA_INT (7)	FDC (8)	(1 a 8)
Argentina	26 753	26 837	10 834	179	17	3 366	2 351	1 049	71 386
Bolivia (Plur. State of)	1 542	4 498	1 839	10	2	282	955	403	9 529
Brazil	64 067	104 361	52 628	1 060	164	12 537	15 037	8 355	258 209
Chile	14 642	30 839	16 038	83	16	3 974	5 550	2 911	74 053
Colombia	7 084	23 615	10 072	52	6	998	2 749	1 099	45 675
Ecuador	9 140	7 164	2 565	20	5	1 325	1 220	438	21 877
Mexico	117 746	98 005	31 325	1 713	1 395	108 789	62 097	20 676	441 746
Paraguay	4 381	6 903	2 322	10	2	892	896	366	15 772
Peru	8 051	20 397	10 845	47	6	918	2 201	1 148	43 613
Uruguay	3 325	5 869	2 241	4	1	491	765	327	13 023
Venezuela (Bolivarian Rep. of)	537	10 453	2 905	34	1	174	566	242	14 912
Latin America (11)	257 267	338 940	143 614	3 211	1 614	133 744	94 388	37 015	1 009 794

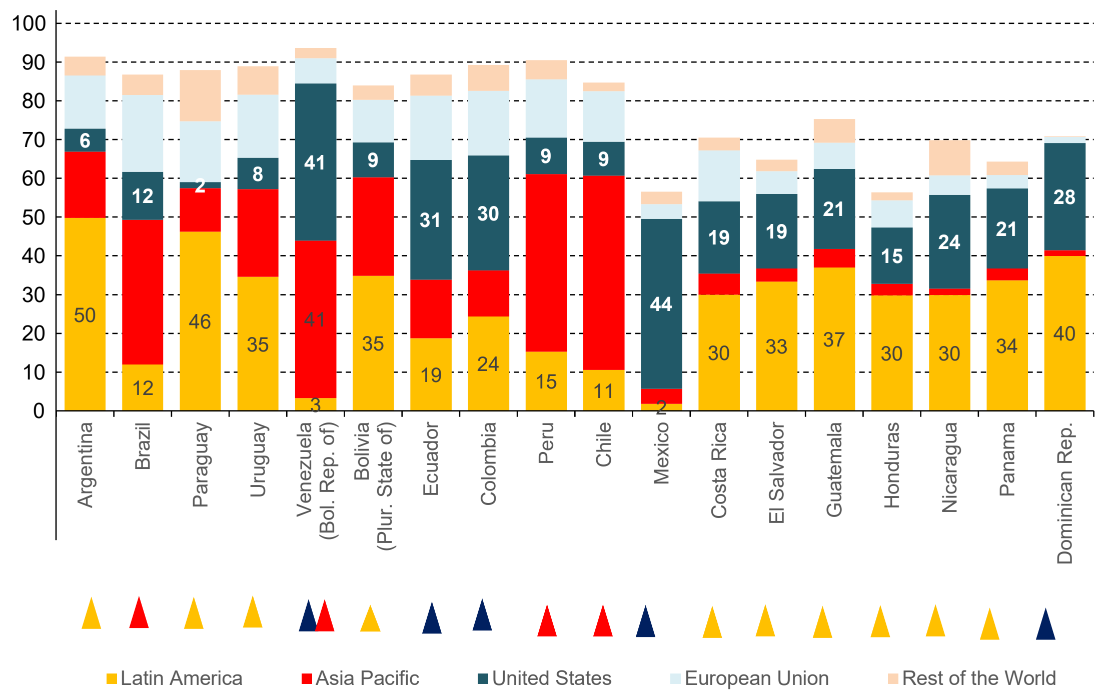
Source: Own elaboration based on the Global IOT constructed in the 2017 Latin America and East Asia Cooperation Forum project, ECLAC-Asian Development Bank and ESCAP.
Notes: VAXfg = Value-added of final goods; VAXig-da = Value-added of directly absorbed intermediate goods; VAXig-reex = Value-added of intermediate goods re-exported to a third country; VAX-rco = Value-added returning to country of origin; CMXdc-do = Double-counted imported component of domestic origin; CMXfg = Imported content of final goods; CMXig = Imported component of intermediate goods, CMXdc-foro = Double-counted imported content of foreign origin.

An additional way to present this decomposition of gross exports according to domestic value added and imported content is by destination and/or origin, i.e. according to the main partners. Additionally, such analysis can be enriched with a sectoral approach. Below are some illustrative results as examples, including analytical interpretation:

The breakdown of national value added exported by main partners shows that the group of countries that export mainly to the region itself includes Argentina, Bolivia (P.S.), Costa Rica, the Dominican Republic, El Salvador, Guatemala, Honduras, Nicaragua, Panama, Paraguay and Uruguay (see Fig. 23). In all cases, the relationship of each country with the integration scheme of which it forms part is particularly noteworthy. Thus, Argentina, Paraguay and Uruguay show greater productive integration with MERCOSUR. Similarly, in the cases of Costa Rica, Nicaragua, Panama and El Salvador, the strongest trade relationship is with their partners in the Central American Common Market.

Among the countries in the region that send the largest proportion of domestic value added to the United States, Mexico stands out, with 44% of a total of 57% of value added going to the United States. Other countries with the United States as the main destination for domestic value added exports are Colombia, Ecuador and Venezuela (B.R.). The six Central American countries and the Dominican Republic have the United States as the second main destination for their exports of domestic value added. Finally, a third group of countries (Brazil, Chile and Peru) exports most of their domestic value added to Asia.

Figure 23
Latin America (18 countries): domestic value added contained in exports, by main destinations, 2017[a]
(Percentages)

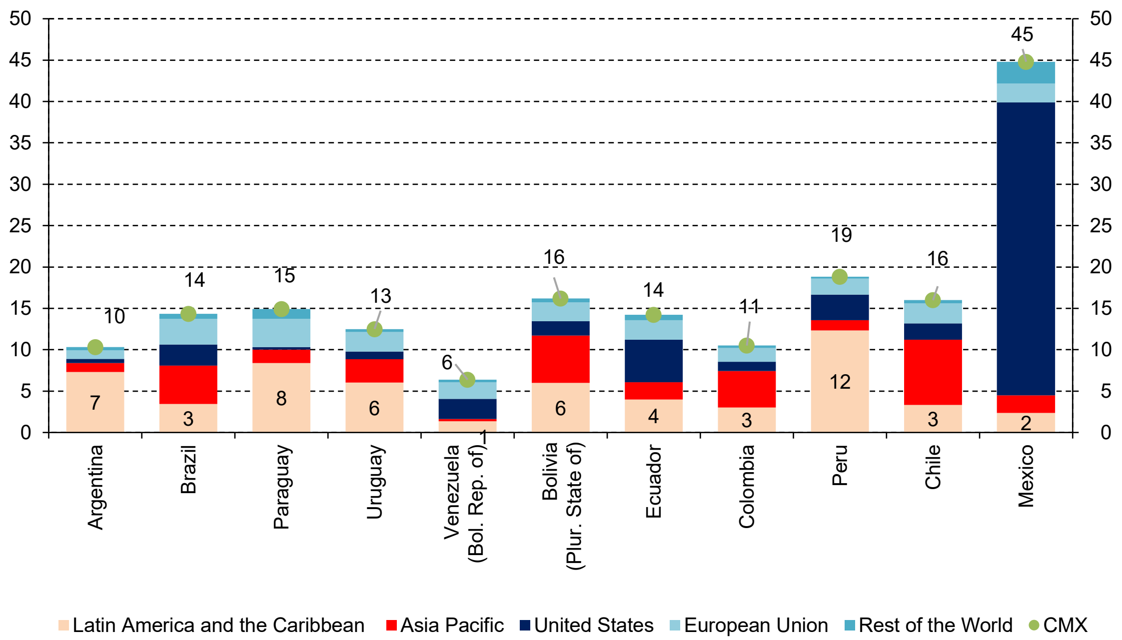


Source: Own elaboration based on the global IOT 2017. The matrix can be downloaded online at: https://www.cepal.org/es/eventos/matrices-globales-insumo-producto-herramientas-facilitar-estudio-la-integracion-america.
Note: The colored triangles indicate the main destination of each country's exports.
[a] In the cases of Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, Panama and the Dominican Republic, calculations were made based on the 2014 Latin American IOT.

The main subregions of Latin America exhibit differentiated patterns of productive insertion with Asia-Pacific. This region has a much greater weight in South America's exports than in those of Central America (see Fig. 23). It is worth noting that the share of value added originating in Latin America in its exports almost doubled between 2011 and 2014, and then plummeted between the latter year and 2017. In the latter period, the fall in intraregional trade was much greater in terms of value added than in gross terms. The evolution of the weight of trade in terms of value added at the intraregional level between 2011 and 2017 shows a similarly procyclical behavior as that shown by gross flows.

The imported content incorporated in exports fluctuates between 6% in Venezuela (B.R.) and 45% in Mexico. In the case of Mexico, this is the result of its high productive integration with the United States, which accounts for 35 percentage points of this total. The share of intra-regional imported content in total exports averages only 3% and fluctuates between 1% and 12% (see Fig. 23). The highest shares are found in Colombia and Paraguay (12% and 8%, respectively), followed by Argentina (7%) and Bollivia, P.S., and Uruguay (6% each). Mexico and Venezuela (B.R.), are the least integrated countries with the region according to this metric. Greater integration of inputs from Asia and the Pacific, compared with those originating in the region itself, is observed in the cases of Bolivia (P.S.), Brazil, Chile and Peru.

Figure 24
Latin America (11 countries): structure of imported content of total exports, by origin, 2017
(Percentages)

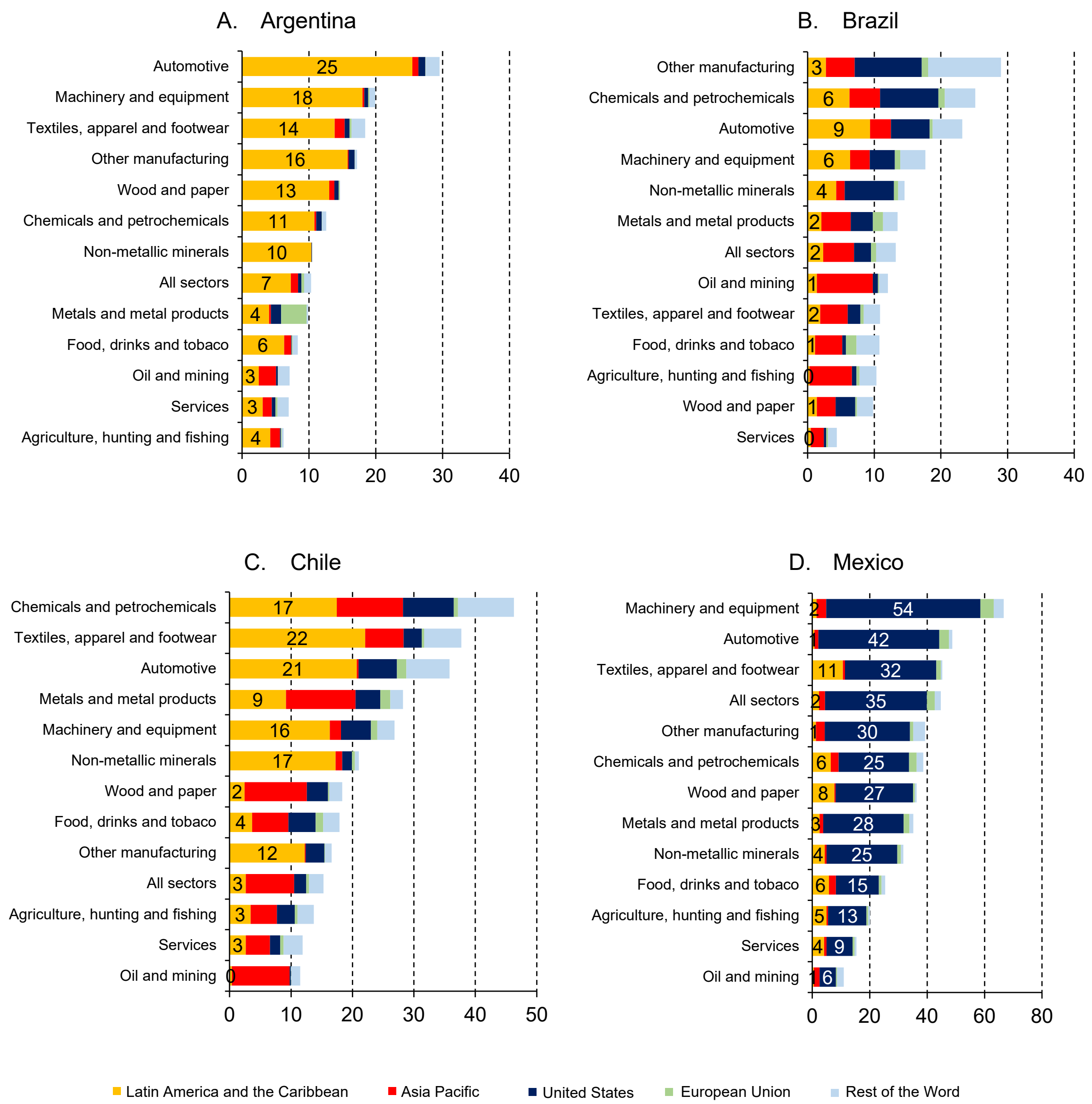


Source: Own elaboration based on the 2017 global IOT. The table can be downloaded online at: https://www.cepal.org/es/eventos/matrices-globales-insumo-producto-herramientas-facilitar-estudio-la-integracion-america.

At the aggregate level, there are no major differences in the share of Latin America and Asia-Pacific in the imported content of the region's exports, which in both cases is around 3% on average. However, there is great heterogeneity by country and sector. For example, Mexico is largely integrated with the United States, and very little integrated with the region (see Fig. 24). The sectors with the highest coefficient of vertical integration with the rest of the region are textiles and apparel (11%) and wood and paper (8%). In general, Mexico shows greater vertical integration with Latin America than with Asia-Pacific, especially in low- and medium-intensity manufacturing sectors. In heavy manufacturing (automobiles and machinery and equipment), there is greater integration with Asia-Pacific.

Brazil, with a lower degree of vertical integration than Mexico, is also not highly integrated with the rest of the region. Its intermediate inputs originate to a greater extent from Asia and the Pacific than from the region, except in the heavy manufacturing, motor vehicles, and machinery and equipment sectors. In contrast, Argentina and Chile show greater integration with the region than with the rest of the world. In general, a large proportion of the inputs imported from the region comes from the bloc to which each country belongs. This is the case of Argentina, Paraguay, and Uruguay (where they come largely from MERCOSUR) and Ecuador and Peru (from the Andean Community) (see Fig. 25).

Figure 25
Latin America (selected countries): structure of imported content embodied in exports, by major economic sectors, 2017
(As a percentage of total exports)



Source: Own elaboration based on the 2017 global IOT. The table can be downloaded online at: https://www.cepal.org/es/eventos/matrices-globales-insumo-producto-herramientas-facilitar-estudio-la-integracion-america.

V. Extensions and applications of input-output tables

So far, economic calculations have been made mostly related to the production structure, linkages and trade, and are mainly based on the value added generated by the countries and the imported content of their exports. However, the input-output methodology can also be used to analyze social and environmental impacts. These impacts can be adapted to the format of the IOT by creating a factor that, pre-multiplied by the Leontief Inverse, generates a so-called multiplier, i.e. offering the total direct and indirect returns of this factor per unit of final product. This procedure has already been put into practice in the present document, in terms of value added as a factor (Eq.(8)), or when measuring the imported content of domestic production (Eq.(22)). Examples of factors (*F*), in addition to value added and its components are: labor by skill level and gender as well as energy, land, water, coal, oil, pollutants (emissions) and materials (aluminum, copper, iron). In the case of value added and its components, the factor is presented directly in the input-output table itself, so the vector is sectorized and adapted to the matrix format used. In the case of the other factors, the information must be mapped to the sectors according to the matrix used, i.e. the factor must be disaggregated by sector. In addition, every *F* factor requires two conditions in order to obtain multipliers appropriate to the input-output methodology:

i) It must be an impact or factor that is different by sector;

ii) It should increase proportionally with production.

Once the vector F has been constructed, the total requirements of this factor to satisfy the final demand of an economy can be calculated. First, the coefficients of this factor are calculated:

$$f = Fx^{-1} = \begin{bmatrix} \frac{F_1}{x_1} & \frac{F_2}{x_2} & \cdots & \frac{F_N}{x_N} \end{bmatrix}, \tag{43}$$

where F_N is the analyzed factor coefficient *F* of sector *N*, and x_N is the gross value of production (GVP). This *Nx1* vector reports the factor content per unit of output of each sector.

$$MF = \hat{f}(I - A)^{-1} \quad (44)$$

Equation (44) is the multiplier of the F-factor. $\hat{f}$ is the diagonalized vector of the coefficients of that factor. As a matrix expression for three sectors, it reads:

$$MF = \begin{pmatrix} f_1 l_{11} & f_1 l_{12} & f_1 l_{13} \\ f_2 l_{21} & f_2 l_{22} & f_2 l_{23} \\ f_3 l_{31} & f_3 l_{32} & f_3 l_{33} \end{pmatrix} \quad (45)$$

The reading in matrix form informs about the total requirements of the chosen factor, associated to a unit of product destined to satisfy the final demand. Thus, it shows the total requirements of that factor, which industry 1 allocates to itself; $f_1 l_{11}$ hence shows the total requirements of that factor, which industry 1 allocates to itself. A row sum indicates the factor coming from industry 1 associated with the production of all the productive sectors of any economy that satisfy the final demand. A column sum indicates the total factor from all sectors associated with the inputs that the column sector needs to produce one unit of output to satisfy final demand.

Two extensions of the input-output model are exemplified below: the estimation of employment associated with exports and CO_2 emissions associated with production and consumption in South American countries.

A. Estimate of employment associated with exports

For the estimation of direct and indirect employment in the different South American countries, we have used information provided by the national and international institutions in charge of its official provision: National Statistics Institutes, Central Banks, Household Surveys and the Economic Census (Durán and Castresana, 2016). Thus, the information has been cleaned and mapped by country and sector, obtaining a vector of number of employees $N^* = KNx1$ with K being the number of countries and N the number of sectors. The employment vectors have been developed jointly by ECLAC and the International Labor Organization (ILO). They will be published in the future on the ECLAC International Trade and Economic Integration Division website. Once the employment vector has been obtained, the employment coefficient (*EC*) is calculated, expressed in Eq. (40) as a *Nx1* vector that expresses the work per product of sector *i*.

$$CE = N^* x^{-1} = \begin{bmatrix} \frac{N_1^*}{x_1} & \frac{N_2^*}{x_2} & \dots & \frac{N_N^*}{x_N} \end{bmatrix}, \quad (46)$$

where N^*N is the labor factor of sector *N*, x_N is the Gross Value of Production of sector *N*, and CE_N is the analyzed employment coefficient of sector *N*. Following the above steps, we obtain the employment multiplier and its matrix example with three sectors:

$$MCE = \widehat{CE}(I - A)^{-1} =$$
$$\begin{pmatrix} CE_1 l_{11} & CE_1 l_{12} & CE_1 l_{13} \\ CE_2 l_{21} & CE_2 l_{22} & CE_2 l_{23} \\ CE_3 l_{31} & CE_3 l_{32} & CE_3 l_{33} \end{pmatrix} \quad (47)$$

The reading is equal to expression (39). The rows show the number of workers in sector *i* that are directly or indirectly required by that sector and the rest of the sectors of an economy to produce a unit of product that satisfies the final demand. Columns show the number of employees required in sector *j from* all sectors of a country. Finally, to observe the employment associated with exports, the employment multiplier is multiplied by the diagonalized export vector:

$$Export - related\ employment = \widehat{CE}(I - A)^{-1}\hat{e} \quad (48)$$

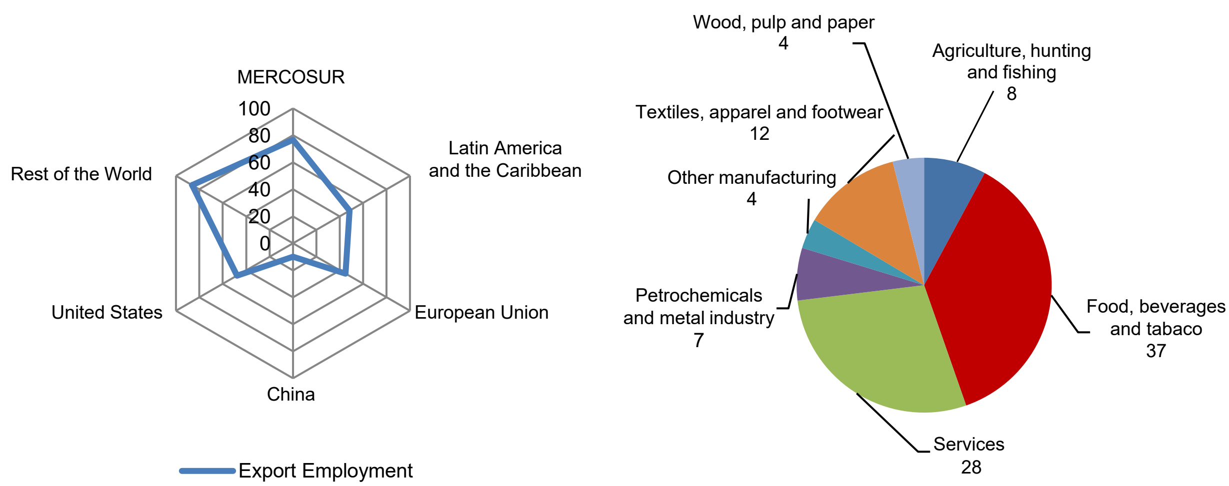
The matrix expression for an illustrative three-sector economy is as follows:

$$Export - related\ employment = \begin{pmatrix} CE_1 l_{11} e_1 & CE_1 l_{12} e_2 & CE_1 l_{13} e_3 \\ CE_2 l_{21} e_1 & CE_2 l_{22} e_2 & CE_2 l_{23} e_3 \\ CE_3 l_{31} e_1 & CE_3 l_{32} e_2 & CE_3 l_{33} e_3 \end{pmatrix} \quad (49)$$

A row reading of expression (43) indicates the total employment from sector *i* that all sectors of an economy require to produce one unit of output for its exports. A columnar reading indicates the total employment from all sectors required by sector *j* to export.

With the IOT SA it is possible to calculate the employment associated with exports (intra- and extra-regional), by country and sector of origin. It also makes it possible to identify the most employment-intensive export destinations. Figure 26 shows the total employment linked to Uruguay's exports and a ranking of major export sectors in terms of total employment. In 2005, Uruguay's exports generated a total of 314,016 jobs, equal to 21.4% of Uruguayan domestic employment. The *Food, beverages and tobacco* sector, followed by *Services*, generated the most jobs when exporting (52% of the employment generated). A total of 162,861 jobs can be attributed to exports in these sectors.

Figure 26
Uruguay: export employment by main destinations and benefited sectors
(Thousands of people and percentages)



Source: Own elaboration based on the SA IOT

In addition, export employment can be identified by type of exported good (intermediate or final), employment intensity, direct employment (generated directly by the sectors themselves) and indirect employment (that arises indirectly in the production phases in all sectors), and employment by gender, level of qualification or other disaggregation such as the number of employees linked to export activities with greater environmental sensitivity (Durán and Castresana, 2016).

B. Carbon footprint

Following the same procedure as for calculating the employment multiplier, this section proceeds to calculate the CO2 emissions multiplier. What is needed are coefficients of the environmental impact or factor (environmental impact caused by a branch per unit of production). Emissions data by branch are obtained mainly from three basic statistical sources of greenhouse gas (GHG) emissions (Genty et al., 2012):

- *Satellite accounts of atmospheric emissions (Environmental Accounts)*, also called *National Accounting Matrix with Environmental Accounts (*NAMEA). These accounts are based on the residency principle[5] and are therefore consistent with the System of National Accounts. They can be used immediately for input-output analysis but are generally not widely available. They are usually offered by the Statistical Institutes.
- *Energy accounts*, whose information comes from the energy balances compiled by the International Energy *Agency (*IEA). The information is based on the territorial principle.[6] For the subsequent calculation of emissions, a linear relationship between emissions and type of activity is assumed, where emissions are the product of multiplying the level of activity, directly linked to the energy accounts, and the emission factor is specific to the pollutant (IPCC, 2006).
- *National inventories* on atmospheric emissions submitted by countries in different initiatives such as the *United Nations Framework Convention on Climate Change* (UNFCCC) and the *Intergovernmental Panel on Climate Change (*IPCC). The information is also based on the territorial principle.

Once the emissions data have been obtained, the emissions coefficient (*Ce*) is calculated. Expression (44) is a *Nx1* vector that expresses the CO_2 emissions per product of sector *i*:

$$Ce = Ex^{-1} = \begin{bmatrix} \frac{E_1}{x_1} & \frac{E_2}{x_2} & \dots & \frac{E_N}{x_N} \end{bmatrix} \tag{50}$$

where Ce_N is the emissions coefficient analyzed for sector *N*, and *xN* is the VBP of that sector. Then, *E* is the total environmental impact (total CO_2 emissions per branch in this case), the elements of *Ce* are the emissions coefficients (emissions per unit of production), where Ce_i indicates the emissions generated per final unit produced in sector *i,* in kilotonnes of CO_2 per million dollars of production of each branch. Expression (50) is the CO_2 emissions multiplier. As a matrix expression for a three-sector economy:

$$ME = \widehat{Ce}(I - A)^{-1} = \begin{pmatrix} Ce_1 l_{11} & Ce_1 l_{12} & Ce_1 l_{13} \\ Ce_2 l_{21} & Ce_2 l_{22} & Ce_2 l_{23} \\ Ce_3 l_{31} & Ce_3 l_{32} & Ce_3 l_{33} \end{pmatrix} \tag{51}$$

Thus, the *ME* emissions multiplier reading refers to the emissions generated per unit of production needed to supply final demand. A row-wise reading gives results on the emissions of sector *i.* This implies considering the sectors as producers of emissions associated with the inputs they sell to the other sectors so that the latter can produce. By columns, we obtain the emissions associated with the production process of sector *j*, destined for final demand. This implies considering the sectors as consumers of emissions associated with the inputs necessary for their production processes. From this multiplier, *Producer Responsibility* RP (marked by the Kyoto Protocol and the Paris Agreement) and *Consumer Responsibility* RC (Carbon Footprint) can be calculated (Hoekstra, 2014; Serrano and Dietzenbacher, 2010).

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5 Residence principle: an institutional unit is considered resident if its center of economic interest is located within the economic territory of the country.

6 Territorial principle: comprises the geographic territory administered by a government, within which people, goods and capital circulate freely. It does not take into account whether economic activities are carried out by residents or non-residents (Durán and Álvarez, 2011).

Studies on the carbon footprint in Colombia have already been carried out by using the IOT SA as a primary data source (Durán and Banacloche, 2017), from which a SRIO analysis with environmental extension has been performed (Serrano and Dietzenbacher, 2010). Thanks to the efforts made by the National Administrative Department of Statistics (DANE) in the development of environmental statistics following the guidelines of the System of Environmental and Economic Accounting (SCAE) framework, it was possible to establish a correlation between the Supply and Use Table with environmental extension of CO_2 emissions to 61 sectors and the IOT SA to 40 sectors to adapt the analysis to our matrix. In the case of the SRIO analysis, in the absence of information on the emissions associated with the imports made by a country, it is assumed that the trading partners use the same technology as the country under study (Domestic Technology Assumption, DTA). The calculations for the MRIO case are not reflected in this section, although they are easier to obtain (Hoekstra, 2014).[7]

For the calculation of producer responsibility (52) the focus is on theemissions that the country produces, regardless of where they are subsequently consumed:

$$RP = \widehat{Ce}(I - A^D)^{-1}\hat{y} = ME\ (\hat{y}^r + \hat{e})\,, \qquad (52)$$

where domestic final demand can be separated into resident final demand y^r and exports. In the case of consumer responsibility (Eq.(53)), the calculation is more complex, since it considers the emissions associated with the goods and services that the country consumes, regardless of where they come from:

$$RC = \left[\widehat{Ce}(I - A^D)^{-1}y^r\right] + \left[\widehat{Ce}(I - A^T)^{-1}[A^M(I - A^D)^{-1}y^r + y^m]\right] =$$
$$[ME\ y^r + ME^T[A^M(I - A^D)^{-1}y^r] + ME^T y^m]\,, \qquad (53)$$

where y^m is final imports and ME^T is the total emissions multiplier (domestic and imported). This includes accounting for emissions associated with domestic production that is consumed within the country, excluding exports (first component), as well as total emissions associated with imported content in domestic production that is ultimately consumed within the country (second component), and emissions associated with final imports (third component). To know whether a country is a net producer or consumer of CO_2 emissions, the Responsibility Balance (REB) is used as the difference between producer responsibility and consumer responsibility (Serrano and Dietzenbacher, 2010; Cadarso et al., 2012).

$$REB = RP - RC \qquad (54)$$

In the case of Colombia, in 2005 the producer responsibility was 60,691 Gigagrams (Gg) of CO_2. Compared to the consumer responsibility (58,324 Gg), the REB defined Colombia as a net producer of CO_2 emissions. The main CO_2 producing sectors are Transportation, followed by the Sugar and Confectionery sector and the primary sector. As net consumers of emissions, Other services, the primary and extractive sector, and Transportation stood out (see Fig. 27).

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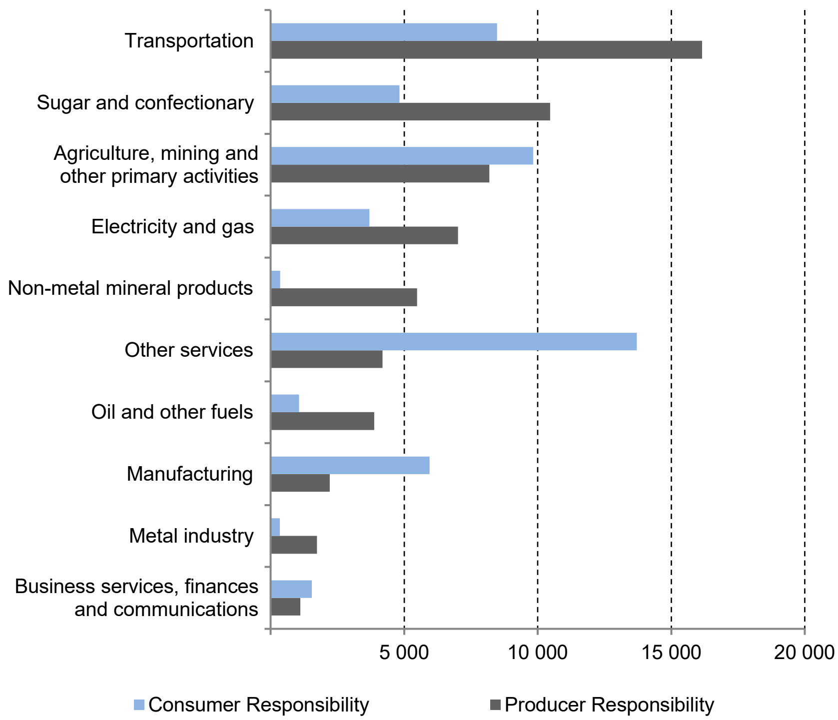
[7] In the case of using a MRIO, the calculation of the carbon footprint is simpler. Since information on CO_2 emissions by sector and country is available, the diagonalized vector can be multiplied by the Global Leontief Inverse, generating a multiplier as shown in Eq. 50. $\widehat{Ce} = \begin{bmatrix} Ce_1 & 0 & \dots & 0 \\ 0 & Ce_2 & \dots & 0 \\ \vdots & \vdots & \ddots & \vdots \\ 0 & 0 & \dots & Ce_N \end{bmatrix}$ multiplied by the Global Leontief Inverse, generating a multiplier like the one shown in Eq. 50. Multiplied by the global final demand, when looking at a country p, a column sum gives the consumer responsibility by sector. A row sum reports the producer responsibility (Serrano and Dietzenbacher, 2010).

Figure 27
Colombia: producer and consumer responsibility, main sectors, 2005
(In gigagrams of CO_2)



Source: Durán and Banacloche (2017).

VI. Conclusions

The input-output model is a very useful and widely used tool in the literature to evaluate production chains and value chains, as well as other applications related to social and environmental aspects. This handbook complements other ECLAC documents on the Input-Output Model (Schuschny, 2005; Durán and Zaclicever, 2013; ECLAC, 2016; Duran and Castresana, 2016; Amar and García Díaz, 2018; Amar and Torchinsky, 2019), with the aim of providing indicators that serve to better understand the region's productive linkages, their potential and their shortcomings. In addition, with the possible extensions of the input-output model, environmental and social policies can be evaluated. In a context marked by the 2030 Agenda and the Sustainable Development Goals (SDG), it is necessary to measure economic growth and sustainable development, from the triple perspective: economic, environmental and social. To this end, the expansion and improvement of statistics is crucial, as it provides a solid basis on which methodologies such as input-output analyses play a decisive role in the study of production linkages, value chains, and associated employment and environmental impacts of economic activity.

Unfortunately, the countries of Latin America and the Caribbean have moved at different speeds in preparing and updating their IOT. Therefore, this handbook is also a call to the countries to promote their use and periodic elaboration. Also, it calls upon them to understand them as an incentive for analysts and decision-makers in the countries of the region to use these tables as a quantitative support tool in the creation of policies aimed at promoting economic growth and sustainable development.

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This manual summarizes the theoretical bases of the input-output model applied in the economic analysis of countries and groups of countries (subregions). The input-output tables developed by the Regional Integration Unit of the International Trade and Integration Division of the Economic Commission for Latin America and the Caribbean (ECLAC) will be of use to government experts for conducting their own calculations and analyses, following and adapting the guidelines and recommendations contained the manual to design specific public policies. Some indicators suggested in the document include the intensity of imported inputs in production and exports, forward and backward production linkages, import dependency analyses, the domestic value added in exports or imported content by trade partner, and extensions and applications related to export employment and CO_2 emissions. This manual can also serve as a useful aide for academics, researchers and students in understanding sometimes elusive and complex literature.

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