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Size, Position and Length in Value Chains in Latin America

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In this article, I develop a framework that divides global value chains into regional and extra-regional and studies the participation of Latin American countries in international fragmentation of production along 25 years of globalization. Measures of depth, position, and length are developed for each kind of value chain. Between 1990 and 2015 the engagement in activities related to international trade increased in every country in Latin America and the prevalent way of integration is in Extra-Regional Value Chains. While South America engages mostly in value chains as a source of value added transformed by others, Central America participates more as end of chains and Mexico switched its position to a net forward position in regional value chains. Finally, the article examines the relationship between participation and length of domestic segment of chains, finding that a deeper participation in Extra-regional Value Chains is associated with shortening of chains, but this relationship does not hold for Regional.

KEYWORDS
Global Value Chains, Regional integration, Input Output, Forward and Backward Linkages

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Tamaño, posición y longitud en las cadenas de valor de América Latina

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Este articulo desarrolla un marco para dividir a las cadenas de valor global en regionales y extrarregionales y estudia la participación de los países de América Latina en la fragmentación internacional de la producción en 25 años de globalización. Se desarrollan medidas de profundidad, posición y longitud para cada tipo de cadena de valor. Entre 1990 y 2015, la participación en actividades relacionadas con el comercio internacional se incrementó en todos los países de América Latina, y la forma prevalente de integración es en Cadenas de Valor Extrarregionales. Mientras América del Sur se involucra en cadenas de valor proveyendo valor agregado transformado por otros, América Central participa más en el final de las cadenas y México modificó su posición neta hacia ser más proveedor que usuario en las cadenas de valor regionales. Finalmente, el trabajo examina la relación entre la participación y la longitud del segmento doméstico de las cadenas de valor, encontrando que la profundización en la participación en cadenas extrarregionales está asociada a un acortamiento de las cadenas, mientras que eso no ocurre en las regionales.

KEYWORDS
Cadenas Globales de Valor, Integración regional, Insumo producto, Encadenamientos hacia adelante y atrás

1 | INTRODUCTION

Globalization caused an increase in the fragmentation of production. Nowadays, several countries participate in the different stages of production of a good, generating a rise in the trade of intermediates goods and a dissociation between gross exports and the domestic value added included in them(Koopman et al., 2014).

Inter-country input-output tables link sectors of different countries and enable a complete evaluation of relationships between final demand, intermediate -domestic and foreign- demand and the value added. In recent years there have been several projects of integration of world input-output tables (WIOT)[1]. Using these data, economic literature developed a set of measures to characterize the size, position, or length of global value chains (GVC).

Most of these measures are conceived for global value chains and so the regional character of value chains, noted early by Johnson and Noguera (2012), is less frequently studied with a complete framework. Many reasons can justify the inclusion of a regional dimension in measures. First, the regional integration approach needs a benchmark to contrast results, and domestic and extra-regional results are the best candidates. Also, trade policy with regional partners has its own issues not always shared with global -or multilateral- trade policy. Finally, is well documented that globalization is a result of the offshoring of firms and frequently this strategy starts with nearshoring and then expands worldwide.

While regional integration studies using input-output tables have a long tradition in regional economics, there seems to be certain divorce in the toolkits used by regional economics and tools used by international economics.

In this paper, I adapt global measures developed by Wang et al. (2017a,b) to divide total activity into domestic, regional, and extra-regional. By doing so, I will identify exclusively domestic, regional, or extra-regional value chains and a residual category comprising mixed value chains. Then, using the EORA database (Lenzen et al., 2013), I depict the evolution of value added in Latin American countries according to the participation in each type of trade in 1990-2015

Wang et al. (2017b) develop a measure of participation in global value chains, arising from the decomposition of total final goods and services production, splitting the value added in domestic stages from the foreign value added and also considering the place of final consumption. According to Wang et al. (2017b), total production can be split into pure domestic value added included in domestic consumed production, pure domestic value added included in final goods and services exported and global value chain production, characterized by international trade of intermediates and so vertical specialization.

Wang et al. (2017a) defines new measures of length of production and upstreamness. These measures rely conceptually on the existing literature (Antràs and Chor, 2013; Antràs et al., 2012; Fally, 2012), but they are applied to WIOT instead of local matrices. In this sense, their work is close to Antràs and Chor (2018); Miller and Temurshoev (2017), with the difference that their measures are defined as ratios of value added instead of ratios of production. Also, they apply the length of production in each of the terms defined in Wang et al. (2017b), leading to a new set of measures of GVC participation that considers both domestic and international value chains.

Both Wang et al. (2017b,a) measures of participation in GVC and length are used in 2017 and 2019 Global Value Chain Development Report (WTO, 2017). These two contributions help us to understand the evolution of depth and length of GVC participation. They show how GVC activities gained participation in total value-added and raised their length until the 2008-09 crises and then they stopped their pace and slightly shortened.

[1]Some examples of projects are: Tsigas et al. (2011), Johnson and Noguera (2012), Timmer et al. (2015), Lenzen et al. (2013)

These measures rely on a parsimonious decomposition of value-added included in the output according to two perspectives. First, for the exports of intermediates, they decompose the demand, that is, the use that is made in a country or sector of destination. Second, they decompose the supply, that is, the source of value added included in the production. In all cases, both the final demand-the destination- and the origin of value –the supply- is decomposed according to domestic and foreign. They can be conceived as steps to divide total value chains into domestic and global value chains.

This paper contributes to the literature of measuring regional integration adapting a framework conceived for global production. In this sense, it relates with Antràs and de Gortari (2020) measure of regional value chains used in NAFTA, Fan et al. (2019) measure of regionalization in China or Bolea et al. (2019) measure of different patterns of value chains in Europe. Also based on Borin and Mancini (2019) measure of participation in Global Value Chains, World Bank's Global Value Chains Report 2020 also applies measures of regionalization of international value chains (WorldBank, 2019).

This paper includes, in addition to this introduction, three sections. Section 2 introduces the methodological scheme built in previous work and develops the adaptation of these measures to divide international trade into regional and extra-regional. Section 3 shows the results of the application for Latin America and discusses some features of the regional value chains and Section 4 draws some conclusions.

2 | MEASURES OF DEPTH, LENGTH AND POSITION IN DOMESTIC, REGIONAL, GLOBAL AND MIXED VALUE CHAINS

2.1 | General notation and definitions

Inter-country input output tables organize the world supply and demand according to a structure akin to depicted in Table 1. Regional countries are arranged in the first rows and columns and extra regional are placed subsequently. Countries s, t and u belong to region G {s,t,u $\in$ G} and f and k are countries of the rest of world H { f,k $\notin$ G; f, k $\in$ H}. Then, there are G+H countries in the table.

TABLE 1 Regional input output table

Destination →	Intermediate Regional			Intermediate Extraregional			Final regional use			Final Extra-regional use			Output
↓ Source	1	…	G	1′	…	H	1	…	G	1′	…	H	
1	Z^{11}	…	Z^{1t}	$Z^{11'}$	…	Z^{1k}	Y^{11}	…	Y^{1t}	$Y^{11'}$	…	Y^{1k}	X^1
s	Z^{s1}	…	Z^{st}	$Z^{s1'}$	…	Z^{sk}	Y^{s1}	…	Y^{st}	$Y^{s1'}$	…	Y^{sk}	X^s
⋮	⋮	⋱	⋮	⋮	⋱	⋮	⋮	⋱	⋮	⋮	⋱	⋮	⋮
G	Z^{t1}	…	Z^{tt}	$Z^{t1'}$	…	Z^{tk}	Y^{t1}	…	Y^{tt}	$Y^{t1'}$	…	Y^{tk}	X^t
1′	$Z^{1'1}$	…	$Z^{1't}$	$Z^{1'1'}$	…	$Z^{1'k}$	$Y^{1'1}$	…	$Y^{1't}$	$Y^{1'1'}$	…	$Y^{1'k}$	$X^{1'}$
f	Z^{f1}	…	Z^{ft}	$Z^{f1'}$	…	Z^{fk}	Y^{f1}	…	Y^{ft}	$Y^{f1'}$	…	Y^{fk}	X^f
⋮	⋮	⋱	⋮	⋮	⋱	⋮	⋮	⋱	⋮	⋮	⋱	⋮	⋮
k	Z^{k1}	…	Z^{kt}	$Z^{k1'}$	…	Z^{kk}	Y^{k1}	…	Y^{kt}	$Y^{k1'}$	…	Y^{kk}	X^k
V. Added	va^1	…	va^t	$va^{1'}$	…	va^k							
Output	X^{1^T}	…	X^{t^T}	$X^{1'^T}$	…	X^{1^T}							

Where Z^{st} is a *NxN* matrix of intermediate inputs produced in country *s* and used in country *t*, Y^{st} is a *Nx1* vector of final goods produced in country *s* and consumed in country *t*, X^s is a *Nx1* vector of output of country *s* and Va^s is a *1xN* vector of direct value added in country *s*. *T* is the transpose operator. Terms labeled with *k* instead of *t* have analogous interpretation.

It is useful to aggregate every destination of final demand faced by regional countries according to the sourcing country and sector, but distinguishing demand in domestic (Y^D)[2], regional (excluding domestic; Y^R) and extra regional demand (Y^F). Also, all demand faced by extra regional countries is aggregated in Y^H.

$$Y^D = \begin{bmatrix} Y^{ss} \\ Y^{tt} \\ \vdots \\ Y^{uu} \\ 0 \\ \vdots \\ 0 \end{bmatrix}; Y^R = \begin{bmatrix} \sum_{s\neq t} Y^{st} \\ \sum_{t\neq u} Y^{tu} \\ \vdots \\ \sum_{u\neq t} Y^{ut} \\ 0 \\ \vdots \\ 0 \end{bmatrix}; Y^F = \begin{bmatrix} \sum_H Y^{sf} \\ \sum_H Y^{tf} \\ \vdots \\ \sum_H Y^{uf} \\ 0 \\ \vdots \\ 0 \end{bmatrix}; Y^H = \begin{bmatrix} 0 \\ 0 \\ \vdots \\ 0 \\ \sum_{t\in G} Y^{ft} + \sum_{f\in H} Y^{fk} \\ \vdots \\ \sum_{t\in G} Y^{kt} + \sum_{k\in k} Y^{kf} \end{bmatrix};$$

All these are *N(G+H)x1* vectors and the sum equivales to total final demand.

$$Y = Y^D + Y^R + Y^F + Y^H \tag{1}$$

Then, in a general notation, final demand *Y* and production *X* can be expressed as *N(G+H)x1* vectors, *Z* is a *N(G+H)xN(G+H)* matrix and *Va* is a *1xN(G+H)* vector.

The Leontief matrix $A = Z\hat{X}^{-1}$ enables the usual notation in input output analysis. The

[2]Note that Y^D excludes domestic demand of countries outside the region.

operator ˆ indicates that the vector is expressed as a diagonal matrix. The usual decomposition of production is:

$$X = AX + Y \tag{2}$$

$$\text{Where: } A = \begin{bmatrix} A^{ss} & \dots & A^{st} & A^{sf} & \dots & A^{sk} \\ \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ A^{ts} & \dots & A^{tt} & A^{tf} & \dots & A^{tk} \\ A^{fs} & \dots & A^{ft} & A^{ff} & \dots & A^{fk} \\ \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ A^{ks} & \dots & A^{kt} & A^{kf} & \dots & A^{kk} \end{bmatrix}$$

Each A^{sr} is an *NxN* matrix containing the ratios of utilization of origin *s* in the production of country *r*. In the main diagonal $s = r$ and correspond to domestic intermediate supply, whereas when $s \neq r$ is the case of international trade of intermediates.

The International Leontief inverse matrix is defined as:

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

$$B = \begin{bmatrix} B^{ss} & \dots & B^{st} & B^{sf} & \dots & B^{sk} \\ \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ B^{ts} & \dots & B^{tt} & B^{tf} & \dots & B^{tk} \\ B^{fs} & \dots & B^{ft} & B^{ff} & \dots & B^{fk} \\ \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ B^{ks} & \dots & B^{kt} & B^{kf} & \dots & B^{kk} \end{bmatrix}$$

Each sub matrix B^{sr} is the total output necessary in each sector n of country s to fulfill one additional unit of final demand in each sector n of *r* (B^{sf} has the same interpretation).

From the column perspective, the output is the result of the combination of intermediate inputs plus the value added (Va). This equation illustrates the Leontief function of production:

$$X^T = u\hat{X} = uZ + Va = uA\hat{X} + V\hat{X} \tag{4}$$

Where, *V* is an $1xN(G + H)$ row vector of ratios of value added to product and u is an $1xN(G + H)$ vector of ones.

Posmultiplying by $\hat{X}^{-1}$ the expression is:

$$u = uA + V$$

That gives rise to the decomposition formula for production.

$$uI - uA = u(I - A) = V \rightarrow u = V(I - A)^{-1} = VB \rightarrow u = u\hat{V}B \tag{5}$$

Since it enables splitting any vector, this equation is crucial in the references. In particular, final demand or total output can be decomposed according to the country and sector of origin of the value. $\hat{V}B$ has some useful properties. Postmultiplied by a diagonal matrix of

final demand it leads to a complete decomposition of value added included in it. On the direction of any column, sectoral output is divided according to the country-sector of origin of the value, and total sum of column equal the final demand of each sector. On the direction of rows, the value added of a country-sector is divided according to the country-sector of final use, and total sum equal total value added of this country-sector[3].

Following Wang et al. (2017b), A contains both domestic and foreign coefficients of input utilization, that can be split in a matrix of domestic requirements ($A^{D'}$) and a matrix of international requirements (A^F). Then $A^F X$ represent the international trade in intermediates.

$$A^{D'} = \begin{bmatrix} A^{ss} & \dots & 0 & 0 & \dots & 0 \\ \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ 0 & \dots & A^{tt} & 0 & \dots & 0 \\ 0 & \dots & 0 & A^{ff} & \dots & 0 \\ \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ 0 & \dots & 0 & 0 & \dots & A^{kk} \end{bmatrix}; A^F = A - A^{D'} = \begin{bmatrix} 0 & A^{su} & A^{st} & A^{sf} & \dots & A^{sk} \\ A^{us} & \ddots & \vdots & \vdots & \ddots & \vdots \\ A^{ts} & \dots & 0 & A^{tf} & \dots & A^{tk} \\ A^{fs} & \dots & A^{ft} & 0 & \dots & A^{fk} \\ \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ A^{ks} & \dots & A^{kt} & A^{kf} & \dots & 0 \end{bmatrix}$$

While Wang et al. (2017b) split total requirements in domestic and international, in this paper will be necessary further decompositions. The key technical step to obtain domestic, regional, and extra-regional results is defining auxiliary matrices that are in fact submatrices of A and their complements.

$$A^{reg} = \begin{bmatrix} A^{ss} & \dots & A^{st} & 0 & \dots & 0 \\ \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ A^{ts} & \dots & A^{tt} & 0 & \dots & 0 \\ 0 & \dots & 0 & 0 & \dots & 0 \\ \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ 0 & \dots & 0 & 0 & \dots & 0 \end{bmatrix}; A^{-reg} = A - A^{reg} = \begin{bmatrix} 0 & 0 & 0 & A^{sf} & \dots & A^{sk} \\ \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ 0 & \dots & 0 & A^{tf} & \dots & A^{tk} \\ A^{fs} & \dots & A^{ft} & A^{ff} & \dots & A^{fk} \\ \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ A^{ks} & \dots & A^{kt} & A^{kf} & \dots & A^{kk} \end{bmatrix}$$

$$A^{d} = \begin{bmatrix} A^{ss} & \dots & 0 & 0 & \dots & 0 \\ \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ 0 & \dots & A^{tt} & 0 & \dots & 0 \\ 0 & \dots & 0 & 0 & \dots & 0 \\ \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ 0 & \dots & 0 & 0 & \dots & 0 \end{bmatrix}; A^{reg-d} = A^{reg} - A^{d} = \begin{bmatrix} 0 & A^{su} & A^{st} & 0 & \dots & 0 \\ A^{us} & \ddots & A^{ut} & \vdots & \ddots & \vdots \\ A^{ts} & \dots & 0 & 0 & \dots & 0 \\ 0 & \dots & 0 & 0 & \dots & 0 \\ \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ 0 & \dots & 0 & 0 & \dots & 0 \end{bmatrix}$$

$$A^{ext} = \begin{bmatrix} 0 & \dots & 0 & 0 & \dots & 0 \\ \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ 0 & \dots & 0 & 0 & \dots & 0 \\ 0 & \dots & 0 & A^{ff} & \dots & A^{fk} \\ \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ 0 & \dots & 0 & A^{kf} & \dots & A^{kk} \end{bmatrix}; A^{-ext} = A - A^{ext} = \begin{bmatrix} A^{ss} & \dots & A^{st} & A^{sf} & \dots & A^{sk} \\ \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ A^{ts} & \dots & A^{tt} & A^{tf} & \dots & A^{tk} \\ A^{fs} & \dots & A^{ft} & 0 & \dots & 0 \\ \vdots & \ddots & \vdots & \vdots & \ddots & \vdots \\ A^{ks} & \dots & A^{kt} & 0 & \dots & 0 \end{bmatrix}$$

[3] $\hat{V}B\hat{Y}u^T = Va$ and $u\hat{V}B\hat{Y} = Y^T$

It should be defined also the Leontief Inverses matrices of these partitions of A.

$$L' = (I - A^{D'})^{-1}; L = (I - A^{d})^{-1}; B^{reg} = (I - A^{reg})^{-1}; B^{ext} = (I - A^{ext})^{-1}$$

Given that A^{d}, A^{reg} and A^{ext} are subparts of A, then L, B^{reg} and B^{ext} are a smaller amount of B.

The hypothetical extraction method followed by an important strand of the literature in GVC (Los et al., 2016; Los and Timmer, 2020; Miroudot and Ye, 2018; Johnson, 2018) apply an equivalency between Leontief inverse matrix and some partition of it. Following this literature and Borin and Mancini (2019) a set of relationships will be defined. See Wang et al. (2017b) for a demonstration of (6) and Appendix A.1 for a demonstration of (7), (8), and (9).

As long as $A = A^{D'} + A^{F}$, it can be shown that:

$$B = L' + L'A^{F}B \tag{6}$$

As long as $A = A^{reg} + A^{-reg}$, it can be shown that:

$$B = B^{reg} + B^{reg}A^{-reg}B \tag{7a}$$
$$B = B^{reg} + BA^{-reg}B^{reg} \tag{7b}$$

As long as $A^{reg} = A^{d} + A^{reg-d}$, it can be shown that:

$$B^{reg} = L + LA^{reg-d}B^{reg} \tag{8a}$$
$$B^{reg} = L + B^{reg}A^{reg-d}L \tag{8b}$$

As long as $A = A^{ext} + A^{-ext}$, it can be shown that:

$$B = B^{ext} + B^{ext}A^{-ext}B \tag{9a}$$
$$B = B^{ext} + BA^{-ext}B^{ext} \tag{9b}$$

2.2 | Measuring the participation in Global Value Chains

At global value, total value added equals total final demand. The link between value added in the sector i of country s and the final demand of sector j in country r is represented by the N(G + H)xN(G + H) matrix $\hat{V}B\hat{Y}$.

$$\hat{V}B\hat{Y} = \begin{bmatrix} v_1^1 b_{11}^{11} y_1^1 & v_1^1 b_{12}^{11} y_2^1 & \dots & v_1^1 b_{1j}^{1r} y_j^r \\ v_2^1 b_{21}^{11} y_1^1 & v_2^1 b_{22}^{11} y_2^1 & \dots & v_2^1 b_{2j}^{2r} y_j^r \\ \vdots & \vdots & \ddots & \vdots \\ v_i^s b_{i1}^{s1} y_1^1 & v_i^s b_{i2}^{s1} y_2^1 & \dots & v_i^s b_{ij}^{sr} y_j^r \end{bmatrix}$$

The generic term $v_i^s b_{ij}^{sr} y_j^r$ represents the total direct and indirect value added sourced in sector i of country s (v_i^s) included in final goods production of sector j in country r (y_j^r).

Note that $\hat{V}B\hat{Y}$ show the splitting of value-added contribution to final goods production

irrespective of where they are consumed, as also do a part of literature (Los et al., 2016; Timmer et al., 2015; Los and Timmer, 2020). Johnson (2018) names this option as the "GVC Income" view because it traces the value added embodied in final goods by source country along the value chain. Los and Timmer (2020) also use this view to define their VAX_P concept, that is the value added exported for final production [4].

$\hat{V}B\hat{Y}$ enables two perspectives of value chain analysis. In the row perspective, the value added sourced in a country sector is used in the production of final goods of other sectors and countries. This view originates in the sourcing of value in some country sector and ends its circulation (as intermediate) when is included in a final product. This is the *forward perspective* and it goes from the sourcing sector s to final use. In the direction of columns, the production of final goods is divided according to the country-sector of origin of value. This view goes from the final production and tracks backward where the value was included. This is the *backward perspective*. The forward perspective is useful to characterize the circulation of value that a country has while the backward perspective is more suited to analyze the sourcing function of production. In the following sections, some measures according to either one or the other perspective will be showed. It is important to remark that, if $\hat{V}B\hat{Y}$ is used as the starting point, always one of the two perspectives must be chosen.

2.2.1 | The forward perspective of value chains: Following the use of domestic value added

Applying (7a) in $\hat{V}B\hat{Y}$ we get:

$$\hat{V}B\hat{Y} = \hat{V}B^{reg}\hat{Y} + \hat{V}B^{reg}A^{-reg}B\hat{Y} \tag{10}$$

Substituting B^{reg} in (10) and using (8a) we get that:

$$\hat{V}B\hat{Y} = \hat{V}L\hat{Y} + \hat{V}LA^{reg-d}B^{reg}\hat{Y} + \hat{V}LA^{-reg}B\hat{Y} + \hat{V}LA^{reg-d}B^{reg}A^{-reg}B\hat{Y}$$

Also, B in the third term can be decomposed using (9a).

$$\hat{V}B\hat{Y} = \hat{V}L\hat{Y} + \hat{V}LA^{reg-d}B^{reg}\hat{Y} + \hat{V}LA^{-reg}B^{ext}\hat{Y} + \hat{V}LA^{-reg}B^{ext}A^{-ext}B\hat{Y} + \hat{V}LA^{reg-d}B^{reg}A^{-reg}B\hat{Y}$$

First-term accounts for domestic value added included in final goods without border crossing of intermediates. It can be divided according to the destination of final goods, using (1).

$$\begin{aligned}\hat{V}B\hat{Y} = \hat{V}L\hat{Y}^{D} + \hat{V}L\hat{Y}^{R} + \hat{V}L\hat{Y}^{F} + \hat{V}L\hat{Y}^{H} + \hat{V}LA^{reg-d}B^{reg}\hat{Y} + \hat{V}LA^{-reg}B^{ext}\hat{Y} + \\ \hat{V}LA^{-reg}B^{ext}A^{-ext}B\hat{Y} + \hat{V}LA^{reg-d}B^{reg}A^{-reg}B\hat{Y}\end{aligned} \tag{11}$$

Eq. (11) is a generalization of Wang et al. (2017b) when regional and extra-regional countries are considered. It can be shown that if the region is the entire world and so the extra region is null ($A^{-reg} = 0; \hat{Y}^{F} = 0$), only the first, second, and fifth terms are non-null. In this case, we get $\hat{V}B\hat{Y} = \hat{V}L\hat{Y}^{D} + \hat{V}L\hat{Y}^{F} + \hat{V}LA^{F}B\hat{Y}$ which is Wang et al. (2017b) disaggregation.

[4] An alternative matrix can be defined by the country of consumption of final goods leading to Johnson and Noguera (2012) "valued added in exports", which traces value added from sourcing to consumption. Note that this alternative matrix is a $N(G+H)x(G+H)$ matrix, where rows denote the country sector of origin and columns indicates country of consumption.

Each term of (11) is an $N(G+H)xN(G+H)$ matrix. Pos-multiplying each term by an $N(G+H)x1$ vector of ones (u^T) we get accounting segregation of value added of each country-sector according to their participation in value chains and in international trade. This split only holds for the first NG rows that represent the countries of the region. The NH following rows do not have interest from the perspective of regional value added.

$$\begin{aligned}\hat{V}B\hat{Y}u^T = \hat{V}BY = Va = \hat{V}LY^D + \hat{V}LY^R + \hat{V}LY^F + \hat{V}LA^{reg-d}B^{reg}Y + \\ \hat{V}LA^{-reg}B^{ext}Y + \hat{V}LA^{-reg}B^{ext}A^{-ext}BY + \hat{V}LA^{reg-d}B^{reg}A^{-reg}BY\end{aligned} \tag{12}$$

Now, instead of matrices we get seven vectors. The first NG rows are each sector of the G regional countries. Each flow is presented in table 2.

TABLE 2 Accounting segregation of value added according to circulation

Term	Name	Concept
$\hat{V}LY^D$	Pure domestic value added	Domestic VA included directly in domestically consumed final goods
$\hat{V}LY^R$	Traditional exports to the region	DVA included directly in final goods exported to the region
$\hat{V}LY^F$	Traditional exports to extra-region	DVA included directly in final goods exported to extra-region
$\hat{V}LA^{reg-d}B^{reg}Y$	Regional value chains	DVA incorporated to the production of final goods in the region without stages in extra-region
$\hat{V}LA^{-reg}B^{ext}Y$	Extra regional value chains	DVA in intermediates exported to extra-region for production of final goods without stages in any country of the region
$\hat{V}LA^{-reg}B^{ext}A^{-ext}BY$	Mixed Value Chains	DVA in intermediates included in production of final goods where both regional and extra-regional countries participate
$\hat{V}LA^{reg-d}B^{reg}A^{-reg}BY$	Mixed Value Chains	*(Idem)*

Source: Own elaboration

The first term of (12) is the pure domestic value added included in local production for domestic demand. This value added does not cross any border. This term represents the activity of a country not related to international trade. Except for some small countries, this term accounts for most of the activity of a country. Analogously, $\hat{V}LY^R$ is pure domestic value added in final goods exports to a regional partner. The total sum of this term is below total exports of final goods because this term only accounts for domestic value added, and gross exports account also for foreign intermediates in export production. This value added only crosses borders once. The third term is analogous to the second but for extra-regional instead of regional consumption. The sum of the first, second, and third terms of table 2 is the value added of a country directly included in production of final goods without crossing

any border. Note that, as long as the production of final goods in a country can use foreign inputs, this value is lower than final goods production itself.

The rest of the terms (4 to 7) of table 2 is value added included in the export of intermediates and so involves any kind of Global Value Chains trade. The fourth term is the value added included in final goods produced in a regional country without any further stage in extra zone. It is labeled as Regional Value Chains (RVC) because it entails regional trade of intermediates but, at least from the perspective of the sourcing country s, it does not include extra-regional stages. RVC represents two or more regional countries sharing a chain of production. The fifth term is the value added in intermediates that are exported to extra zone countries and transformed there into final goods without further participation of any regional country (including s). It is labeled as EVC as opposition to RVC and it represents the integration of a country with extra regional production instead of regional integration. The final two terms, sixth and seventh, are the more complex and also less sizable. They account for value added in s that is exported as intermediate and included in chains that involve both regional and extra-regional countries. As will be noted later, these chains have a minimum length of three, because it intervenes at least one stage in the domestic country, one stage in the regional country and one stage in the extra-regional country. The difference between term sixth and seventh is the order of the operation, while in the former the order of value added flow is domestic-extra regional-regional in the latter the sequence is domestic-regional-extra regional. They are labeled as Mixed Value Chains.

2.2.2 | The backward perspective of value chains: Tracking the origin of value

Summing $\hat{V}B\hat{Y}$ across columns leads to the total final production of each country sector. If instead of using Eqs. (7a), (8a) and (9a) we split $\hat{V}B\hat{Y}$ using Eqs. (7b), (8b) and (9b) and instead of pos multiplying $\hat{V}B\hat{Y}$ by a column $N(G+H)x1$ vector of ones, we pre multiply by a row $1xN(G+H)$ vector of ones we get a disaggregation of final demand according to the origin of value. Again, this holds only for the first NG columns and not for the following NH columns. The equivalent for (12) to the backward-perspective segregation is:

$$\begin{aligned} u\hat{V}B\hat{Y} = VB\hat{Y} = Y^{T} = VL\hat{Y}^{D} + VL\hat{Y}^{R} + VL\hat{Y}^{F} + VB^{reg}A^{reg-d}L\hat{Y} + \\ VB^{ext}A^{-reg}L\hat{Y} + VBA^{-ext}B^{ext}A^{-reg}\hat{Y} + VBA^{-reg}B^{reg}A^{reg-d}LY \end{aligned} \tag{13}$$

Where the first, second, and third terms account for the domestic value added directly included in the country of reference in domestic, regional, and extra-regional final demand respectively. The fourth term is the regional value added included in final production without any stage outside the region. That is, is the regional value added that after some regional circulation is used by the country of reference in its production of final products. It represents the backward view of regional integration in Value Chains. The fifth term is the extra regional value added used in domestic final production without any stage in the rest of the region. It represents the backward view of participation in Extra regional Value Chains, as defined before. The sixth and seventh terms are both mixed value chains in a backward perspective. They include the regional and extra-regional value added included in domestic production in final goods that contain stages both in regional and extra-regional countries.

2.2.3 | Single and complex value chains and links with other measures of participation in value chains

At this point, it is useful to point out that RVC and EVC include flows of intermediates that only cross borders once. This means that the intermediates imported by a country are not further exported but simply used in domestic production. The multiple border crossing of intermediates is one of the most salient features of globalization and is behind the increasing divorce between statistics of trade and level of activity (Koopman et al., 2014).

To capture these flows (Wang et al., 2017b) split the global value chains term according to single and complex value chains, both for forward and backward perspective. In our scheme, this distinction can be made directly for regional and, with some additional definition, for extra-regional value chains.

Regional value chains in forward-perspective (fourth term of 12) can be divided into single and complex chains according to the following decomposition:

$$RVC_{fw} = SRVC_{fw} + CRVC_{fw} = \hat{V}LA^{reg-d}LY^{D} + \hat{V}LA^{reg-d}(B^{reg}Y - LY^{D}) \quad (14)$$

Note that the first term of (14) contains only one term linked to international trade (A^{reg-d}) and the rest of the terms are local ($\hat{V}$, L and Y^{D}). The second term, that is complex value chains, is calculated as the difference between total and single. Note that $B^{reg} \geqslant L$ and $Y \geqslant Y^{D}$, then, once the intermediate is exported from the sourcing country, the complex chains can be the result of cross bordering of intermediates or final products.

The calculus for extra regional value chains is similar but some extra notation is required. The final production for domestic use in extra regional countries (Y^{DE}) is a subpart of Y^{H}(see eq. 1). Then, $Y^{H} = Y^{DE} + Y^{*}$, where Y^{*} is the share of the final production of extra regional countries that is exported. Both Y^{DE} and Y^{*} are $N(G+H)x1$ vectors. L' is defined in Eq. 6.

$$EVC_{fw} = SEVC_{fw} + CEVC_{fw} = \hat{V}LA^{-reg}L'Y^{DE} + \hat{V}LA^{-reg}(B^{ext}Y - L'Y^{DE}) \quad (15)$$

The definition of single and complex in the backward perspective is analogous and so it will be omitted.

Borin and Mancini (2019) defined the Hummels et al. (2001) classical indexes of Vertical Share (VS) (for backward participation) and VS1 (for forward participation) in an overall formula. They define the GVC participation ratio used in the 2020 World Development Report (WorldBank, 2019) at a country level as $GVCX^{S} = uE^{S*} - DAVAX^{S*}$, where last term is defined as:

$$DAVAX^{s*} = \sum_{r \neq s}^{G} V^{S}L^{S}Y^{sr} + \sum_{r \neq s}^{G} V^{s}L^{s}A^{sr}L^{r}Y^{rr} \quad (16)$$

DAVAX is the value added exported from s to r that is directly absorbed there, without any further border crossing. The first term is equivalent to traditional exports in the Wang et al. (2017b) scheme and the second is equivalent to single value chains. Given that these terms are netted from total exports the remaining is GVC participation. It is straightforward to conclude that Borin and Mancini's measure of GVC trade captures the same transactions as the Wang et al. (2017b) "Complex GVC trade". The difference between Borin and Mancini (2019) and Wang et al. (2017b) Complex CGV ratio participation is that whereas the latter

measure is based on value added terms, Borin and Mancini (2019) measure is based on gross export. While the former is useful to size the penetration of GVC in economic activity, the latter is used to characterize specifically international trade.

2.3 | Measuring the length and the position

Fally (2012), Antràs et al. (2012), and Antràs and Chor (2013) were the firsts to introduce definitions of product length, upstreamness, and dowstreamness. In doing so, they used the United States input-output table and did some adjustments to fit with international trade. Later, Antràs and Chor (2018) and Miller and Temurshoev (2017) used these definitions to characterize countries and sectors with World Input-Output Tables. While both articles find a strong correlation between upstreamness and downstreamness, Miller and Temurshoev (2017) show that these measures can be regarded as row and column sums of the same set of information, and define the Output Upstreamness and Input Downstreamness to characterize sector and country position in global value chains. These authors show that upstreamness defines the relations from output to final consumers (households, governments and investors) and downstreamness defines the relations from factors (again: households, governments and investors) to output, through the inputs.

This literature measures output upstreamness, from output to final demand, as the average number of times that the value is counted until it is included in a final good. Alternatively, defined the input downstreamness as the average number of times that the value added has been counted until it is included in the output.

Eq 2 can be rewritten recursively. Each term of the recursive series contains the number of times that production had been used as input until is finally consumed.

$$X = AX + Y = A(AX + Y) + Y = (I + A + A^2 + A^3 + A^4 + \dots)Y$$

Production included directly as final demand is IY, this flow is counted only one time in output. The production used as input for final production is AY, this flow is counted once as intermediate and once included in final demand. The production used as intermediate by a supplier of a final producer is $AAY = A^2Y$, is counted twice in intermediate production and once in final production.

Antràs et al. (2012) propose as a measure of distance to final consumption a transformation of this series that consists of a weighted sum of the terms, where the weights are the number of times that output is counted as production until it reaches final demand. The average number of times that the production had been counted as production is:

$$OU = \hat{X}^{-1}(1.I + 2.A + 3.A^2 + 4.A^3 + 5.A^4 + \dots)Y = \hat{X}^{-1}BBY$$

This equation uses the equivalence [5]:

$$1.I + 2.A + 3.A^2 + 4.A^3 + 5.A^4 + \cdots = BB$$

While using the same concepts behind previous definitions of upstreamness, downstreamness, and length of production, Wang et al. (2017a) point that those measures are inconsistent because they start from the gross output and have been defined as gross measures,

[5] $BB = (I - A)^{-1}(I - A)^{-1} = (I + A + A^2 + A^3 + A^4 + \dots)(I + A + A^2 + A^3 + A^4 + \dots)$. Developing this series, we get: $I + A + A^2 + A^3 + A^4 + \cdots + A + A^2 + A^3 + A^4 + A^5 + \cdots + A^3 + A^4 + A^5 + A^6 + \cdots = I + 2A + 3A^2 + 4A^3 + 5A^4 + \dots$

whereas, if defined from primary factors to the production of final goods, upstreamness and downstreamness of a particular country-sector in a global production network are the two faces of the same coin. Wang et al. (2017a) states that both concepts are useful only concerning production length, and so they measure the relative distance of a particular production stage (country–sector) to the origin of value and the final production.

In a matrix notation, Wang et al. (2017a) defines the average length of a chain as the element-wise ratio of two matrices:

$$PL = \frac{\hat{V}BB\hat{Y}}{\hat{V}B\hat{Y}} \tag{17}$$

The denominator is a matrix equivalent to $v_i^s b_{ij}^{sr} y_j^r$, that is, the total value added from a country sector included in final production from another country sector. The numerator is, like in Antràs and Chor (2018), the average number of times that the value added originated in a sector of a country is counted as output in final production from another country sector. Then, PL represents the weighted average of times that the value added of a country´s sector is counted as output in final production, and the weights are the amount added itself.

As mentioned earlier, the average length is useful if defined as row or column sum. As in previous measures (Antràs et al., 2012; Miller and Temurshoev, 2017), the forward perspective or producer's perspective of length is the row sum of the Ghosh inverse Matrix (H). This yields an $N(G+H)x1$ vector.

$$PL_v = \frac{\hat{V}BB\hat{Y}u^T}{\hat{V}B\hat{Y}u^T} = Hu^T \tag{18}$$

Analogously, the backward perspective or user's perspective of length is the column sum of the Leontief inverse Matrix. This yields a $1xN(G+H)$ vector.

$$PL_y = \frac{u\hat{V}BB\hat{Y}}{u\hat{V}B\hat{Y}} = uB \tag{19}$$

While the forward- perspective traces the average number of times that value added of sector i of country s is counted in production until it is transformed in final demand in sector j of country r, the backward perspective traces the average number of stages that final production of sector i in country s must undergo from primary inputs.

The originality of Wang et al. (2017a) is that they apply the measures to the decomposition stated in Wang et al. (2017b), instead of doing it for the general set of information. By doing so, they can isolate the length of each specific kind of chain: there is a length for pure, domestic chains, a length for traditional trade chains, and a length for global value chains. They define a length of chains for each of these three terms of their decomposition of $\hat{V}B\hat{Y}$.

Following Wang et al. (2017a) method, I divide the forward perspective of the total length of chains in the length of each term of Eq 12. By doing so, it could be identified the length of chains according to the kind of integration being considered. Each term of regional or extra-regional value chain can be divided into two linkages: those taking place in the sourcing country and those taking place in the regional / extra-regional partner. The usefulness of this division is not only conceptual but also operative. Without dividing RVC or GVC total sharing into the stages ensued before the first border crossing and the rest, it is not possible to get a formula for the accounting. Table 3 shows the length formula for each term. Appendix A.1 demonstrates the results of table 3.

TABLE 3 Measures of forward perspective of length in value chains

Name	Formula	Concept
TOTAL	$\hat{V}BBY$	Total forward length of chains
Pure domestic value added	$\hat{V}LLY^{D}$	Length of pure domestic chains
Traditional exports to region	$\hat{V}LLY^{R}$	Length of domestic chains for regional export of final goods
Traditional exports to extra-region	$\hat{V}LLY^{F}$	Length of domestic chains for extra regional export of final goods
Regional value chains	$\hat{V}LLA^{reg-d}B^{reg}Y$	Domestic length of RVC
	$\hat{V}LA^{reg-d}B^{reg}B^{reg}Y$	Regional length of RVC
Extra regional value chains	$\hat{V}LLA^{-reg}B^{ext}Y$	Domestic length of EVC
	$\hat{V}LA^{-reg}B^{ext}B^{ext}Y$	Extra regional lenght of EVC
Mixed Value Chains	$\hat{V}LLA^{-reg}B^{ext}A^{-ext}BY$	Domestic length of mixed chains type 1
	$\hat{V}LA^{-reg}B^{ext}B^{ext}A^{-ext}BY$	Extra regional length of mixed chains type 1
	$\hat{V}LA^{-reg}B^{ext}A^{-ext}BBY$	Global length of mixed chains type 1
Mixed Value Chains	$\hat{V}LLA^{reg-d}B^{reg}A^{-reg}BY$	Domestic length of mixed chains type 2
	$\hat{V}LA^{reg-d}B^{reg}B^{reg}A^{-reg}BY$	Regional length of mixed chains type 2
	$\hat{V}LA^{reg-d}B^{reg}A^{-reg}BBY$	Global length of mixed chains type 2

Source: Own elaboration

In the case of mixed chains, as long as they have stages in the domestic country, in the region, and also in the extra zone, this length of chains is defined from the three types of circulation. Given that the relevance of mixed chains is scarce, their length has conceptual interest but not empirical.

Eq. 19 sets that there can be also a backward perspective of the length of chains, considering the number of stages that value added can have before being used as final goods by country of reference. Instead of using Eq 12, this perspective must use the backward-looking decomposition of Eq 13. Table A.2 in Appendix shows the measures of length for backward perspective.

3 | MEASURING REGIONAL AND GLOBAL INTEGRATION IN VALUE CHAINS IN LATIN AMERICA

3.0.1 | Definition and sources

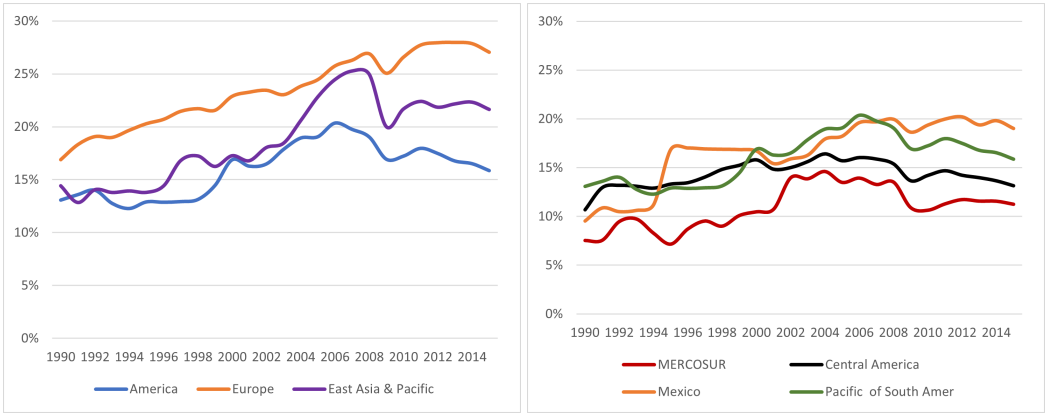
Latin American countries participate in several trade agreements with regional and extra-regional partners. Mexico is engaged in the USMCA which explains most of its trade. Central American countries have trade agreements with North American partners and some of them, such as Costa Rica, have trade agreements with many developed countries. South American countries are involved in an incomplete free trade zone (under many ALADI agreements) and there are big differences between Atlantic coastal countries, which belongs to MERCOSUR and have limited access with extra zone countries, and Pacific coastal countries, which have a strong network of trade agreements with developed and emerging countries. Because of this heterogeneity the definition of region will be arbitrary.

For Mexico, the trade with the USA and Canada will be labeled as regional and the rest is extra-regional. For the seven Central American countries (including also Dominican Rep.), the trade among themselves will be regional and the rest is extra-regional. Finally, for the ten South American countries the same definition holds, that is trade among themselves is considered regional while the rest is considered extra-regional. I also construct regional and extra-regional trade for some other regions used as a benchmark. Table A.3 in Appendix shows the definition of each region and also the countries that, for computational aspects or for having problems in data were left behind.

The data used is extracted from EORA- UNTACD database and covers in principle 189 countries and 26 sectors for the period 1990-2015. Data consists of a matrix of local and international intermediate transactions, local and international final demand, and value added (Lenzen et al., 2013). Despite having less disaggregation than other databases such as WIOD, their extensive period and availability of data for every Latin American country make it a database useful for studies for developing regions.

3.1 | The overall evolution of the international trade-related activity

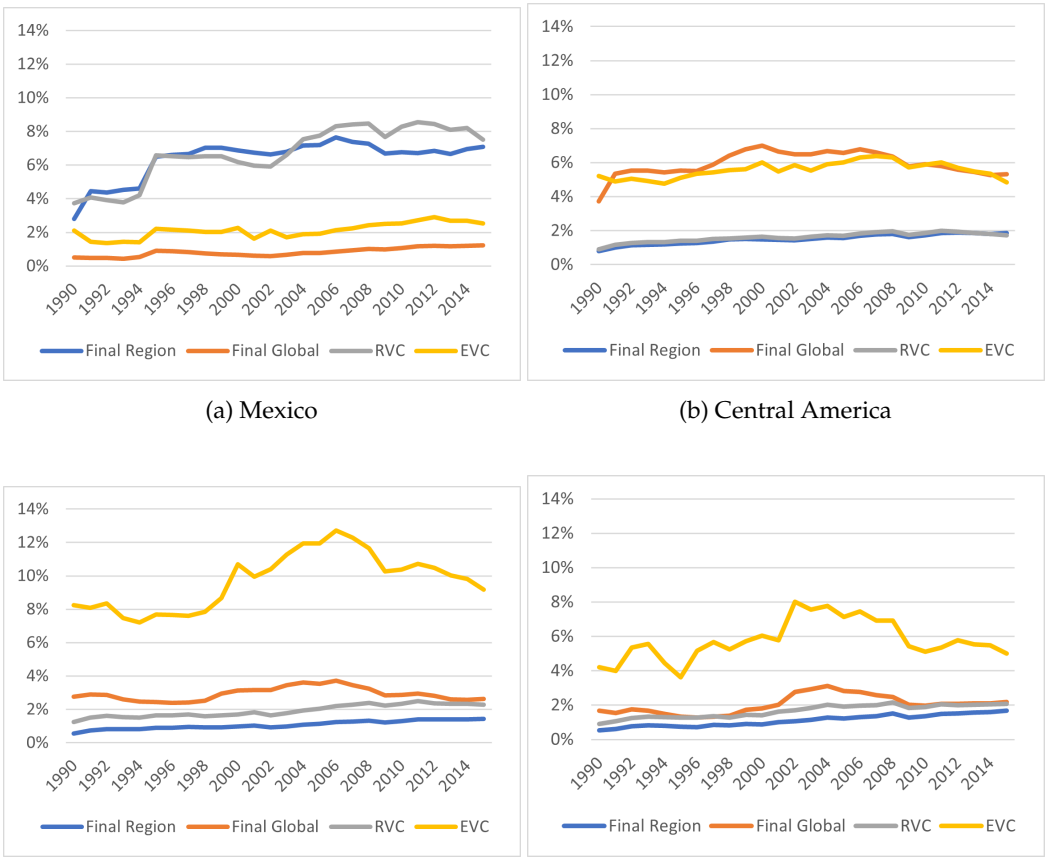
Based on Eq. 12, Figure 1 shows the evolution of value added in activities related to international trade in the period from 1990 to 2015. It consists of all value except domestic value engaged in final domestically consumed goods and services. The graph shows that, despite being a minor share of economic activity of countries, the value related to international trade increased in the period analyzed for all regions. In panel 1a the three main hubs are depicted. The so-called North American Factory relies less on international trade than the European or the Asiatic factories. Both the European and Asiatic factories increased the share of international trade-related activity by 60% and 50% respectively, but the USCMA factory raised about 28%. Graph 1 also shows that the global crisis of 2008-09 decreased the level of fragmentation especially in Asia, but the decrease was not so pronounced for North Americans and Europeans. Panel 1b compares the situation for Latin American blocs. In Mexico the weight of international trade activities in total Gross Domestic Product doubled in the period, changing from 9,5% to 19% of the national value-added. In contrast, Central American countries only raised this weight two percentage points. MERCOSUR raised its share by only three percentage points and appears as the Latin American region with less importance of international trade on activity.



(a) Global manufacturing hubs (b) Latin America

FIGURE 1 Share of activities related to international trade in value added. *Notes:* MERCOSUR:Argentina, Brazil, Paraguay and Uruguay. Central America: Panama, Costa Rica, Guatemala, Honduras, El Salvador, Nicaragua and Dominican Rep. SA-Pacific: Chile, Peru, Ecuador and Colombia. *Source:* Own elaboration based in EORA.

Based on the forward decomposition of the value stated in table 2, figure 2 split the value added included in international activities of each subregion of Latin America. The final region term (term 2 in table 2) and the final global term (term 3) account for the domestic value added included in final goods exported and RVC (term 4) and EVC (term 5) measure the importance of domestic value added included in intermediates used either exclusively in regional final production (RVC) or extra-regional final production (without further participation of a regional partner: EVC). Mixed value chains, as defined in table 2 (see terms 6 and 7) are not graphed because of their very low participation. The graph shows that in Mexico all kinds of trade raised their share, but regional final production and value chains outperform. In Central America, despite being more important than regionals, extra- regional final trade and EVC increased slowly until 2006 and decreased thereafter. In contrast, there is some evidence of a continuous process of regionalization, starting from very low levels. South American countries (see graphs 2c and 2d) are dominated by EVC trade, which experienced a rise until the global crises and a fall afterward. In both regions, starting from low levels, RVC and regional final trade increased in the period, contrasting with final extra regional trade, which remained in 2015 nearly at the same level as 1990.



(a) Mexico

(b) Central America

(c) South America Pacific

(d) MERCOSUR

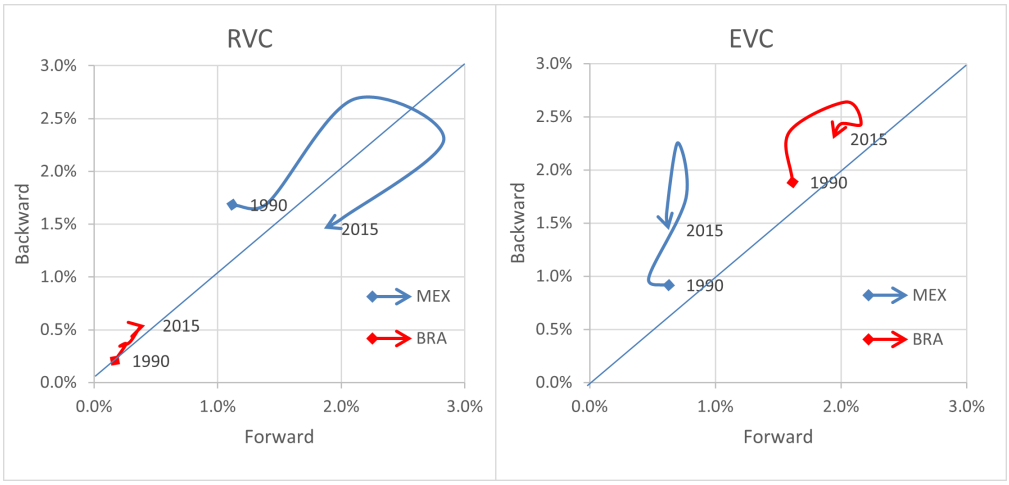
FIGURE 2 Value added related to international trade by type of activity as share of total value added (in percentages). *Source:* Own elaboration based in EORA.

3.2 | Size and Position of Latin American Countries in Regional and Extra regional value chains

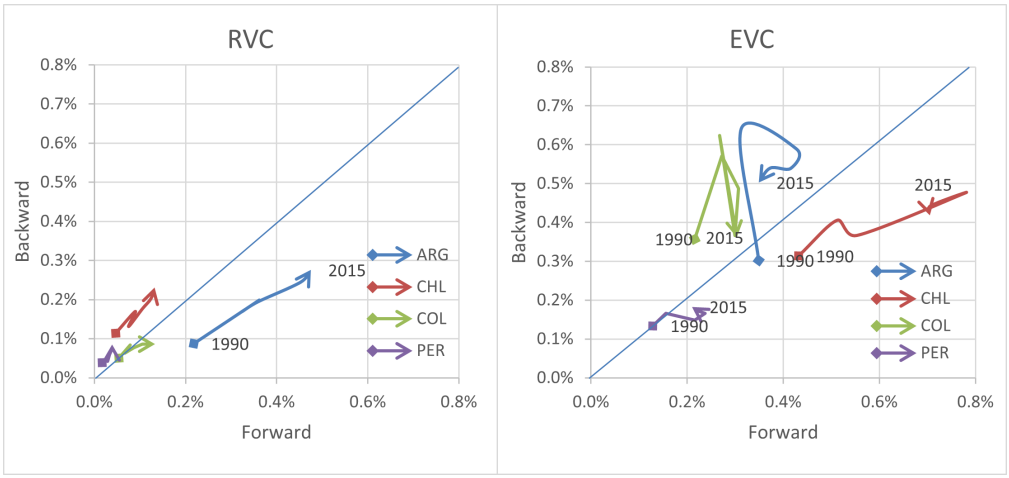
As Wang et al. (2017b) point out, the role of a country in value chains cannot be completely described only by analyzing the use or destination of its own value added, but should also consider the use that it does of other countries' value. That is, the backward perspective must complement the forward. In Wang et al. (2017b) framework, the comparison between forward and backward linkages makes sense only for value chain terms because the terms that capture domestic value added in final goods production do not show differences at a country level. In the next set of figures, the evolution in value chains will be depicted in various levels: first, the total value added in value chains from a country as a share of total value added on Latin American region. An increase in the value means that the value chain activity of this country is increasingly important in the region. Second, in the same graph, forward participation share in total value (calculated as shown in table 2) is depicted in the horizontal axis and backward participation share (calculated as shown in table A2 in Appendix) in total value is depicted in the vertical axis. A position below the 45-degree line means that a country held a forward position in this type of chain, that is, tends to include more value-added in chains used by their partners than the foreign value added that it uses. Conversely, a position above the 45-degree line means that a country holds a backward position, using more value added in its final production of a particular kind of chain than

the value it provides to international markets. Note that this kind of graph can also be done for each country sector pair, but for simplicity here only the country position will be depicted. These graphs give an intuitive interpretation: a departure from zero means that value chains activities of a country are rising their importance in Latin America but this rise can be done as a provider of value (growing parallel to horizontal axis), as a user of value instead of source (growing upwards), or in both measures, parallel to the 45-degree line. As a consequence of working with ratios of total Latin American countries, the comparison must be done among countries of similar size.

Figure 3 shows the evolution of performance and position in big and middle-sized countries of Latin America[6]. It shows that the two biggest countries in the region exhibit very different kinds of integration.



(a) Big countries in LAC



(b) Middle size countries in LAC

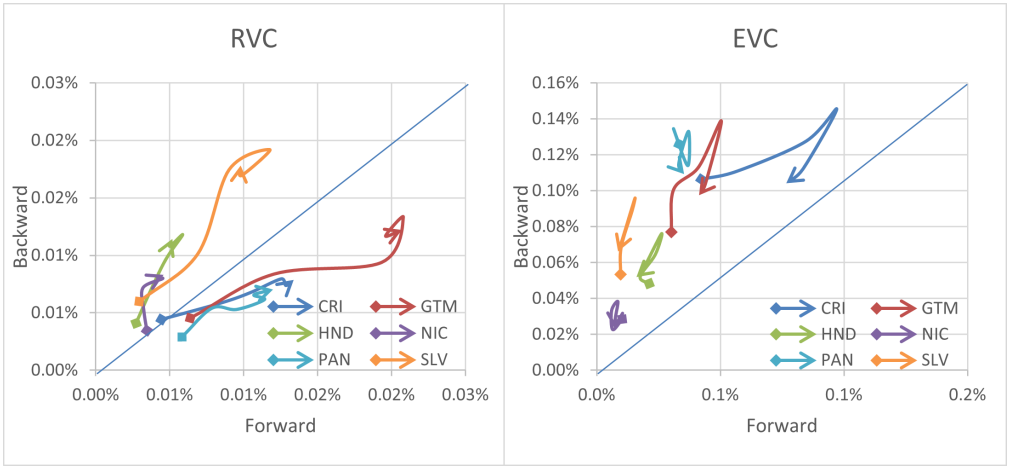
FIGURE 3 Position in regional and global value chain: value included in value chain trade as share of total Latin American value. Forward and Backward perspective. From 1990 to 2015, in % *Source:* Own elaboration based in EORA.

[6]Despite being a middle size country, Venezuela is excluded form the graph because its position does not fit with any category. Venezuela has a scarce participation in RVC and a very strong forward position in GVC, due to oil exports. Its domestic vale added in GVC ranged from 1.5% in 1990, reaching 2,5% in 2007 and ending the period with 1,8%. Nevertheless, their backward share in GVC averaged 0,5% in the period.

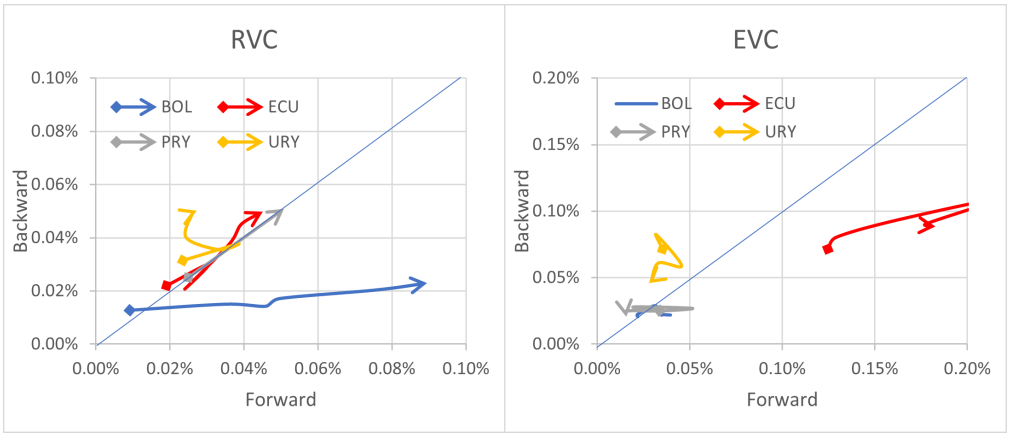
While Mexico is a key player in regional value chains, Brazil tends to participate in extra regionals. Both countries perform backward biased participation. In Brazil, it means that the use of foreign inputs in domestic manufacturing production surpasses the value added included in their sizable mining production. Mexico is an example of backward integration in value chains, mostly regional. Nevertheless, the graph shows that if we take into account only the regional interaction of this value, Mexico changed its position in the period. The reason behind the surprising wave in Mexico is the increasing use of extra regional inputs in Mexican production, mostly from China. Comparing both extremes of the data period, Mexico raised their forward participation in RVC, that is, it includes more domestic value in intermediates sold to USMCA, but raised its backward participation only in ECV, not in RVC, that is, the share of USMCA value in their total production remained at 1,5% of total Latin American value. This result is consistent with Antràs and de Gortari (2020) finding of a U-shaped relation in integration and trade costs. This switch from regional to extra-regional supply is behind the tightener rules of origin that USA promoted under the USMCA Treaty.

Panel b) of Figure 3 shows the results for four middle size Latin American countries, all located in South America. Except for Argentina, every country participates more in extra regional than in regional chains. Argentina is strongly integrated with Brazil and scarcely with global markets. This country raised its share in regional trade in the period, keeping a forward position. Also, in the period Argentina raised its backward position with the rest of the world. Chile raised its share in both types of chains and has a very differentiated position: forward in global and backward in regional. Colombia and Peru exhibit very low participation in RVC. In EVC, Colombia is a backward participant. It means that their domestic value added in intermediate commodities exported such as oil products does not compensate for the use of foreign inputs, similar to the Brazilian case.

Figure 4 shows the same graph for two other sets of countries. Panel a) draw the situation of Central American countries and b) draws the situation of small South American countries. Every Central American country experienced a rise in EVC participation until the global crisis and a fall thenceforth. All Central American countries' participation in EVC is backward biased, showing that these countries tend to participate in international trade at the end of global chains. RVC in Central America is less important but they have a rising tendency. While Guatemala, Costa Rica, and Panama hold a forward position, El Salvador, Honduras, and Nicaragua tend to be backward. RVC is important for Paraguay and Bolivia, especially in the forward perspective. Ecuador is strongly forward in EVC and Uruguay is backward both in RVC and EVC. All these countries' participation in international value chains raised their importance in the period.



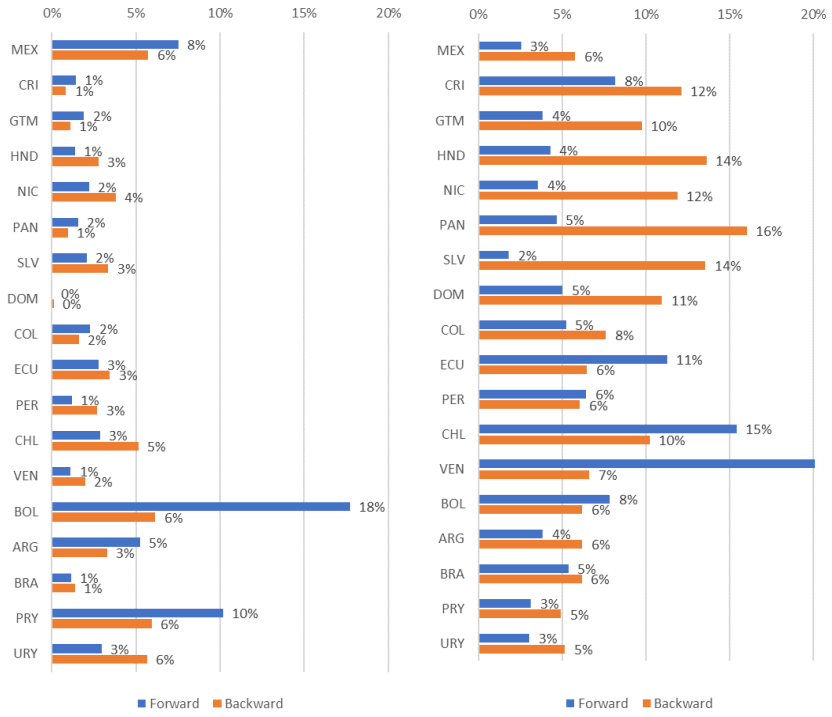
(a) Central America



(b) South America - small

FIGURE 4 Position in regional and global value chain: value included in value chain trade as share of total Latin American value. Forward and Backward perspective. From 1990 to 2015, in %
Source: Own elaboration based in EORA.

Graph 5 consolidates the backward and forward position for all Latin American countries, as a share of their own value added in Regional and Extra regional chains.



(a) Regional Value Chains (b) Extra Regional Value Chains

FIGURE 5 Forward and Backward participation in value chains. As shares in value added of each country. Years 2014-15 *Source:* Own Elaboration using EORA

3.3 | Single and complex value chains participation and relationship with other measures

As noted in section 2, RVC and EVC can also be divided in Single and Complex value chains according to the number of borders that the value added crosses. While in Single Value Chains the value added crosses borders just once and is consumed in destination, the attribute of Complex is the multiple border crossing. In the forward perspective, it means that value added exported by country s to country r is then reexported by r as another intermediate or final good. This flow gives rise to double counting of value added if gross exports are used[7].

Eq. (14) and (15) show the division among single and complex value chains. Figure 6 shows the dispersion of the share of complex value chains in total in two periods for Latin American countries, according to the kind of value chain. Complex accounts for about a third of ERV in both periods. While in Central American countries and in Mexico the share of the complex in total in ERV decreased in the period, in most South American countries the trend was the opposite. In RVC, Complex VC shares a small portion of the total but the magnitude raised about 50% in the period.

[7]Double counted value is the difference between imported content and genuine foreign value included in gross exports of a country. It arises from the fact that foreign intermediates sourced from country s can include value from another country and that this value was already counted in the relationship among s and their supplier, so the following cross border of this value should not be considered as value added (Koopman et al., 2014; Los et al., 2016; Los and Timmer, 2020; Borin and Mancini, 2019).Double counting is behind the gap among gross exports and value added exports

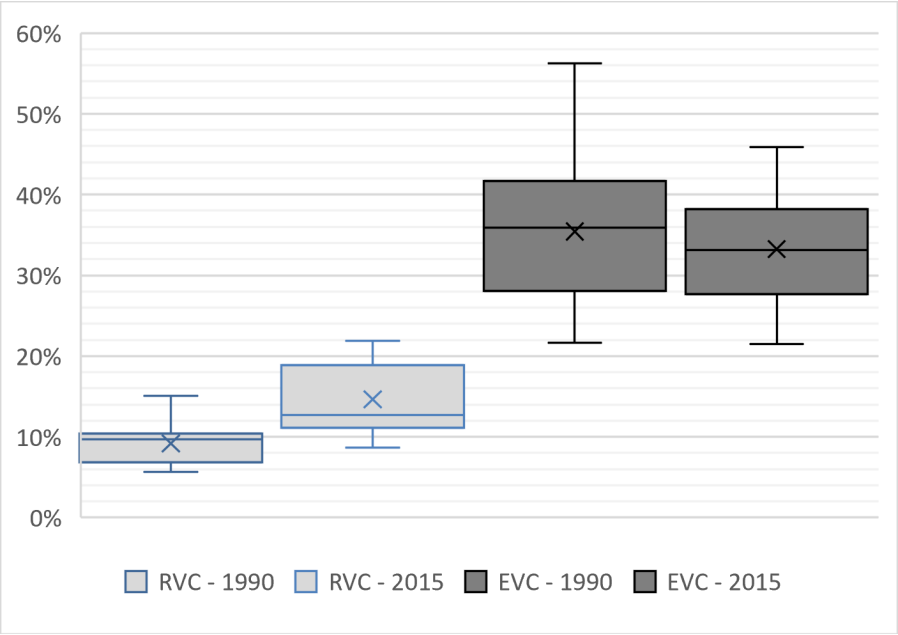


FIGURE 6 Dispersion of share of Complex Value Chains in Total Value Chain, by kind of Chain. 1990 and 2015. Latin American countries *Source:* Own Elaboration using EORA

The distinction made between simple and complex is useful for the purpose of comparing the measures used in this article with some measures commonly used in the literature. Borin and Mancini (2019) set a measure of participation in GVC that includes classic VS measure of backward participation and a new measure for VS1 concept of forward participation (Hummels et al., 2001).

Figure 7 shows the forward and backward participation in GVC indexes according to Borin and Mancini (2019) methodology. The sum of backward and forward participation gives the total participation in value chains. Most countries range between 35% and 25% of total participation, and backward linkages prevail over forward. The figure sorts the countries in a similar way as in Figure 5, except for some differences. Chile, Mexico, and Peru are the countries with higher participation of GVC in trade. While Mexico is heavily backward, Peru is strongly forward, and Chile appears as both Forward and Backward. Paraguay appears as the country less integrated into value chains.

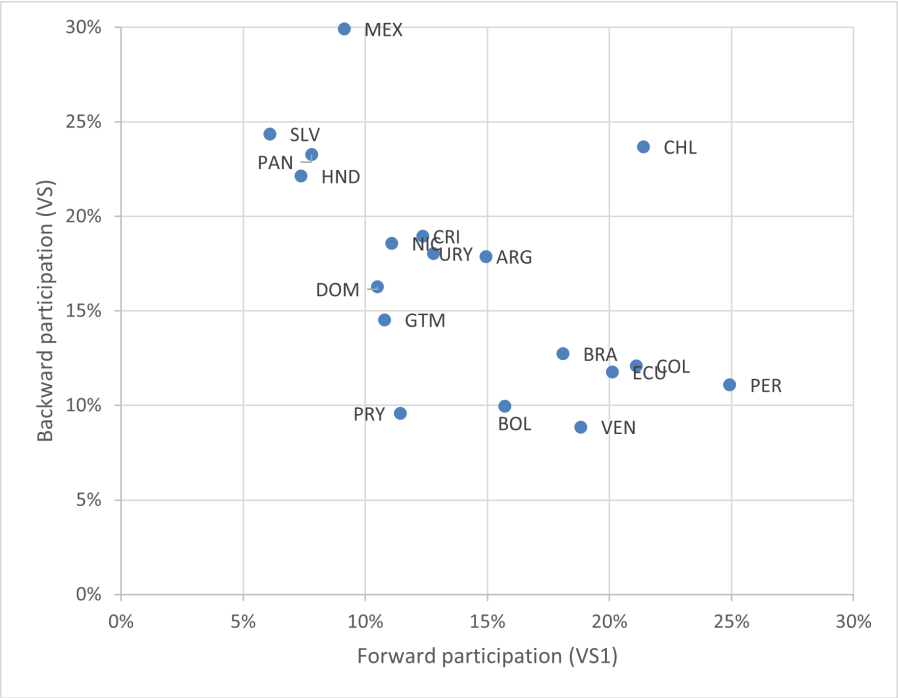
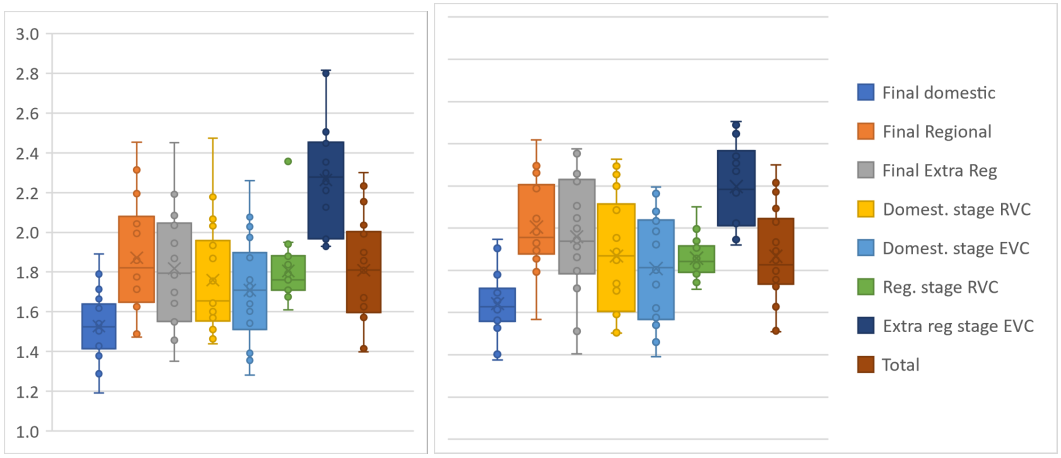


FIGURE 7 Forward and Backward participation in Global Value Chains in Latin American Countries. 2015 *Source:* Own Elaboration using EORA

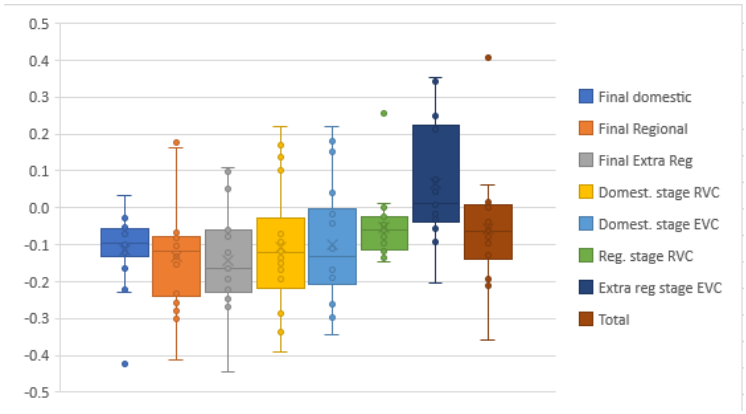
3.4 | Exploring the sources of length in global value chains

Section 2 showed the adaptation of Wang et al. (2017a) to the framework of regional and global value chains. While Table 3 showed the decomposition of total length in Domestic, Regional, Extraregional, and Mixed Value Chains from a forward perspective, Table A.2 in Appendix showed it from a backward perspective.

The total length of chains of a given country is the sum of production done along all domestic and international stages that use this value added until is incorporated in final demand. Total production, included in the first row of table 3 can be split in every term shown in the next rows of the table. A useful way to interpret changes in the length of chains is with the average length of each segment, that is, dividing each term of table 3 by its corresponding value-added term of table 2.



(a) 2014-15 (b) 1992-93



(c) Differences (2014-5 – 1992-3)

FIGURE 8 Dispersion of average length of chains according to segment. Forward perspective. Latin American countries. Years 1992/3 and 2014/5 and differences between periods. *Source:* Own elaboration based in EORA.

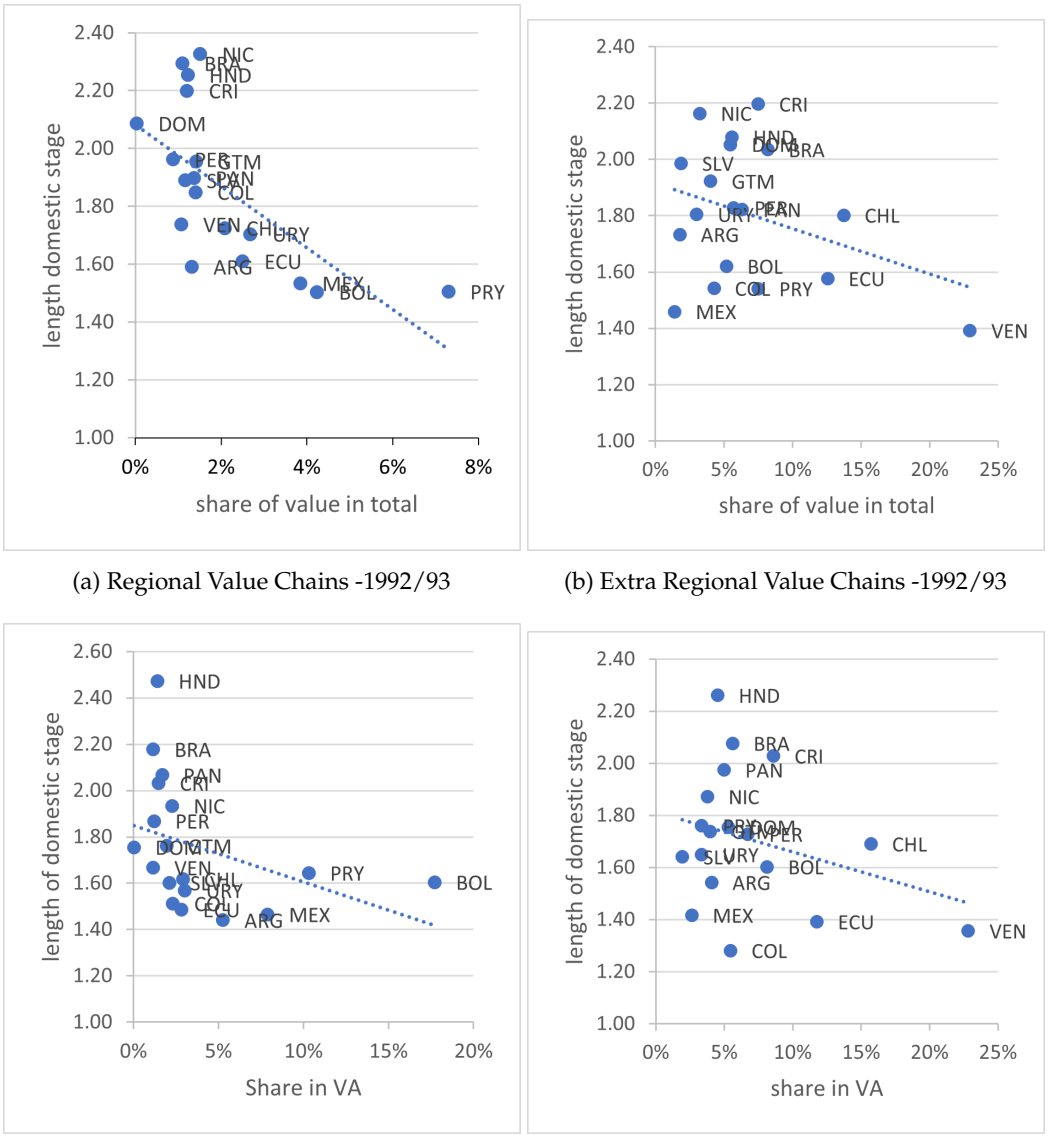
Figure 8 shows the average length of chains considering every component of table 3 divided by their corresponding term of table 2. Figure A.1 in the Appendix shows the evolution by country in each term.

Domestic value chains for domestic consumption are systematically shorter than other stages. Domestic length in final good exports decreased considerably in the period, with a special pace in extra-regional exports of final goods. The domestic stage of Regional and Extra regional value chains also decreased and are consistently higher in RVC. The extra regional length of EVC is higher than any other and also increased in the period, showing higher fragmentation of production in the world. As a result of these changes, the total length of chains decreased in Latin American countries, except in Bolivia, where the rising importance of the relatively long regional stage of RVC counterweighted the decreasing trend in domestic stages. The backward view[8], retrieves a picture almost identical, with less dispersion of values in international stages.

The average length of a chain in a country is a useful indicator of how participation in Global Value Chains determines the specialization of a Country. Figure 9 shows the relation of participation in chains (as a share of value added) with the length of the domestic stage

[8]Backward figures are available upon request to the author

of value chains in two periods, in early stages of fragmentation and in most recent years available.



(a) Regional Value Chains -1992/93

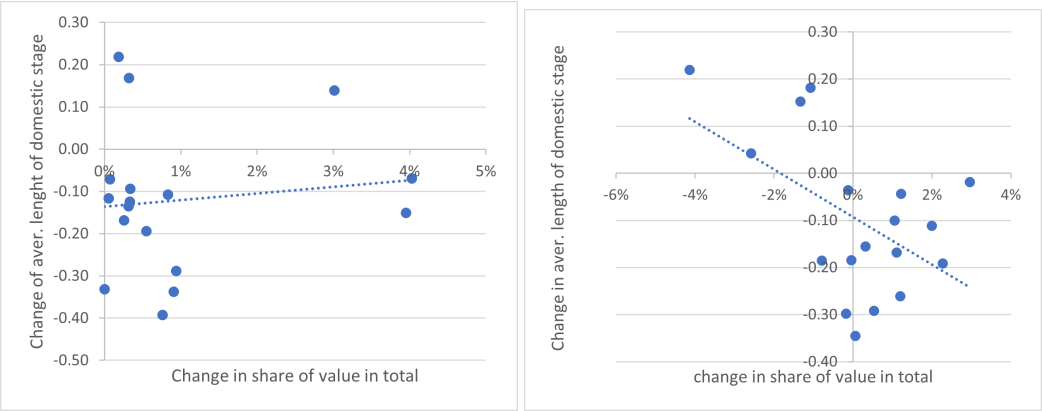
(b) Extra Regional Value Chains -1992/93

(c) Regional Value Chains -2014/15

(d) Extra Regional Value Chains -2014/15

FIGURE 9 Length of domestic stage of value chains (Forward Perspective) and share of value added of country included in GVC according to the type of chain. *Source:* Own elaboration using EORA

At the beginning of the period of study there where a strong negative correlation between the size of RVC for countries and the length of it, and this relationship was less clear in extra-regional chains. At the end of the period the relationship loses strength in RVC. Figure 10 depicts the dynamic of the negative relationship, showing that the countries that increased their involvement in extra-regional value chains decreased more the domestic length of their chain. In regional trade this relationship is less clear, giving the idea that the participation in regional value chains did not result in increasing specialization of Latin American countries.



(a) Regional Value Chains (b) Extra Regional Value Chains

FIGURE 10 Change in average length and in share of value in total value added of Latin American Countries. Change in 2014/5 relative to 1992/93. In differences. *Source:* Own elaboration based in EORA.

As long as the backward length of the domestic segment of chains has less variance than forward in levels and in changes, the negative relationship between length and participation does not hold.

4 | CONCLUDING REMARKS

Nearby 1990 Latin American countries engaged in a process of openness of their economies and integration of their markets through multiple trade agreements signed with regional partners and also with non-Latin American countries. This strategy was very heterogeneous across the subcontinent. Meanwhile, developments in infrastructure and information and communication technology and changes in the governance of global trade fed the second wave of globalization characterized by growing rates of international trade systematically higher than GDP, whereas the rise of trade in global value chains in one of the outstanding facts. In this context, both regionalization and globalization changed the structure of supply and demand of production in Latin American countries.

From 1990 to 2015, the engagement on activities related to international trade as a share of total activity grew in every country of Latin America, with a stop around the global crisis of 2008-09. Nevertheless, except for Mexico, every subregion of Latin America still maintains a level of interaction with international markets lower than the Western and Central European or the Southeast and East Asian countries.

While the participation in global value chains was increasing in every country of the sample, there are strong differences in the kind of participation measured as the position in the value chain and also in the geographical scope of the trade. Argentina, Bolivia, and Paraguay increased strongly their involvement in RVC as the source of value (forward), while Mexico did it mostly as a user, although in the last years it increased the use of extra-regional value. Central American countries, despite having increased their participation in value chains, still underperform compared with Mexico. Nevertheless, they have an increasing regional trade pattern. Medium-sized South American countries with a strong base in mining industry, like Peru, Chile, and Ecuador, have a strong position as the source of value involved in value chains, but some other Mining countries such as Colombia or Brazil have a net Backward position, in a context of scarce participation in value chains.

This article showed how slicing the participation in the value chain can be useful to ana-

lyze the sources of the change in length of chains and found a negative association between participation and length of chains in Latin American countries, that is, the countries more involved (in terms of their own activity) in value chains tend to increase the specialization in the production process, essentially in Extra Regional Value Chains. This preliminary finding encourages more systematic research about the relationship in participation and length of chains not only in Latin America but in other more integrated regions.

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A.1 | ALGEBRA

A.1.1 | Demonstration of 7a, 7b, 8a, 8b, 9a, 9b

A.1.1.1 | Demonstration of 7a:

$B = B^{reg} + B^{reg}A^{-reg}B \rightarrow B - B^{reg} = B^{reg}A^{-reg}B$

$B^{reg}A^{-reg}B = B^{reg}(A - A^{reg})B = (I - A^{reg})^{-1}(A - A^{reg})(I - A)^{-1} =$
$(I + A^{reg} + A^{reg^2} + A^{reg^3} + \dots)(A - A^{reg})(I + A + A^2 + A^3 + \dots) =$
$(A + A^{reg}A + A^{reg^2}A + A^{reg^3}A + \dots - A^{reg} - A^{reg^2} - A^{reg^3} - A^{reg^4} + \dots)$
$(I + A + A^2 + A^3 + \dots) =$
$A + A^{reg}A + A^{reg^2}A + A^{reg^3}A + \dots - A^{reg} - A^{reg^2} - A^{reg^3} - A^{reg^4} + \dots + A^2 + A^{reg}A^2 +$
$A^{reg^2}A^2 + A^{reg^3}A^2 + \dots - A^{reg}A - A^{reg^2}A - A^{reg^3}A - A^{reg4}A - \dots + A^3 + A^{reg}A^3 +$
$A^{reg^2}A^3 + A^{reg^3}A^4 + \dots - A^{reg}A^2 - A^{reg^2}A^2 - A^{reg^3}A^2 - A^{reg^4}A^2 + \dots$
$= A + A^2 + A^3 + A^4 + \dots - A^{reg} - A^{reg^2} - A^{reg^3} - A^{reg^4} + \dots =$
$(A + A^2 + A^3 + A^4 + \dots) - (A^{reg} + A^{reg^2} + A^{reg^3} + A^{reg^4} + \dots) =$
$((I - A)^{-1} - I) - ((I - A^{reg})^{-1} - I) = (B - I - (B^{reg} - I)) = B - B^{reg}$

A.1.1.2 | Demonstration of 7b:

$B = B^{reg} + BA^{-reg}B^{reg} \rightarrow B - B^{reg} = BA^{-reg}B^{reg}$

$BA^{-reg}B^{reg} = B(A - A^{reg})B^{reg} = (I - A)^{-1}(A - A^{reg})(I - A^{reg})^{-1} = (I + A + A^2 +$
$A^3 + \dots)(A - A^{reg})(I + A^{reg} + A^{reg^2} + A^{reg^3} + \dots) =$

From here, the sequence is identical to the case above.

A.1.1.3 | Demonstration of 9a and 9b:

$B = B^{ext} + B^{ext}A^{-ext}B$

Replacing B^{ext} instead of B^{reg} and A^{-ext} instead of A^{-reg} and applying the same logic as above, the relationship is demonstrated.

A.1.1.4 | Demonstration of 8a and 8b:

$B^{reg} = L + LA^{reg-d}B^{reg}$

Replacing L instead of B^{reg} in 7a ,B^{reg} instead of B and A^{reg-d} instead of A^{-reg} and applying the same logic as above, the relationship is demonstrated.

A.1.2 | Algebra of Domestic Length and regional length of RVC

Note: This Appendix includes only the algebra for RVC (that is, $\hat{V}LA^{reg-d}B^{reg}Y$). Replacing A^{reg-d} by A^{-reg} and B^{reg} by B^{ext}, the same can be done for EVC.

$\hat{V}LA^{reg-d}B^{reg}Y = \hat{V}(I - A^d)^{-1}A^{reg-d}(I - A^{reg})^{-1}Y = \hat{V}(I + A^d + A^{d^2} + A^{d^3} +$
$A^{d^4} + \dots)A^{reg-d}(I + A^{reg} + A^{reg^2} + A^{reg^3} + A^{reg^4} + \dots)Y = \hat{V}A^{reg-d}Y + \hat{V}A^dA^{reg-d}Y +$
$VA^{reg-d}A^{reg}Y + \hat{V}A^dA^dA^{reg-d}Y + \hat{V}A^dA^{reg-d}AY + \hat{V}A^{reg-d}A^{reg}A^{reg}Y + \dots$

So, total value added in Regional Value Chains can be divided in infinite terms that multiply some domestic stages and some regional stages. X_d accounts for stages occurring before the cross border (A^{reg-d}) and X_f accounts for the cross border and the stages

occurring after. Total stages are $X_d + X_f$. Dividing the chains in this way, we can reproduce the logic of the original method of counting stages.

TABLE A.1 Accounting for stages in regional value chains according to place of production

Total Stages	Value Added	Stages before A^{reg-d}	Stages in A^{reg-d} and after	Weight in X_d	Weight in X_i
2	$\hat{V}A^{reg-d}\hat{Y}$	$\hat{V}$	A^{reg-d}	1	1
3	$\hat{V}A^{d}A^{reg-d}\hat{Y}$	$\hat{V}A^{d}$	A^{reg-d}	2	1
3	$\hat{V}A^{reg-d}A^{reg}\hat{Y}$	$\hat{V}$	$A^{reg-d}A^{reg}$	1	2
4	$\hat{V}A^{d}A^{d}A^{reg-d}\hat{Y}$	$\hat{V}A^{d}A^{d}$	A^{reg-d}	3	1
4	$\hat{V}A^{d}A^{reg-d}A^{reg}\hat{Y}$	$\hat{V}A^{d}$	$A^{reg-d}A^{reg}$	2	2
4	$\hat{V}A^{reg-d}A^{reg}A^{reg}\hat{Y}$	$\hat{V}$	$A^{reg-d}A^{reg}A^{reg}$	1	3
5	$\hat{V}A^{d}A^{d}A^{d}A^{reg-d}\hat{Y}$	$\hat{V}A^{d}A^{d}A^{d}$	A^{reg-d}	4	1
5	$\hat{V}A^{d}A^{d}A^{reg-d}A^{reg}\hat{Y}$	$\hat{V}A^{d}A^{d}$	$A^{reg-d}A^{reg}$	3	2
5	$\hat{V}A^{d}A^{reg-d}A^{reg}A^{reg}\hat{Y}$	$\hat{V}A^{d}$	$A^{reg-d}A^{reg}A^{reg}$	2	3
5	$\hat{V}A^{reg-d}A^{reg}A^{reg}A^{reg}\hat{Y}$	$\hat{V}$	$A^{reg-d}A^{reg}A^{reg}A^{reg}$	1	4
...	...	...	...	...	...

Source: Own elaboration

Total Value Added can be split in all the terms of second column of table A.1.

$VY_{RVC} = \hat{V}A^{reg-d}\hat{Y} + \hat{V}A^{d}A^{reg-d}\hat{Y} + \hat{V}A^{reg-d}A\hat{Y} + \hat{V}A^{d}A^{d}A^{reg-d}\hat{Y} + \hat{V}A^{d}A^{reg-d}A\hat{Y} + \hat{V}A^{reg-d}AA\hat{Y} + \hat{V}A^{d}A^{d}A^{d}A^{reg-d}A\hat{Y} + \hat{V}A^{d}A^{d}A^{d}A^{reg-d}A\hat{Y} + \hat{V}A^{d}A^{d}A^{reg-d}AA\hat{Y} + \hat{V}A^{reg-d}AAA\hat{Y} + \cdots =$

$= \hat{V}(I + A^{d} + (A^{d})^{2} + \ldots)A^{reg-d}\hat{Y} + \ldots \hat{V}(I + A^{d} + (A^{d})^{2} + \ldots)A^{reg-d}A\hat{Y} + \hat{V}(I + A^{d} + (A^{d})^{2} + \ldots)A^{reg-d}A^{2}\hat{Y} + \cdots = \hat{V}(I - A^{d})^{-1}A^{reg-d}(I - A)^{-1}\hat{Y} = \hat{V}LA^{reg-d}B\hat{Y}$

Domestic Length of RVC (X_{dRVC}) accounts for the stages that happen in the economy of reference:

$X_{dRVC} = \hat{V}A^{reg-d}\hat{Y} + \hat{V}A^{reg-d}A^{reg}\hat{Y} + 2\hat{V}A^{d}A^{reg-d}\hat{Y} + 3\hat{V}A^{d}A^{d}A^{reg-d}\hat{Y} + 2\hat{V}A^{d}A^{reg-d}A^{reg}\hat{Y} + \hat{V}A^{reg-d}A^{reg}A^{reg}\hat{Y} + 4\hat{V}A^{d}A^{d}A^{d}A^{reg-d}\hat{Y} + 3\hat{V}A^{d}A^{d}A^{reg-d}A^{reg}\hat{Y} + 2\hat{V}A^{d}A^{reg-d}A^{reg}A^{reg}\hat{Y} + \hat{V}A^{reg-d}A^{reg}A^{reg}A^{reg}\hat{Y} + \ldots$

$= A^{reg-d}(I + A^{reg} + A^{reg}A^{reg} + \ldots)\hat{Y} + 2\hat{V}A^{d}A^{reg-d}(I + A^{reg} + A^{reg}A^{reg} + \ldots)\hat{Y} + 3\hat{V}A^{d}A^{d}A^{reg-d}(I + A^{reg} + A^{reg}A^{reg} + \ldots)\hat{Y} + \cdots = \hat{V}(I + 2A^{d} + 3A^{d}A^{d} + \ldots)A^{reg-d}(I + A^{reg} + A^{reg}A^{reg} + \ldots)\hat{Y} = \hat{V}(I + A^{d} + A^{d^{2}} + \ldots)(I - A^{d})^{-1}A^{reg-d}B^{reg}\hat{Y} = \hat{V}LLA^{reg-d}B^{reg}\hat{Y}$

While, International Length of RVC (X_{iRVC}) accounts for the stages that happen after the input abandoned the country of reference:

$X_{iRVC} = \hat{V}A^{reg-d}\hat{Y} + 2\hat{V}A^{reg-d}A^{reg}\hat{Y} + \hat{V}A^{d}A^{reg-d}\hat{Y} + \hat{V}A^{d}A^{d}A^{reg-d}\hat{Y} + 2\hat{V}A^{d}A^{reg-d}A^{reg}\hat{Y} + 3\hat{V}A^{reg-d}A^{reg}A^{reg}\hat{Y} + \hat{V}A^{d}A^{d}A^{d}A^{reg-d}\hat{Y} + 2\hat{V}A^{d}A^{d}A^{reg-d}A^{reg}\hat{Y} + 3\hat{V}A^{d}A^{reg-d}A^{reg}A^{reg}\hat{Y} + 4\hat{V}A^{reg-d}A^{reg}A^{reg}A^{reg}\hat{Y} + \ldots$

$= (I + A^{d} + A^{d}A^{d} + \ldots)A^{reg-d}\hat{Y} + 2\hat{V}(I + A^{d} + A^{d}A^{d} + \ldots)A^{reg-d}A^{reg}\hat{Y} + 3\hat{V}(I + A^{d} + A^{d}A^{d} + \ldots)Areg - dAregAreg\hat{Y} + \cdots = \hat{V}LA^{reg-d}B^{reg}(I + A^{reg} + A^{reg^{2}}) + \ldots)\hat{Y} = \hat{V}LA^{reg-d}B^{reg}B^{reg}\hat{Y}$

Total length of chains is $X_{dRVC} + X_{iRVC} = \hat{V}LLA^{reg-d}B^{reg}\hat{Y} + \hat{V}LA^{reg-d}B^{reg}B^{reg}\hat{Y}$

The average times that value added from sector i of country s involved in regional value chains is counted as output is:

$$\frac{X_{dRVC} + X_{iRVC}}{VY_{RVC}} = \frac{\hat{V}LLA^{reg-d}B^{reg}\hat{Y} + \hat{V}LA^{reg-d}B^{reg}B^{reg}\hat{Y}}{\hat{V}LA^{reg-d}B^{reg}\hat{Y}}$$

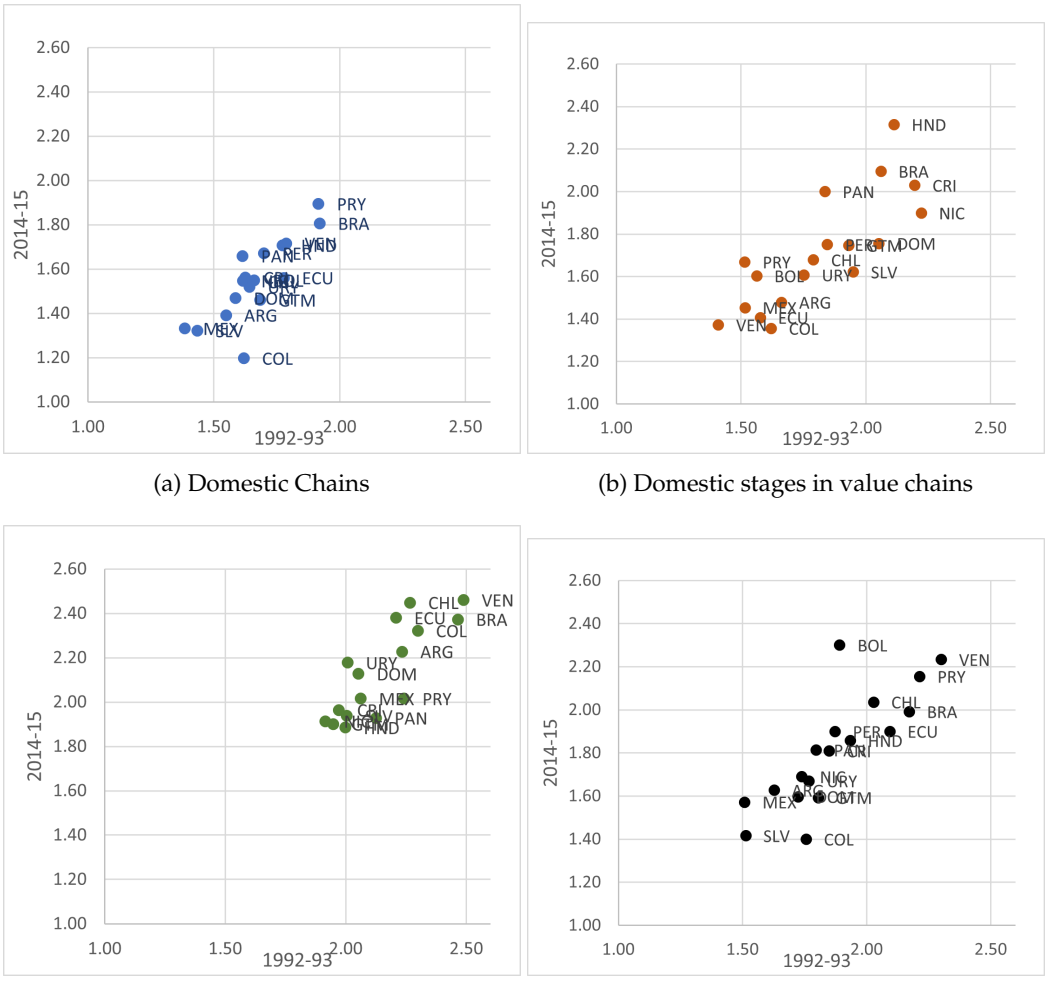
A.2 | TABLES

TABLE A.2 Measures of backward perspective of length in domestic, regionals, extra regionals and mixed value chains

Name	Formula	Concept
TOTAL	$VBB\hat{Y}$	Total backward length of chains
Pure domestic value added	$VLL\hat{Y^D}$	Length of pure domestic chains
Traditional exports to region	$VLL\hat{Y^R}$	Length of domestic chains for regional export of final goods
Traditional exports to extra-region	$VLL\hat{Y^F}$	Length of domestic chains for extra regional export of final goods
Regional value chains	$VB^{reg}A^{reg-d}LL\hat{Y}$	Domestic length of RVC
	$VB^{reg}B^{reg}A^{reg-d}L\hat{Y}$	Regional length of RVC
Extra regional value chains	$VB^{ext}A^{-reg}LL\hat{Y}$	Domestic length of EVC
	$VB^{ext}B^{ext}A^{-reg}L\hat{Y}$	Extra regional length of EVC
Mixed value Chains	$VBA^{-ext}B^{ext}A^{-reg}LL\hat{Y}$	Domestic length of mixed chains type 1
	$VBA^{-ext}B^{ext}B^{ext}A^{-reg}L\hat{Y}$	Extra regional length of mixed chains type 1
	$VBBA^{-ext}B^{ext}A^{-reg}L\hat{Y}$	Global length of mixed chains type 1
Mixed value Chains	$VBA^{-reg}B^{reg}A^{reg-d}LL\hat{Y}$	Domestic length of mixed chains type 2
	$VBA^{-reg}B^{reg}B^{reg}A^{reg-d}L\hat{Y}$	Regional length of mixed chains type 2
	$VBBA^{-reg}B^{reg}A^{reg-d}L\hat{Y}$	Global length of mixed chains type 2

Source: Own elaboration

A.3 | ADDITIONAL FIGURES



(a) Domestic Chains

(b) Domestic stages in value chains

(c) International stages in value chains

(d) Total length of chains

FIGURE A.1 Average length of chains of Latin American Countries. Years 1992/3 and 2014/5 *Source:* Own elaboration using EORA

A.4 | DATA AND REGIONS

TABLE A.3 Regions considered, and other criteria applied.

Region	Countries	ISO - Code
North America	Canada, Mexico, United States	CAN, MEX, USA
Central America	Dominican Republic, Costa Rica, El Salvador, Guatemala, Honduras, Nicaragua, Panama	DOM, CRI, SLV, GTM, HON, NIC, PAN
South America	Argentina, Brazil, Bolivia, Chile, Colombia, Ecuador, Peru, Paraguay, Uruguay, Venezuela	ARG, BRA, BOL, CHL, COL, ECU, PER, PAR, URY, VEN
European Union and EFTA Countries	Austria, Belgium, Bulgaria, Switzerland, Czech Rep., Germany, Denmark, Spain, Finland, France, United Kingdom, Greece, Croatia, Hungary, Ireland, Italy, Lithuania, Luxembourg, Netherlands, Norway, Poland, Portugal, Romania, Slovakia, Slovenia, Sweden	AUT, BEL, BGR, CHE, CZE, DEU, DNK, ESP, FIN, FRA, GBR, GRC, HRV, HUN, IRL, ITA, LTU, LUX, NLD, NOR, POL, PRT, ROU, SVK, SVN, SWE
ASEAN + 3	China, Hong Kong SAR (China), Indonesia, Japan, Korea Rep., Lao PDR, Malaysia, Myanmar	CHN, HKG, IDN, JPN, KOR, LAO, MYS, MMR, NZL, PHL, SGP, TWN, THA, VNM Rest
44 countries		
Dropped due to computational problems	Azerbaijan, Kazakhstan, Ukraine	AZE, KAZ, UKR
Dropped by size	78 countries will less than 0,05% of world GDP outside LAC	

Source: Own elaboration