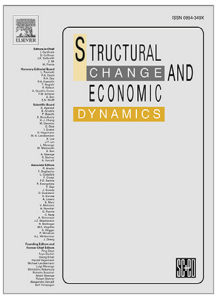

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Productive specialization and integration in South America: A global input-output analysis

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Abstract

In the current context, where a large part of international trade in goods and services is linked to global production chains, the policy course to reap the gains from this trade differs according to the point of view adopted. While from a country's point of view, the strategy is to join global production chains and upgrade to higher value-added activities, from the point of view of the regions, the new scenario offers opportunities to deepen productive integration. In the present paper, we aim to examine the role played by South America in global production chains and the potential for strengthening regional integration. We observe that considering extra-regional markets, the region maintains a pattern of specialization biased towards the export of primary commodities. However, intra-regional trade is based on more technologically complex sectors with favorable prospects for promoting regional production chains.

Keywords: regional value chains, productive integration, South America, input-output analysis keyword one, keyword two

1. Introduction

In the last decades of the twentieth century, several institutional and technological factors conjugated, leading to the redefinition of global trade and production conditions. Among the institutional changes, the fall of the soviet countries bloc, the transition of China toward a market economy, and the liberalization of the Indian economy significantly affected international commercial and financial relations (Milberg and Winkler, 2013). Furthermore, the process of unilateral trade liberalization in several developing economies following the crisis of inward development strategies and the consequent shift to export-led growth policies also stands out (Palley, 2012). Among the technological changes, the rise of information and communication technologies and improvements in transportation logistics have facilitated the remote coordination of complex production processes (Baldwin, 2011).

As is well known, these changes allowed multinational firms to relocate production segments (or outsource them) toward countries that offered attractive markets or cost advantages. Production processes previously vertically integrated within domestic borders began to expand and cross borders, forming the so-called global production chains (or networks). This process's logical consequence was the trade increase in intermediate inputs and capital goods.

In this new scenario, industrialization became easier for developing economies since it was no longer required to develop a competitive domestic sector to compete in global markets but only

develop a competitive activity or segment to participate in a global production chain (Baldwin, 2011). An alternative development strategy emerged, consisting of participating first in labor-intensive segments with low technological complexity. Then, upgrade toward more sophisticated segments of higher technological complexity, or jump toward more dynamic production chains.

Specialized scholars are divided between those who regard the insertion of developing countries into global production chains as an opportunity for development and those who regard it as a limitation or restriction (Fernández, 2015). The division responds to the divergent experiences about the gains from joining global production chains. Scholvin et al. (2022) claim that negative experiences concentrated in Africa and Latin America, where there has not been a diversification of the economic structure biased toward exporting raw materials. Instead, regional production chains were formed in Asia, Europe and North America, where local firms are highly linked and sell their products to the regional markets. Baldwin (2011) denotes these production areas as 'factories.' These large manufacturing conglomerates are institutionally framed and regulated by mega-regional treaties and agreements.

Whereas from the viewpoint of single countries, the action course is to join global production chains, from the viewpoint of regions, the new scenario seems to offer an opportunity for deepening productive integration. The present paper seeks to study the state of productive integration of the South American region. Following Amar and García Díaz (2018), we define productive integration as the degree of inter-connectivity of production processes in a region between member countries. The study contributes to the debate about the feasibility of a development strategy based on building regional production chains, such as those evidenced in Asia, Europe, and North America. So far, this strategy has received little attention from policymakers in the current context despite a long-standing theoretical tradition that defends the importance of productive integration as a path to development.

We find that the region has not overcome its traditional export pattern, which is biased toward producing agricultural and mining commodities whose main outlets are extra-regional destinations (mainly North America and East Asia). These commodities and their initial transformation stages are the region's main source of exported value added. Conversely, trade within the region is focused on activities more technologically complex (like the automotive, chemical and capital goods-producing industries). This type of trade and the activities involved could be promoted by deepening integration as a part of a development strategy amid the current heterogeneities between blocs and member countries within the region. Furthermore, we assess the effects of deepening regionalization with the global hypothetical extraction method and find substantial benefits from stronger productive integration. However, the distributions of the gains are not balanced. These heterogeneities may translate into a political obstacle to promoting regional integration.

Following this introduction, the next section reviews input-output analyses addressing the issue of regional integration in South America. Section 3 presents the methodology and illustrates an alternative decomposition of income activated by final foreign demand to distinguish production locations and destination of final demand. In section 4, we present and discuss our results. The last section concludes the paper.

2. Literature review

The literature on Latin American economic integration originates in the pioneering studies of the United Nation's Economic Commission for Latin America and the Caribbean (ECLAC). According to Vázquez López (2011), the proposal of this institution was part of a broader body of theory and considered a greater degree of integration to be positive as a way of expanding national markets, diversifying export and import baskets and modifying patterns of productive specialization.

Recently, ECLAC has promoted the study of regional and global production chains through input-output matrices, including the estimation/construction of multi-regional input-output tables for the region with different sectoral aggregations (NU CEPAL, 2016), as well as technical manuals for their use (Alvarez and Durán Lima, 2011). For this reason, most of the works prepared by the commission addressing the issue of productive integration use this tool.

Among the studies on bilateral integration, it is worth mentioning the work by Amar and García Díaz (2018, 2019) on the productive integration of Argentina with Brazil and Argentina with Chile, respectively, analyzed through the approach developed by Koopman et al. (2014) and complemented with the bilateral extension proposed by Stehrer (2013). When decomposing gross exports into different components, they observe the vertical integration modalities between Argentina and these two countries in different industries and their insertion in global production chains. The authors find that the productive integration between Argentina and Brazil deepened, especially following the creation of Mercosur and in manufacturing industries. However, the integration process was asymmetric and heterogeneous, benefiting mainly Brazilian industries. In the case of integration between Argentina and Chile, the authors find a low level of integration. However, some potential complementarities exist in the food processing, chemical, basic metals, and machinery industries. Furthermore, the energy-producing industries may be integrated with the exploitation of Vaca Muerta.

On the other hand, Durán Lima et al. (2018) examine the productive relations between Colombia and Ecuador. For this purpose, in addition to using input-output matrices, they incorporate a mapping of value chains based on the computation of the Grubel-Lloyd index at the sectoral level. High values of this indicator mark growing intra-industry trade, which is considered a proxy for the integration level. Other works using the same methodology are those by Durán Lima and Lo Turco (2010) for the case of Latin America as a whole and Molinari et al. (2012) for Mercosur.

Another group of papers dealing with the issue of productive integration addresses the existing dynamics within Latin American sub-regions. Orozco and Minzer (2020), based on the input-output matrix prepared by ECLAC for 2011, analyze productive integration in Central America, Mexico and the Dominican Republic by assessing intra-regional trade in intermediate inputs. This type of trade is typical of regional production chains. According to the authors, only 5.8% of the exports of these countries are directed to countries in the region. Only 2.6% of this percentage corresponds to trade in intermediate inputs.

Regarding South America, the works of Amar and Torchinsky Landau (2019) and Banacloche et al. (2020) stand out. The former authors use a matrix elaborated by ECLAC for the year 2011. In their work, they investigate the type of participation of each country in trade integrated

by Regional Value Chains (RVC) and analyze their characteristics, with special emphasis on the sectors included and the market to which their production is destined. Additionally, they calculate backward and forward linkages to determine each industry's pulling and pushing capacity. Banacloche et al. (2020) perform a comparative analysis of results according to the database used. Specifically, they use the South American input-output matrix prepared by ECLAC for 2011 and the 2018 edition of the OECD Inter-Country Input-Output tables. In this way, the biases of underestimation of value added in the region and overestimation of value added outside the region are observed in the regional tables, which consider the rest of the world as exogenous.

Both studies agree on the clear differentiation between purely regional chains and those destined for extra-regional markets, the former being integrated by technologically more complex sectors and the latter dominated by primary activities. A common aspect between these and other studies on productive regional integration in Latin America is that this process is limited and below its potential compared with other regions (Pietrobelli and Seri, 2023; Zaclicever, 2017).

In the present paper, we aim to incorporate new evidence on specialization patterns and the potential effect of greater integration on the region's development, specifically in South America. Another contribution is the combination of dimensions that are analyzed separately in similar studies, namely, the different types of chains and the origin of demand. Finally, we introduce the intensity with which R&D activities are carried out as a proxy for sectoral technological complexity. This aspect is scarcely developed in input-output studies regarding the region.

3. Methodology

The empirical framework of our analysis is the global input-output model. It consists of a multi-regional input-output scheme where national economies represent regions. The model has no exogenous sources of income and demand because the "rest of the world" is an endogenous, consolidated composite region.

The database employed is the 2021 edition of the OECD Inter-Country Input-Output Tables. The estimated tables contain information for 45 industries based on ISIC Revision 4 and 67 regions (66 countries plus the "rest of the world" region) from 1995 to 2018. Therefore, the table has information on $45 \times 67 = 3015$ localized activities. The countries included in South America are Argentina, Brazil, Chile, Colombia, and Peru.

Given its extended use in the input-output community, and the familiarity of its notation, we employ Miller and Blair's definitions of a "many-regions" model (Miller and Blair, 2009, ch. 3). Within this framework, $\mathbf{x}^r$ denotes the vector of gross outputs of industries in country r; $\mathbf{f}^{rs}$ designates the vector of exogenous demand for goods made in country r and shipped to country s; $\mathbf{A}^{rr}$ is the intracountry input coefficients matrix; $\mathbf{A}^{rs}$ and $\mathbf{A}^{sr}$ are the intercountry input coefficients matrices.

In a p-country model, the complete vector of gross outputs, matrix of input coefficients, and

matrix of exogenous demand are, respectively:

$$\mathbf{x} = \begin{bmatrix} \mathbf{x}^1 \\ \vdots \\ \mathbf{x}^p \end{bmatrix}, \quad \mathbf{A} = \begin{bmatrix} \mathbf{A}^{11} & \cdots & \mathbf{A}^{1p} \\ \vdots & \ddots & \vdots \\ \mathbf{A}^{p1} & \cdots & \mathbf{A}^{pp} \end{bmatrix}, \quad \mathbf{F} = \begin{bmatrix} \mathbf{f}^{11} & \cdots & \mathbf{f}^{1p} \\ \vdots & \ddots & \vdots \\ \mathbf{f}^{p1} & \cdots & \mathbf{f}^{pp} \end{bmatrix}$$

For a given level of final demands, assuming that both intracountry and intercountry input coefficients are stable, the required gross outputs in all countries can be found with the usual solution:

$$\mathbf{x} = (\mathbf{I} - \mathbf{A})^{-1}\mathbf{F}\mathbf{i} = \mathbf{L}\mathbf{F}\mathbf{i}$$

Where $\mathbf{L}$ is the global Leontief's inverse matrix, and $\mathbf{i}$ is a column vector of 1's of appropriate dimension (in this case, p).

The global input-output model is useful to compute the recent indicators developed in the literature to track "implicit trade flows" in the context of production fragmentation. The indicator we will employ throughout our analysis is the so-called value-added exports developed by Johnson and Noguera (2012).

Formally, a country's value-added exports (also called VAX) can be computed as the income induced by foreign final demand. The latter may be defined as a final-demand matrix that excludes the exogenous demand from country r.

Let r be the country of interest; q represent a consolidated region that includes country's r regional peers; t another consolidated region that represent the rest of countries. Country r value-added exports may be computed as:

$$\begin{bmatrix} (\mathbf{v}_c^r)' & \mathbf{0}' & \mathbf{0}' \end{bmatrix} \begin{bmatrix} \mathbf{L}^{rr} & \mathbf{L}^{rq} & \mathbf{L}^{rt} \\ \mathbf{L}^{qr} & \mathbf{L}^{qq} & \mathbf{L}^{qt} \\ \mathbf{L}^{tr} & \mathbf{L}^{tq} & \mathbf{L}^{tt} \end{bmatrix} \begin{bmatrix} \mathbf{0} & \mathbf{f}^{rq} & \mathbf{f}^{rt} \\ \mathbf{0} & \mathbf{f}^{qq} & \mathbf{f}^{qt} \\ \mathbf{0} & \mathbf{f}^{tq} & \mathbf{f}^{tt} \end{bmatrix} \begin{bmatrix} 1 \\ 1 \\ 1 \end{bmatrix}$$

Where $\mathbf{v}_c^r$ is the vector of value-added coefficients of the industries of country r.

As can be seen, the final-demand block can be decomposed according to two dimensions. The first is related to the localization of the final stage of production, which may be domestic or in a country within or outside the region. In the first case, the income induced is because of exports of final goods. In the second case, it is due to the export of intermediate commodities. The second dimension considers the destination of final production. In this case, the destination can be a country within or outside the region. Therefore, we may decompose value-added exports into six elements (Table 1).

	Regional peers demand	Rest of countries demand
Domestic	$(\mathbf{v}_c^r)'\mathbf{L}^{rr}\mathbf{f}^{rq}$	$(\mathbf{v}_c^r)'\mathbf{L}^{rr}\mathbf{f}^{rt}$
Within the region	$(\mathbf{v}_c^r)'\mathbf{L}^{rq}\mathbf{f}^{qq}$	$(\mathbf{v}_c^r)'\mathbf{L}^{rq}\mathbf{f}^{qt}$
Outside the region	$(\mathbf{v}_c^r)'\mathbf{L}^{rt}\mathbf{f}^{tq}$	$(\mathbf{v}_c^r)'\mathbf{L}^{rt}\mathbf{f}^{tt}$

Table 1: Alternative sources of income induced by final foreign demand. Source: Own elaboration.

To analyze the specialization pattern, we employ the taxonomy developed by the OECD (Galindo-Rueda and Verger, 2016) based on the intensity of industries' engagement in R&D

activities. The classification considers measures such as patent registration, investment in innovations, and knowledge-based capital purchases. R&D intensity is measured as the expenditure on R&D over gross value added at the industry level.

Given the relevance of some specific sectors in the generation of value added in South American countries, we slightly modify the taxonomy. Specifically, we consider the extractive industries, Agriculture and Mining (energy and non-energy) separately. Both sectors are regarded as non-manufacturing activities of low and medium-low R&D intensity in the OECD taxonomy.

Other relevant industries in generating value added are non-manufacturing activities with low R&D intensity, such as the provision of trade, transportation, and storage services. Since input-output transactions are registered at basic prices, it is likely that income in these sectors consists mainly of trade and transport margins.

4. Results

4.1. General overview

The temporal coverage of the OECD-ICIO tables allows for examining the trend behavior of our study variables. Value-added exports as a percentage of GDP have been stable from 2015 onwards in South American countries. Therefore, the present paper focuses on 2018, the last year available on the dataset. The structural relationships addressed are assumed to be stable and may still represent South America's current productive structure.

Table 2 shows that the income induced by final foreign demand in South America amounts to US$ 454,876 million, representing 15% of the regional GDP. This percentage quantifies the exposure of these countries to the volatility of external demand, which can be interpreted as the degree of dependence on international commerce to generate income in the region. It varies when analyzing individual countries. On the one hand, Chile and Peru have a significantly higher VAX in terms of GDP than the rest of the countries in the sample, with 25% and 21%, respectively. These are countries with greater trade openness, which is partly linked to the fact that they are the economies with the smallest population in the sample, and their domestic consumption markets are relatively small (Dowrick and Golley, 2004). The opposite case is found in Brazil, which has the lowest ratio, around 13%.

Despite the growing relevance of activities integrated into global production chains in recent decades in Latin America, the region is lagging compared with European and East Asian countries. According to Lalanne (2023), the percentage of income induced by international trade relations is around 26% in Europe and 20.4% in East and South East Asia. Other studies reach similar results employing alternative indexes (Stöllinger et al., 2018; Miroudot and Nordström, 2020; Xiao et al., 2020).[1] Within South America, the countries that are part of the two most important trade blocs, Mercosur and the Pacific Alliance (PA from now on), show different trajectories, with the latter being the most integrated sub-region.[2] Using the data in Table 2,

[1] Zaclicever (2017) finds that Latin America presents the lowest level of integration to global markets in terms of the import content of gross exports.

[2] The Pacific Alliance is formed by Chile, Colombia, Mexico and Peru. On the other hand, the full members of Mercosur are Argentina, Brazil, Paraguay and Uruguay. Chile, Colombia, and Peru are associated states.

it follows that the porcentage of income induced by international trade is 13.3% in Mercosur and almost 20% in the PA.

Country	VAX	VAXR	GDP	X	XR	θ (%)	υ (%)	ρ (%)
ARG	65,902	13,366	470,842	74,773	17,382	14.0	88.1	76.9
BRA	228,318	19,640	1,733,678	269,540	26,812	13.2	84.7	73.3
CHL	70,898	5,510	281,784	84,351	7,154	25.2	84.1	77.0
COL	44,812	4,641	317,468	52,084	6,398	14.1	86.0	72.5
PER	44,946	3,475	210,422	53,240	4,981	21.4	84.4	69.8
Total	454,876	46,632	3,014,193	533,987	62,727	15.1	85.2	74.4

Notes: Absolute values are expressed in millions of US dollars. Row legends: ARG: Argentina; BRA: Brazil; CHL: Chile; COL: Colombia; PER: Peru. Column legends: VAX: Value-Added Exports; VAXR: Regional VAX; GDP: Gross Domestic Product; X: Gross exports; XR: Regional gross exports; θ: VAX in terms of GDP; υ: VAX ratio; ρ: Regional VAX ratio.

Table 2: Value-added exports, output, and gross exports in South America in 2018. Source: Own elaboration based on OECD-ICIO data.

A widely used measure to grasp the extent of production fragmentation is the VAX ratio (υ), the ratio between the value added exported by each country and total exports for a given period (Johnson and Noguera, 2012). At the aggregate level, this indicator varies between 0 and 100 using percentages (or between 0 and 1 with a base ratio of 1). A lower value indicates a higher trade intensity in intermediate inputs, whereas higher values indicate the opposite. Another interpretation, as highlighted by Johnson and Noguera (2012), is to consider this indicator as a proxy for the domestic content of exports. The region's average of the VAX ratio is close to 85%, a value that partly reflects either the low productive integration of the region in the chain phenomenon or a high domestic content in their exports. Values by countries are not so different.

When analyzing the dynamics of intra-regional gross exports and the income induced by them, a different pattern emerges. A first possible interpretation would indicate that it is related to the region's importance for each country. On the other hand, the regional VAX ratio (ρ), the ratio between the value added activated by final regional demand and intra-regional gross exports, decreases significantly relative to υ (from 85.2% to 74.4% for the region as a whole). According to the definitions provided above, this decrease reflects a regional trade supported to a greater extent by the exchange of intermediate inputs. Fan et al. (2019) argue that geographical proximity makes this trade more convenient, resulting in deeper productive fragmentation. According to the authors, a lower regional ratio can also be linked to the design of regional trade policies and negotiations of regional trade agreements more conducive to increasing fragmentation.

In this case, values by country are more heterogeneous. Peru has the lowest ratio (69.8%), followed by Colombia with 72.5% and Brazil with 73.3%. Chile and Argentina stand out for presenting the highest value in this indicator (77%), reflecting a low productive integration, even considering the regional market. This denotes a pattern of specialization similar to the aggregate. In the case of Chile, both in its trade with the countries of the region and with the rest of the world, there is a low preponderance of imported intermediate inputs. In the case of Argentina, the value reflects the importance of domestic linkages in production.

In summary, Table 2 shows some shared characteristics among South American countries: low productive integration, low exposure to global trade and greater productive integration via regional trade. However, there are some particularities that we will try to delimit in the following subsections. For example, does productive integration have any relationship with the specific destination of production? What type of relationship exists between the spatiality of the chains and the destination of production in South America? Furthermore, when we delve into national particularities, what structural factors explain the lesser regional integration in Argentina and Chile?

4.2. Specialization profile by production location and destination of final demand

Table 3 breaks down South America's value-added exports according to their destination and location in the chain. First, extra-regional foreign demand is overwhelmingly more relevant than regional demand, which accounts for 90% of total activated value added. This leads us to infer a bias in production structures towards exports to markets in the rest of the world.

Second, the most relevant type of chain is the extra-regional chain (63%), followed by the domestic chain (32%), which together account for 95% of the value added exported. The income induced by trade in intermediate goods (the sum of regional and extra-regional chains) amounts to 68% of the activated value added, which is consistent with other studies on South America (Amar and Torchinsky Landau, 2019). This, a priori, seems to contradict the previous evidence based on VAX ratios, which indicate a low presence of input trade. However, this information complements the previous indicator. It allows understanding that it refers to the production of intermediate goods but with high domestic value-added content, which is strongly linked to the high participation of the extractive branches and their upstream positioning (with no need for many other inputs for their production).

Considering the destination of final demand, it can be seen that the internal and extra-regional chains activate most of their income due to extra-regional demand. In other words, integrated production processes within national territories mainly aim at demand from countries outside the region. Furthermore, exports of intermediate goods are mainly associated with processing and consumption outside the region. On the other hand, regional chains stand out for supplying almost exclusively the regional market. This market divides its activated income approximately equally between internal and regional chains.

These last two features are relevant since they provide insight into the processes occurring in the region. Regional chains refer to those that begin and end entirely within regional borders and involve local productive factors (capital and labor) from more than one country in the region. These are chains in which the firms involved supply inputs within the region, sharing the final destination of the goods and services produced. Strengthening these chains reinforces productive integration. On the other hand, internal chains supply final goods to the regional market; they do not promote integration through fragmentation but through 'traditional' specialization. Both processes are associated with greater demand proximity, which gives the region greater autonomy concerning global macroeconomic dynamics.

Two significant conclusions can be drawn so far about the questions posed above. First,

external markets are unimportant for fostering 'target' regional productive integration.[3] However, they can be relevant for the supply of foreign exchange in return for providing inputs through global chains. It also allows understanding that the low productive integration and slight dependence are related to the restricted role in the supply of upstream inputs, which require little regional processing and foreign inputs.

Second, regional production integration is observed within the regional and internal chains, the former being mainly directed towards regional markets. This aspect provides another dimension of the greater productive integration observed in Table 2 since the main difference is in joint production through regional chains, demonstrating the strategic importance of nearby destinations. We again ask ourselves: Are there differences in the associated production structures that allow understanding these patterns? In what follows, we will deepen the analysis to determine the existence of structural differences in the specialization profiles according to the origin of the demand. For this purpose, we will use the taxonomy developed by the OECD outlined in the methodological section.

Location	Destination		Total	Shares
	Regional	Extra-regional		(location)
Domestic	23,623	122,727	146,350	32%
Regional	22,052	1,888	23,940	5%
Extra-regional	957	283,628	284,586	63%
Total	46,632	408,244	454,876	100%
Shares (destination)	10%	90%	100%	

Notes: Absolute values are expressed in millions of US dollars.

Table 3: Income decomposition by source of final demand in South America in 2018. Source: Own elaboration based on OECD-ICIO data.

Table 4 shows the differences in the specialization patterns according to the destination of final demand. First, as mentioned above, the activities with low R&D intensity are mostly non tradable, all very relevant in generating value added in the region. Therefore, this group is the most important, regardless of the origin of the demand considered, activating US$ 168,568 million, which represents 37% of the regional value added.[4]

Second, when analyzing extra-regional demand, a specialization in primary sectors and the processing of raw materials is noticeable. By looking at the column referring to extra-regional demand, the most relevant activities are Agriculture, Mining and Medium-low R&D intensity (mainly consisting of the food industry, textiles, wood and paper, and oil refining, among others, i.e., natural-resource processing). This picture emerges considering value-added exports or the normalized revealed comparative advantage index (NRCA henceforth).[5] Together, the Agriculture and Mining sectors account for more than US$ 133,048 million (30% of the value

[3]Scholvin et al. (2022) point to the existence of regional chains that are functionally interconnected to supply global markets and call them 'target,' which produce for the region and are supplied with inputs through it. These chains are the objective of an integration strategy.

[4]In what follows, we ignore this group of activities for the above-mentioned reasons in the methodology section.

[5]Note that the indicator rarely falls within the ranges established to detect advantages (from 0.33 to 1) or disadvantages (from –1 to –0.33), according to Alvarez and Durán Lima (2011, 76). However, what we are interested in investigating is the change in sign and magnitude in the face of changes in destination and sector.

added exported to the rest of the world). If we add medium-low R&D intensity activities to them, they reach US$ 216,536 million (almost 48% of the value added induced by extra-regional final demand).

Third, a different specialization pattern is observed when considering regional demand. Most activities change the sign of their NRCA index. Both Medium and High R&D intensity activities grow in comparison to extra-regional demand, but the Medium-high R&D intensity group stands out strongly. The latter includes activities that are key to enhancing a regional development process due to their technological complexity and the chains that can be developed from them, namely Machinery and equipment (capital goods), Transportation equipment (the automotive industry, which is strongly regionalized), Chemicals (inputs that are demanded by various sectors), and Electrical Equipment.

Unlike the activities that are more relevant when considering extra-regional demand, located at the extremes of the production chains, the activities that gain relevance with regional demand are located in the intermediate stages of the value chains and are more technologically complex. In addition, the firms in these sectors participate mainly in regional production chains; they obtain their inputs from other regional firms and sell their products within the region. These results align with those reported by Amar and Torchinsky Landau (2019); Banacloche et al. (2020).

A comparative analysis distinguishing regional and extra-regional trade blocs is also interesting. Disaggregation allows for detecting differences in the profiles activated by certain groups of countries, which is fundamental information for comparing the effects and designing differentiated trade policies. Regional demand breaks down into demand from Mercosur and the Pacific Alliance. Extra-regional demand is decomposed into demand from ASEAN countries plus Japan and Korea (ASEAN2), China, the European Union, NAFTA, and the rest of the world.

Table 4 shows that NAFTA countries are the region's main source of income activation. Its demand activates US$ 95,548 million (21% of the region's exported value added). The second most important trading partner for South America is China, which accounts for US$ 90,685 million (20%). Far behind, in third and fourth place, are the European Union (US$ 72,104 million; 16%) and ASEAN2 (US$ 55,989 million; 12%). Notably, a single country (China) activates almost the same income as North America and more than the European Union and the rest of East and Southeast Asia.

Excluding activities with low technological complexity, the industries activated by extra-regional blocs' demand differ greatly. East and South East Asia's demand (i.e., China and ASEAN2) activate most of the regional income in extractive industries: Agriculture and Mining. Demand from ASEAN2 is concentrated mainly in mining (US$ 18,182 million; around 32% of exported value added), whereas China demands output from agriculture and mining activities in almost equal parts (US$ 18,271 million or 20% of VAX and US$ 20,647 million or 18% of VAX, respectively). Furthermore, China also has a high demand for Medium R&D-intensive activities. This group includes activities producing Basic metals, representing one of the region's main exports to the country (Jenkins, 2011).

North America's and Europe's demand (i.e., NAFTA and the EU) activate a larger pro-

portion of income in activities with Medium-low R&D intensity. As mentioned earlier, these activities consist mainly of the first stages in processing natural resources). Moreover, these blocs also have a relatively higher demand for Medium-high R&D-intensive activities.

Considering regional blocs, there are some slight differences between Mercosur and the Pacific Alliance. The former is more relevant for activating income (US$ 26,131 million against US$ 20,501 million). Regarding the demand structure, both blocs have a stronger demand (although Mercosur's higher) in Medium and Medium-high R&D-intensive activities, as shown by the value of the NRCA index. On the other hand, both demand relatively less of Agriculture and Mining output.

Concerning Mining, the Pacific Alliance has a higher demand than Mercosur. However, it should be noted that, unlike exports to extra-regional destinations, dominated by non-energy minerals, regional demand is associated with coal, oil, and gas extractive industries. Notably, mining activities, that is, the extraction of minerals and fuel extraction industries, demand many inputs and capital goods. Such goods are produced by medium-high R&D-intensive activities; therefore, generating relevant regional chains among these industries would be possible.

Sector	Origin of demand									Total
	PA	Mercosur	**Regional**	ASEAN2	China	EU	NAFTA	RoW	**Extra-regional**	
Agriculture	1,487	1,522	**3,009**	5,488	18,271	8,836	6,954	10,711	**50,260**	53,269
Mining	2,802	1,733	**4,535**	18,182	20,647	8,743	15,795	11,878	**75,244**	79,778
Low	8,231	11,228	**19,459**	17,947	27,809	29,454	35,973	37,927	**149,109**	168,568
Medium-low	3,642	4,356	**7,997**	9,003	12,382	15,777	19,815	18,515	**75,491**	83,488
Medium	1,516	2,435	**3,950**	3,146	8,206	4,532	8,982	6,969	**31,834**	35,785
Medium-high	2,610	4,655	**7,265**	2,038	3,139	4,345	7,460	7,203	**24,185**	31,450
High	214	203	**417**	185	230	418	571	716	**2,120**	2,537
Total	20,501	26,131	**46,632**	55,989	90,685	72,104	95,548	93,918	**408,244**	454,876
					NCRA index					
Agriculture	–0.235	–0.336	**–0.289**	–0.089	0.265	0.023	–0.233	–0.013	**0.025**	
Mining	–0.124	–0.451	**–0.287**	0.299	0.130	–0.182	–0.030	–0.162	**0.025**	
Low	0.040	0.074	**0.059**	–0.072	–0.094	0.049	0.008	0.043	**–0.007**	
Medium-low	–0.016	–0.048	**–0.034**	–0.066	–0.147	0.088	0.061	0.036	**0.004**	
Medium	–0.031	0.084	**0.037**	–0.167	0.070	–0.112	0.089	–0.029	**–0.004**	
Medium-high	0.296	0.441	**0.385**	–0.310	–0.333	–0.069	0.061	0.052	**–0.077**	
High	0.303	0.164	**0.232**	–0.256	–0.374	0.020	0.034	0.155	**–0.036**	

Notes: Absolute values are expressed in millions of current US dollars. NAFTA (North America Free Trade Agreement) includes the United States, Canada, and Mexico; ASEAN2 (Association of South East Asian Nations) includes includes Brunei, Cambodia, Indonesia, Laos, Malaysia, Philippines, Singapore, Thailand, Vietnam, Japan and South Korea; EU (European Union); NRCA index: Normalized Revealed Comparative Advantages index.

Table 4: Value-added exports by industry and destination of final demand in South America in 2018. Source: Own elaboration based on OECD-ICIO data.

4.3. Differences in national patterns

Each country's situation differs concerning the relative importance of each activity group and the market to which their production is destined. Analyzing different national patterns is useful because it provides a clue as to the possibilities of complementarity that could give rise to new integration processes.

Table 5 displays the value-added exports by each country in the region according to the destination of final demand. As mentioned above, China is the second most important destination for the region; however, more than half of the value added it generates is due to exports from Brazil, which accounts for almost 24% of the income generated by exports to that country, amounting to US$ 53,588 million. When adding to this value the US$ 17,320 million that Chile activates for exports to the same destination, these two countries account for nearly 78% of the added value exported to China. It must be recalled that the region's trade with the Asian country is concentrated in primary activities.

Argentina's main source of value-added exports is the European Union, whereas Peru and mainly Colombia generate a larger proportion of income from exports to NAFTA. The main export sectors are the first transformations of raw materials extracted in the primary sector.

The main conclusion emerging from Table 5 relates to the existing differences between and within the trade blocs established in the region. On the one hand, for those countries that make up the Pacific Alliance (Chile, Colombia, and Peru), neither Mercosur nor the bloc itself represents relevant destinations from the point of view of export income generation. A priori, it can be concluded that this integration scheme seeks to become a platform for exporting natural resources to the rest of the world.

On the other hand, in Mercosur, Argentina and Brazil show an asymmetry in their dependence on the bloc to activate value added. Thus, whereas Argentina generates around 13% of its value-added exports from international commerce within Mercosur, Brazil only generates 5%. According to Bekerman and Rikap (2010), Brazil experienced a process of de-regionalization during the first decade of this century, supported mainly by higher relative growth in demand from third countries. According to the authors, this is due to the development of dynamic comparative advantages within Mercosur. This evidence helps to explain the difference in expectations and strategies these countries maintain with the bloc.

Destination final demand	Country										Total	
	ARG		BRA		CHL		COL		PER			
PA	4,961	(7.5)	9,224	(4.0)	1,654	(2.3)	2,643	(5.9)	2,018	(4.5)	20,501	(4.5)
Mercosur	8,405	(12.8)	10,415	(4.6)	3,856	(5.4)	1,998	(4.5)	1,457	(3.2)	26,131	(5.7)
Regional	**13,366**	**(20.3)**	**19,640**	**(8.6)**	**5,510**	**(7.7)**	**4,641**	**(10.4)**	**3,475**	**(7.7)**	**46,632**	**(10.3)**
ASEAN2	7,104	(10.8)	24,521	(10.7)	14,088	(19.9)	2,162	(4.8)	8,114	(18.1)	55,989	(12.3)
China	6,052	(9.2)	53,588	(23.5)	17,320	(24.4)	5,239	(11.7)	8,487	(18.9)	90,685	(19.9)
EU	12,092	(18.3)	37,796	(16.6)	8,585	(12.1)	6,930	(15.5)	6,701	(14.9)	72,104	(15.9)
NAFTA	9,002	(13.7)	45,609	(20.0)	14,735	(20.8)	16,154	(36.0)	10,047	(22.4)	95,548	(21.0)
RoW	18,287	(27.7)	47,164	(20.7)	10,659	(15.0)	9,687	(21.6)	8,122	(18.1)	93,918	(20.6)
Extra-regional	**52,536**	**(79.7)**	**208,678**	**(91.5)**	**65,388**	**(92.2)**	**40,171**	**(89.6)**	**41,471**	**(92.4)**	**408,244**	**(89.7)**
Total	65,902	(100)	228,318	(100)	70,898	(100)	44,812	(100)	44,946	(100)	454,876	(100)

Notes: Absolute values are expressed in millions of current US dollars. Percentages in parenthesis.

Table 5: Value-added exports by country and destination of final demand in 2018. Source: Own elaboration based on OECD-ICIO data.

Figure 1 depicts the distribution of value-added exported by activity in South American countries. As can be seen, all countries in the region have a higher proportion of value-added exports in primary extractive industries when considering extra-regional demand. In the case of Argentina and Brazil, this is observed mainly in Agriculture, whereas Chile, Colombia and Peru are more dependent on Mining. In Chile and Peru, the most relevant sub-sector is non-energy mining (i.e., minerals); in Colombia, it is energy mining (i.e., hydrocarbons).

Furthermore, Argentina and Brazil's dependence on agriculture is lower than that of Chile and, above all, Colombia and Peru on mining. Therefore, in these countries, the importance of the extractive mining demand and the extra-regional destination adds additional complexity to the lack of common aspects among the South American countries.[6]

Medium-low R&D intensive industries, generally linked to the processing of natural resources, play a major role in generating income in all countries. However, the destination of this production differs according to the country considered. Once again, in Argentina and Brazil, extra-regional demand is more significant for this type of goods. In contrast, Chile, Colombia and Peru depend more on the regional market. It should be noted that in all cases, the differences are negligible. One possible interpretation of these differences is linked to the fact that the processing of agricultural products in Argentina and Brazil leads to food exports, a market in which they have competitive advantages. Instead, the extraction of certain mining products, such as oil, has limited possibilities for upgrading for many reasons, e.g., higher costs of refining plants due to lower capacity and scale.

Within the Medium R&D intensity goods and services, the case of Chile stands out since both regional and extra-regional demand activate a large proportion of the total value added exported, in the order of 15% and 19%, respectively. Within this sector are sub-sectors such as Basic Metals and Other Non-metallic Minerals, both manufacturing sectors that carry out the first transformations of minerals. Such strong concentration in the first stages may be one of the reasons behind its lower productive integration with other regional countries. This case is an exception because China's incipient smelting and refining process, mainly in copper and aluminum, has not yet managed to displace Chile completely (Ericsson and Hodge, 2012). On the other hand, except in Chile and Colombia, these manufacturing sectors are mainly oriented to supply regional demand. This is in line with case studies highlighting regional chains that start with iron ore in Brazil and continue in Argentina with the smelting and manufacture of steel tubes (Amar and García Díaz, 2018).

In all countries, without exception, goods and services whose R&D intensity is Medium-high show a marked increase in their preponderance when considering regional demand. These are mostly intermediate goods and services, such as information technology, which are widely used throughout the industrial complex and have the potential to generate chains with other productive sectors, both upstream and downstream. For example, the automotive industry, widely referred to as a "producer-driven" chain (Gereffi, 2009), with a great capacity to coordinate

[6] Another aspect worth noting, although not shown in the figure, is that domestic chains dominate the production of agricultural goods. In contrast, extra-regional chains prevail in the mining industry, especially in the non-energy sector. This is due to the close relationship between the type of extractive sector and the chains they promote. In the case of mining, the good is sold almost exclusively as input.

production networks that include thousands of firms and obtain gains from technological and organizational rents, boasts a regional exported value added between Argentina and Brazil alone amounting to US$ 3.4 billion for 2018. Another industry with a strong potential to become a vector of regional integration is the chemical industry, which has value-added exports to the region for a total of US$ 1.6 billion.

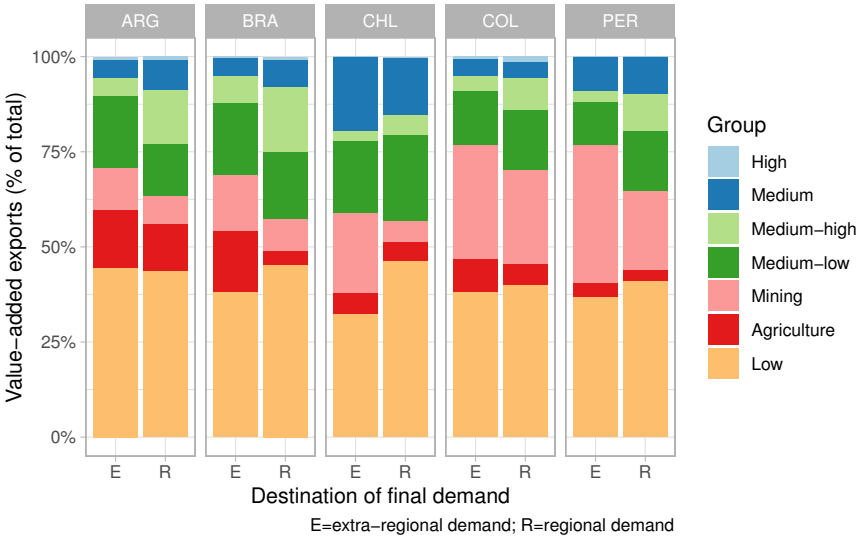

Figure 1: Distribution of exported value added by destination of final demand. Source: Own elaboration based on OECD-ICIO data.

4.4. An assessment of the effects of deepening regionalization

As a final exercise, we propose a simulation to assess the potential consequences of deepening the regionalization process. For this purpose, we resort to the hypothetical extraction method from a global perspective (Dietzenbacher et al., 2019; Giammetti et al., 2022). The simulation assumes that South American firms substitute foreign inputs for regional inputs. For example, suppose the Brazilian automotive sector requires steel as an input, of which 35% comes from Argentina, 20% from Chile, 10% from Colombia and Peru, and the remainder from outside the region (35%). Suppose Brazil no longer purchases extra-regional steel. In that case, we assume that purchases to regional peers increase by the same percentage and add up to 100% again (in this example, by 53.8%). This procedure creates a new global intermediate input coefficients matrix whose column sum equals the original.

We assess two scenarios: first, a 25% substitution of extra-regional imports and second, the complete substitution of extra-regional imports. Table 6 shows the relative gains in activated value added.

As the table shows, the regionalization process is beneficial for all. However, the distribution of the gains is not balanced among countries, which may translate into a stumbling block to promoting the productive integration of the region at the political level. For example, in Mercosur, a 25% substitution rate is enough for Argentina to increase value-added exports equivalent to 4.1 p.p. of its GDP, indicating that the process can greatly generate income through regional chains. For Brazil, greater integration only means an improvement equivalent

to 0.7 p.p. of its GDP, which contrasts sharply with the importance mentioned for Argentina and implies a difficulty in facing joint productive policies. On the other hand, improvements are more balanced among the members of the Pacific Alliance. On average, the increase in value-added exports is equivalent to 2.8 p.p. of their GDP. Among them, Chile stands out with an improvement equivalent to 3.4 p.p., whereas Peru and Colombia show an equal increase of 2.6 p.p. of GDP. In fact, within this trade bloc, there are more similarities in the economic effects, which can induce its members to deepen integration.

Another point to highlight is the distribution of the gains by groups of activities. In this case, a similar outcome is observed between the two blocs. In Mercosur and the Pacific Alliance, the industries that gain the most after the activities with low technological complexity are those with Medium-low and Medium-high R&D intensity. This outcome implies a certain density in the integration that would take, in which the regionalization of chains requires logistics and the production of manufactured products such as Food, Oil Refining, and Transport Equipment.

The scenario of complete substitution may be considered an extreme case that delimits the potential income effects of deepening regional integration, given the current productive structure. In this case, the gains in value-added exports amount to a total of 8 p.p. of the regional GDP. Such a gain should be interpreted as the maximum income increase resulting from an effective regional import substitution policy. However, it should be noted that this figure may be an overestimation, since it does not considers capacity limits and other resource constraints.

	ARG	BRA	CHL	COL	PER	Total
Value-added exports (% of GDP)						
Agriculture	2.0	2.0	1.5	1.2	0.8	1.8
Mining	1.4	1.8	4.9	4.0	7.4	2.6
Low	6.0	4.8	8.4	5.4	7.9	5.6
Medium-low	2.7	2.6	4.8	2.2	2.5	2.8
Medium	0.7	0.7	4.7	0.7	2.0	1.2
Medium-high	1.0	1.2	0.7	0.6	0.8	1.0
High	0.1	0.1	0.1	0.1	0.0	0.1
Total	14.0	13.2	25.2	14.1	21.4	15.1
Regional import substitution 25% (p.p. of GDP)						
Agriculture	0.4	0.0	0.1	0.1	0.0	0.0
Mining	0.3	0.0	0.2	0.6	0.6	0.6
Low	1.8	0.3	1.5	1.0	1.0	1.0
Medium-low	0.6	0.1	0.7	0.4	0.4	0.4
Medium	0.3	0.1	0.7	0.1	0.3	0.3
Medium-high	0.6	0.1	0.2	0.3	0.3	0.3
High	0.1	0.0	0.0	0.0	0.0	0.0
Total	4.1	0.7	3.4	2.5	2.6	2.6
Complete regional import substitution (p.p. of GDP)						
Total	17.6	3.2	14.7	11.1	11.6	8.0

Table 6: Effects of a deepening of the regionalization process. Source: Own elaboration based on OECD-ICIO data.

5. Concluding remarks

South American countries have not substantially altered their historical insertion to global markets during the process of production fragmentation. Our empirical analysis confirms that extra-regional final demand is the main source of the region's value-added exports. Value added is activated mainly through internal and extra-regional chains; the most dynamic productive sectors are those at the extremes of the value chains. In other words, South American countries specialize in the provision of agricultural and mining raw materials for productive processes located outside the region and whose final production is also consumed outside the region. Other important industries are those with medium-low technological complexity, generally dominated by sectors that carry out the first transformations of natural resources (such as food, textiles, furniture, and oil refining). The main destination for raw materials is East and Southeast Asia. In turn, NAFTA (the region's main buyer – directly and indirectly –) and the European Union activate greater value added in activities with medium-low R&D intensity.

On the other hand, intra-regional trade has different characteristics. Domestic and regional chains that destine their production for regional consumption involve more technologically complex sectors, mainly in the manufacturing area. Exports to Mercosur activate the most value added in these sectors. Industries with Medium R&D intensity stand out, consisting of Rubber and Plastics, Basic metals and Other Non-Metallic Minerals, as well as those of Medium-high intensity, among which are the Automotive industry, Machinery and Equipment, Chemical Products, Electrical Equipment and Computer Services.

These activities have many characteristics that allow us to conclude that they can potentially become vectors for deepening regional integration. First, they are located in the intermediate stages of value chains, meaning they have great potential for generating backward and forward chains. In other words, their production pulls in other productive sectors; in turn, the goods they produce are demanded by numerous industries. For example, the Argentine agricultural-oriented Machinery industry may demand intermediate inputs from the Chilean Basic Metals activities and be demanded by the Agricultural activity, whose production is exported to the rest of the world. This type of chain structure can be replicated in numerous regional activities.

However, strategies for constructing this type of chain require common objectives and coordination in the execution of regional public policies. As described above, national patterns and the incentives they generate to undertake a productive integration strategy differ substantially. The members of the Pacific Alliance would prefer to develop a platform for exporting to extra-regional markets and low levels of regional integration of production. Within Mercosur, there is a marked asymmetry of the bloc's relevance for each member. Whereas Argentina depends substantially on exports to Mercosur for the activation of value added, Brazil does not do so to a great extent.

We have detailed numerous elements throughout our work that allow considering that it makes sense to deepen regional integration among South American countries in order to foster sustained growth in the region and break the dependence on the cycle of international commodity prices. To this end, it is essential to promote industrial policies that encourage more regionally integrated sectors that require highly qualified labor and generate greater value added.

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Highlights:

1. South American countries continue to specialize mainly in providing agricultural and mining raw for production processes outside the region
2. Extra-regional demand activates 90% of the region's value-added exports
3. Regional productive integration is comparatively low, yet it involves more technologically complex activities
4. Medium R&D-intensive sectors have the potential to become vectors for deepening regional integration
5. The gains from deepening integration are not balanced among member countries
6. Countries in the region may not share the common objective of pursuing productive integration

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Authors' contributions

All authors whose names appear on the submission

- made substantial contributions to the conception or design of the work;
- drafted the work or revised it critically for important intellectual content;
- approved the version to be published; and
- agree to be accountable for all aspects of the work in ensuring that questions related to the accuracy or integrity of any part of the work are appropriately investigated and resolved.