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The open veins of Latin America: Long-term physical trade flows (1900–2016)

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A B S T R A C T

Latin America has long played a key role in the global provision of natural resources. Most of the continent's economies are net exporters of low-value, primary products and importers of manufactured goods at a high price. This pattern of specialised trade has highly negative consequences for economic development, the environment, and the local population's wellbeing. Yet to date, little empirical evidence has been collected on Latin America's total contribution to the rest of the world's regions in historical perspective. Applying the Material Flow Accounting methodology, this paper estimates the physical and monetary trade of 16 Latin American economies between 1900 and 2016. Our results show that: (i) yearly net exports of materials went from 4 Mt to 610 Mt between 1900 and 2016, and greatly accelerated since the World War II. (ii) Latin America is a net exporter of most types of materials (fossil fuels, non-energy minerals and biomass), so it harbours socio-environmental problems associated with different types of extractivism. (iii) Different regional export patterns exist: Andeans export subsoil (mining and energy carriers) while the rest export soil (land-based products). The countries with the lowest net exports are the smallest in size and with the highest population density. (iv) Europe and the USA have historically received most of the imports, but since the end of the twentieth century, the Southeast Asia region is the biggest importer of materials from Latin America. (v) The price received for exported material is much lower than the price paid for imported material; and (vi) various historical periods can be differentiated regarding the relationship between economic growth and physical trade balance.

1. Introduction

Latin America has long played a key role in the global supply of natural resources (Wallerstein, 1974; Topik et al., 2006). Despite the existence of historical and geographical differences, most of the region's economies have been net exporters of low-added-value primary products and have tended to import manufactured goods with higher prices (Russi et al., 2008; Williamson, 2011; West and Schandl, 2013). The debate as to the nature and impact of Latin America's insertion in world trade is ongoing (e.g.,; Topik et al., 2006; Ducoing and Peres-Cajías, 2021). But many voices across various disciplines suggest that these countries' commercial specialisation pattern has had negative consequences for economic development, the environment, and for the well-being of the region's inhabitants as a whole (Hornborg, 2012; Prebisch, 1981; Ross, 1999; Sachs and Warner, 2001; Williamson, 2011).

Despite the great progress made in Economic History and Environmental History, no work has hitherto offered an overview of the role of Latin America in the long-term global supply of resources. In the past few years, significant advances have been made regarding the quantification of the total resources extracted, traded and used in Latin America, especially based on the Material Flow Accounting (MFA) methodology (Fischer-Kowalski et al., 2011). There are plenty of monographic analyses of Latin America per region (West and Schandl,

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2013; Gak et al., 2017) or per groups of countries (Russi et al., 2008; Dorninger and Eisenmenger, 2016; Samaniego et al., 2017; Crespo-Marín and Pérez Rincón, 2019) as well as specific national studies such as those on Colombia (Pérez-Rincón, 2006; Vallejo et al., 2011), Chile (Giljum, 2004), Ecuador (Vallejo, 2010), Argentina (Pengue, 2010; Manrique et al., 2013; Díaz de Astarloa et al., 2018) and Mexico (González Martínez and Schandl, 2008). In the same way, global studies can be found in which Latin America is addressed as a territorial entity (e.g., Schandl and Eisenmenger, 2006; Schaffartzik et al., 2014).

The main contributions of this literature can be summarised as follows:

1) Globally, the region of Latin America (along with Central Asia) is the highest net exporter of materials per inhabitant in the world, exceeding one ton per inhabitant per year (Schaffartzik et al., 2014).
2) Among the net export regions, Latin America's export profile is much more diversified and, consequently, the region is subject to a much wider range of environmental impacts (West and Schandl, 2013; Schaffartzik et al., 2014).
3) Since the 1970s, Latin America's material extraction growth has largely surpassed the global average, so the region is playing an ever-larger part in the world's appropriation of resources (Krausmann et al., 2009; West and Schandl, 2013).
4) Despite substantial regional differences and historical shifts in trends, most Latin American economies import at a higher price per unit of weight than they export. Furthermore, their material depletion does not always generate positive economic returns (Hall et al., 2000; Fischer-Kowalski and Amann, 2001; Pérez-Rincón, 2006; Russi et al., 2008).

This literature, however, still presents some limitations. First, the time frame is narrow. At best, information has been provided since 1970 (West and Schandl. 2013; WU Vienna, 2022). The 'veins' of Latin America have been open for much longer.

Second, studies on Latin American material trade do not differentiate bilateral flows, with a few exceptions (e.g., Ricaurte Greene, 2012). In other words, although Latin America's material contribution is assumed to feed the most developed countries, there is actually no evidence to corroborate this hypothesis at an aggregate level.

Third, most studies that follow the MFA methodology effectively document a country's material depletion using its physical trade balances. Rarely, however, do they advance analyses relating physical trade to monetary trade. This makes it difficult to verify the assertion that the continent exports materials at a lower price, or with lower added value, than their imports. There is a long-standing tradition in economics to study exchange relations between countries. In the case of Latin America, this debate – a major one – has revolved around deterioration of the terms of trade and price volatility (Cardoso, 1977; Hadass and Williamson, 2003; Blattman et al., 2007; Ocampo, 2017; Ocampo and Parra, 2010; Williamson, 2008; Williamson, 2011). Nevertheless, international trade analyses that are exclusively monetary in nature fail to address the environmental dimension of trade relations.

The aim of this paper is to shed light on the three issues described above. To this end, following the MFA methodology, we present fresh data on physical and monetary trade balances of a large sample of Latin American countries (a total of 16) between 1900 and 2016. The resulting database will answer the following research questions:

i) How much has Latin America contributed to the material construction of the modern world in the twentieth century?
ii) What patterns of extractive and commercial specialisation exist in the different countries in the region?
iii) What are the material intensity of trade products, how have they evolved over time, and between which trading partners?
iv) How has the relationship between economic growth and material depletion evolved?

2. Methodological notes

2.1. Material flow accounting

Material Flow Accounting (MFA) is an internationally harmonised methodological tool dating back to the late 1990s that has been adopted by the world's leading statistical agencies. It was designed to fill the gaps of classical national accounts regarding the pressures on the environment brought about by economic growth (Fischer-Kowalski et al., 2011). Despite its recognised limitations (Giampietro, 2006), it constitutes a useful and didactic tool to monitor, in biophysical terms, the productive profile, commercial specialisation and consumption levels of national economies (Haberl et al., 2019).

The framework quantifies 'Domestic Extraction' (DE), which corresponds to the amount of material resources that are extracted within the political-territorial unit analysed, typically a country or a world region, and can be used as a proxy for preassure on domestic environment (Steinmann et al., 2017). The difference between imported materials and exported materials is called 'Physical Trade Balance' (PTB), which is a proxy for the outsourcing of impacts to third countries (Giljum and Eisenmenger, 2004): a positive PTB indicates that an economy imports more material goods than it exports, making it a net resource demander, and vice versa. Finally, 'Domestic Material Consumption' (DMC) is defined as the DE plus imports and minus exports of materials, that is, the DE minus the PTB. The DMC reflects the apparent material consumption of the inhabitants in the territory under study, regardless of where the materials are extracted.

2.2. Boundaries of the study

This work focuses exclusively on trade indicators. Specifically, the amount of imports, exports and material balance (PTB) were quantified for a total of 16 Latin American economies for which it was possible to compile reliable long-term information.

Following the MFA methodology, the material flows analysed were disaggregated on Biomass, Fossil Fuels, Metallic Minerals and Non-Metallic Minerals (Eurostat, 2018). In the case of products with mixed materials, we considered them composed by the main material as suggested by Eurostat (2018). Thus, the PTB of each country (i) was estimated as the imports (M) minus the exports (X) of each product group (j):

$$PTB_i = \sum_j M_j - X_j$$

It was possible to reconstruct each country's bilateral trade relations between 1966 and 2016 by distinguishing a total of 268 partners across 6 regions. In addition, we aggregated the countries into 5 regions within Latin America (see Tables 1 and 2 of the Supplementary Material (SM)).

We also estimate monetary trade balances at current prices. With this information, we analyse how the price of imports and the price of exports per material unit have evolved. The ratio (RI) between these two indicators allows the analysis of the evolution of the exchange relations in the way proposed in other works in Ecological Economics (Pérez-Rincón, 2006; Samaniego et al., 2017). Such a relationship can be expressed as follows:

$$RI_i = \frac{m_i}{x_i}$$

where $m_i = \frac{\sum_j M_j^{\$}}{\sum_j M_j^{kg}}$ is the monetary value per unit of total physical imports, and $x_i = \frac{\sum_j X_j^{\$}}{\sum_j X_j^{kg}}$ the monetary value per unit of total physical exports (measured in US\$/kg in both cases, as indicated by superscripts \$ and kg). If RI_i is greater than one, then the price per ton of imports in country i is higher than the price per ton of exports. According to an economic-ecological reading of this indicator, to maintain a trade balance equilibrium in monetary terms requires to sell a greater amount of materials than the amount corresponding to the imports, and, therefore, to materially deplete the country or region studied.

As global value chains have expanded in recent years, direct bilateral relations do not always properly inform of the total amount of the incorporated upstream materials of trade products (Weinzettel and Kovanda,2009; Schoer et al. 2012), or the actual country of origin of the extractions when these occur beyond the direct trade partner (Muñoz et al. 2009). However, Multi-Regional Input-Output (MRIO) models can be employed to overcome this limitation (Wiedmann et al. 2015, Giljum et al. 2015). First, estimating a trade balance considering the upstream raw material requirements of trade, that is, estimating the so-called 'Raw Material Equivalents' (RME) of imports and exports. Second, connecting each import's true origin with the final destination of each exported final product, or in other words, adopting a fully consumer footprint perspective. When trade of raw materials is accounted under such principles is often called physical Trade Balance in RME (RTB). The main shortcoming of this approach is that there are estimates for recent years only, and therefore we only used here the RTB of the Latin American countries in 2016, collected from the GLORIA global environmentally-extended MRIO database (Lenzen et al. 2022) constructed in the Global MRIO Lab (Lenzen et al. 2017), to examine the difference in comparison to the direct and bilateral PTB.[5] While absolute figures of both balances are not directly comparable, a comparison of shares of total materials flowing in and out of Latin America according to both logics can provide indicators of how much extractions end up satisfying consumption beyond the direct trade partner.

Since this work's main contribution is its very long-term approach, we test for structural breaks in the time series aiming to identify the major turning points. To deal with the non-stationary feature of the time series, we fit a trend-lineal model:

$$Y_t = X_t$$

In this model, Y is the time series involved, subindex t denotes time, and the independent variable, X, is a time index into the regression model (Nau, 2020). Optimal partition is selected on the base of the Bayesian information criterion (BIC) and the residual sum of squares (RSS) is implemented in *strucchange* R package (Zeileis et al., 2002). See SM section 3 for details on the breakpoints for the trade balances by country and materials.

2.3. Data sources and calculation procedure

Different sources were combined to reconstruct the physical and monetary trade of the selected Latin American economies over such a long period of time (see Table 3 of the SM for a summary of each country). The information between 1962 and 2016 was extracted from the United Nations Comtrade Database (UNCT). The UNCT is the only global database to provide the bilateral trade information of most countries in the world in both physical and monetary units until the present. Using the UNCT, however, is somewhat problematic. In some countries, the historical series are not complete, and information is not always given in physical units for all products (Dittrich and Bringezu, 2010). We selected 16 economies for which the coverage was almost complete, whereas countries presenting more limited information, both in quantity and quality, were discarded. Information for each year existed for 10 of the economies studied, including the largest (Brazil and Argentina). In the remaining 6 economies, the gaps exceeded 3 years (out of a total of 54 years), except in the case of Uruguay, for which information was lacking for 8 years. We estimated the missing data as follows: (1) if the gap was a loose year in the middle of the historical series, we used linear interpolation; (2) if the non-available information corresponded to several years at the beginning or end of the series, it was estimated based on the variation of other variables. In the case of the series in monetary units, we used each country's imports and exports variations collected in the World Trade Organisation's database (WTO, 2019). In the case of physical trade, we used the index of 'volume of exports' and 'imports' available in the MOxLAD database (2019) for each country under study. Finally, in the case of products for which information was not recorded in physical units but in monetary units, we calculated the value per physical unit (US$/kg) of each product of the countries for which the information was available. The regional average of the price per kilogram was then applied to the monetary data.

UNCT offers several levels of disaggregation when downloading the data. In this study, the SICT-1 system with '3 digits' was used, since it is the only one that makes it possible to obtain information between 1962 and 2016 via a single download, allowing a disaggregation of 182 export and import products.

For the 1900–1961 period, the information was scattered across different national and international sources. Only physical trade was estimated for this period. First, we estimated total physical trade drawing on The League of Nations' data (League of Nations, 1926/44), which provides information on total physical trade for the years 1913 and from 1920 to 1934 for all countries except Uruguay. The remaining data were supplemented with information from each country's trade statistics (Table 3 in the SM). When this was not possible, the MOxLAD 'volume index' (2019) was used to interpolate and extrapolate values. To distinguish the different types of materials we used the series of the International Institute of Agriculture (IIA), 1909; FAO, 1948-1961, the Mitchell's historical statistics (2013), and national trade statistics. When no information could be obtained, we used the nearest year's ratio. Finally, to limit the impact of *outliers* and to smoothen the trend, the series were estimated based on five-year moving medians.

3. Results and discussion

3.1. Latin America's contribution to the global bio-physical economy

Fig. 1 shows Latin America's PTB between 1900 and 2016. First, it is worthy of note throughout the period under study that Latin America was a net supplier of materials to the rest of the world, that is, its exports are always greater than its imports. Second, the levels of material deficit observed have grown relentlessly until today. Net supply is now greater than ever. In 1900, net exports were 4 million metric tons (Mt), and in 2016 they amounted to 610 Mt (Fig. 1a). Growth, however, has not been linear, which leads us to the third observation: the Great Acceleration in the trade of Latin American materials, both in imports and exports, took place after the World War II (WWII) (Fig. 1b). According to the break dates (SM section 3 table 4), the trade balance increased to 7.5 % of the average annual rates during 1947–63, almost twice as much as during the first half of the century (1900–46). However, although still in the context of the Great Acceleration in global resources consumption, growth declined to 0.3 % between 1964 and 1980 due to 'import substitution' policies developed in most Latin American countries (Cárdenas et al., 2000).

After the external debt crisis and the neoliberal turn of the 1980s, state-led growth policies were abandoned throughout most of the continent. Measures of deregulation and openness to international trade were put into practice – or were imposed by the adjustment plans of the international financial institutions (IMF, World Bank and others) – and led to an acceleration in the growth of global exports (Hall et al., 2000; Bértola and Ocampo, 2013). The physical trade returned to high annual rates during the mid-1970 s and early 1980s in Argentina (21,8%), Mexico (13,8%) and Brazil (12,4%), and it was also the case for Costa Rica (13,1%), Colombia (7,5%), and Paraguay (6,5%), among others, during the following decades (see table 9 of the SM for details). At the regional level, the rates of physical trade growth were smaller than during the mid-century Great Acceleration, and similar to the one

[5] Extracted through the portal https://scp-hat.lifecycleinitiative.org/.

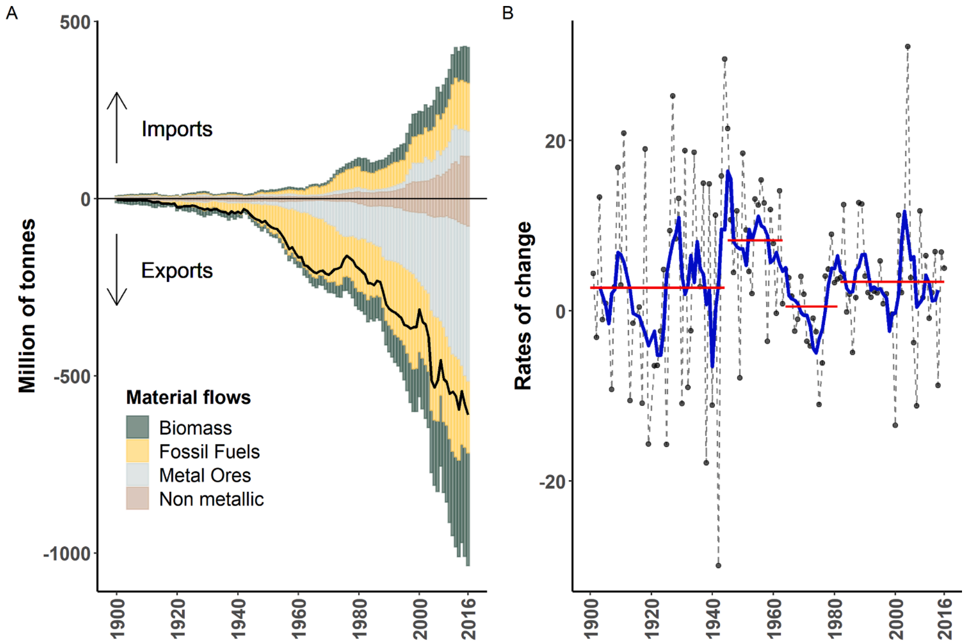

Fig. 1. A) Physical trade balance (PTB) of Latin America and B) annual rates of change for the balance (1900–2016). Note: A) Imports are the positive value bars and exports are the negative value bars. The black line is the balance. B) The black dotted line are the annual rates of change; the straight blue line is the five-years moving average of the rates and the flat red lines correspond to the average of the break date periods (see SM table 4 and 9). (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

reported during the first half of the 20th Century (3.5 % between 1981 and 2016). However, during this period the pace of growth was less volatile, which ensured a treefold increase in the total exports and the net exports, from 316 Mt to 1035 Mt and 204 Mt up to 610 Mt, between 1980 and 2016 respectively. Thus, although at a slower pace, during this second phase of the Great Acceleration, Latin America have experienced a never seen level of physical trade to supply the material needs of the rest of the world.

Between 1980 and 2016, Latin American exports accounted for nearly 10 % of total global exports. This figure is higher in the case of metal mining. During most of the 1980s and 1990s, one in three tons exported in the world came from Latin America. In the case of biomass, the figure exceeds the average and has grown in recent years: today, the region accounts for one in five exported tons. In other words, Latin America played a central role in the second phase of the Great Acceleration and, consequently, in the drastic upsurge in the global use of resources experienced since the year 2000. Exports in 2015 and 2016 may even have surpassed those that took place over three centuries of colonialism.[6]

Fourthly, we observe that commercial specialisation has undergone shifts throughout history (see SM section 2). At the beginning of the twentieth century, biomass, that is, agricultural, livestock and forestry products, were the main export goods. As the twentieth century progressed, fossil fuels became, by far, the main exported material. In 1952, they accounted for three-quarters of all exported materials, but as from that moment onwards, their weight fell significantly for two reasons: first, the drop in exports due to the emergence of new production areas such as the Middle East; and second, because of the rapid expansion of metal mining. At the turn of the twenty-first century, not only were metallic mineral exports consolidated, mainly from Brazil, Chile and Peru, but so was biomass from Brazil and Argentina (Figs. 1–5 in the SM). Today, biomass accounts for 30 % of the region's total exports and already exceeds fossil fuels in weight.

We can observe that the region is a net exporter of all types of materials except non-metallic minerals which generates multiple environmental issues and conflicts in the subcontinent (EJOLT, 2019; Scheidel et al., 2020). In the case of fossil fuels, there is a combination of problems associated with the development of institutions not so functional to foreign trade openness and related power struggles for the profits in Venezuela, Mexico or Bolivia (Ross, 2013; Wenar, 2015). Meanwhile, areas of great ecological value are being destroyed, such as in the case of Yasunni ITT in Ecuador (Larrea and Warnars, 2009). Large-scale mining also leads to the alteration of high-value ecosystems, e.g., in the mining areas of Brazil, Chile or Peru. The main consequence is the large-scale contamination of soils and water (Malm et al., 1990; Castro and Sanchez, 2003; Li, 2015). The biomass trade boom, for its part, has come with drastic deforestation in some of the most carbon-dense and biodiverse forests in the world, such as those of Central America and the Amazon (e.g., Houghton, Lefkowitz and Skole, 1991; Malhi et al., 2008). The intensive nature of export agriculture in Latin America leads to a significant contamination of natural resources and human poisoning (Pengue, 2015). Costa Rica for example, is known for its forceful environmental protection measures. Yet Costa Rica ranks first in the world in the use of pesticides per cultivated area because of its agro-export specialisation in intensively managed crops (based on FAOSTAT data, see also Hall et al., 2000; Galt, 2008; Montero et al., 2021).

3.2. Regional patterns of specialisation

In line with the 'open veins' metaphor, the haemorrhage of natural resources presents a very different picture in each Latin American country, but the dramatic acceleration since the 1980s is a common feature. In 2016 Brazil was the major exporter of materials (644 Mt), followed by Mexico (141 Mt), Colombia (129 Mt), Venezuela (111 Mt) and Argentina (101 Mt) (Fig. 2). In per capita terms, the cumulative net imports (1900–2016) presents a slightly different picture (Fig. 3). The export of fossil fuels from Venezuela makes the country the larger exporter of the region with a negative balance of 6.7 tons per inhabitant per year (t cap-1 year^{-1}). Far away, but with a similar profile, Ecuador (-0.87 t cap-1 year^{-1}) and Colombia (-0.82 t cap-1 year^{-1}) stand up, while biomass and metal ores remain the main materials in Argentina and Brazil.

Venezuela's net exports per capita stand out due to the weight of fossil fuels. Fossil fuels are the material with the most weight in international trade (although they are not the most consumed) because their extraction is concentrated in a few countries, while their consumption is

[6] Assuming, based on a highly simplistic though cautious exercise, that exports prior to 1900 did not exceed the 1900 level.

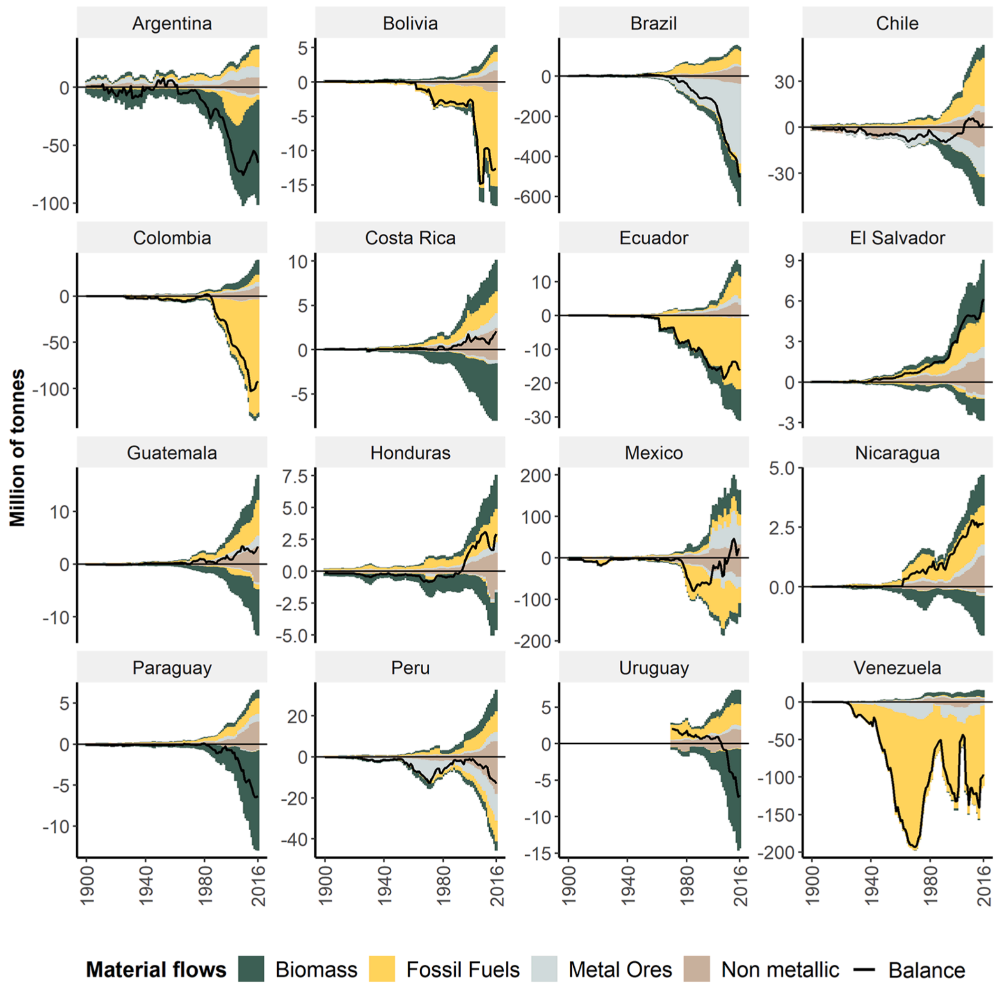

Fig. 2. Physical trade at the national level by type of material and the balance (1900–2016). Note: Imports are the positive value bars and exports are the negative value bars. The black line is the balance. We removed the information on Uruguay between 1900 and 1970 because of non-reliable estimates (see Figs. 7 and 8 in the SM for net imports and per capita numbers, respectively).

widespread throughout the world. Consequently, the main exporters of materials in the world (in per capita terms) are the oil producing countries. Qatar, Kuwait, Brunei and United Arab Emirates, are the leading material exporters worldwide since 1970 (WU Vienna, 2022). In Colombia, Bolivia, Mexico and Ecuador, fossil fuels are the most exported material, but none of them reaches the levels of Venezuela. This specialization is likely to generate political and social problems due to competing societal aims within the country and international pressures for the management of a strategic resource (Ross, 2013).

However, not all the economies analysed are net exporters. A total of 5 economies (those of Central America) present positive balances in absolute and cumulative per capita terms. Among them, El Salvador is the most dependent economy, with net imports of 0.4 t cap-1 year^{-1} over the period studied. In addition, this country is the only net importer of all kinds of materials. The other Central American countries are also net importers, but *only* of minerals and fossil fuels. The remaining economies are net exporters with negative balances ranging from −0.03 t cap-1 year^{-1} in Uruguay up to −0.5 t cap-1 year^{-1} in Bolivia. Thus, the material specialisation pattern of trade within the region varies widely.

The matrix in Fig. 4 shows the type of commercial specialisation of all countries. Specifically, the levels of imports or exports of products extracted from the fertile soil's surface mantle (biomass) are compared to the products extracted from the subsoil (minerals and fossil fuels). In this figure, values above the unit indicate an export profile and values below point to an import profile. Thus, according to each specialization, we identify-three groups: agrarian exporters, mineral exporters, and total exporters.

First, among agrarian exporters, we find countries from Central America and the Southern Cone (Fig. 4). Although all of them hold a long-term specialisation in agrarian products (Bértola and Ocampo, 2013), Central American countries export biomass products which are more intensive in labour and in industrial inputs (Galt, 2008; Montero et al., 2021), while the traditional Cone Sur countries specialisation has been in grains and livestock products extensively grown due to the relative abundance of the land factor over labour (O'Rourke and Williamson, 1999). As a common trait, these countries are importers of subsoil materials like fossil fuels, metal ores, and non-metallic minerals (see Figs. 3–5 in the SM).

Second, the mineral exporters' group comprises Perú, Venezuela, Colombia, and Mexico, but there are some differences according to their different natural resource endowments (Hinojosa, 2011). While Peru is an exporter of metal ores, the remaining countries are specialized in fossil fuels. Despite that, all of them are importers of biomass, which is related to the deterioration of its food self-sufficiency and the increasing imports of cereals since the 1980s (Falconi et al., 2017; Urrego-Mesa, 2021 and Fig. 2 in SM).

Third, the total exporters. Although Bolivia, Ecuador, Chile, and Brazil are exporters of soil and subsoil, the pattern of specialization among this group is more heterogeneous. Bolivia and Ecuador are exporters of fossil fuels, while Brazil and Chile remain the first and the second major exporters of metal ores in the region. Currently, in the Chilean case, the large dependence on fossil fuels offsets the exporter

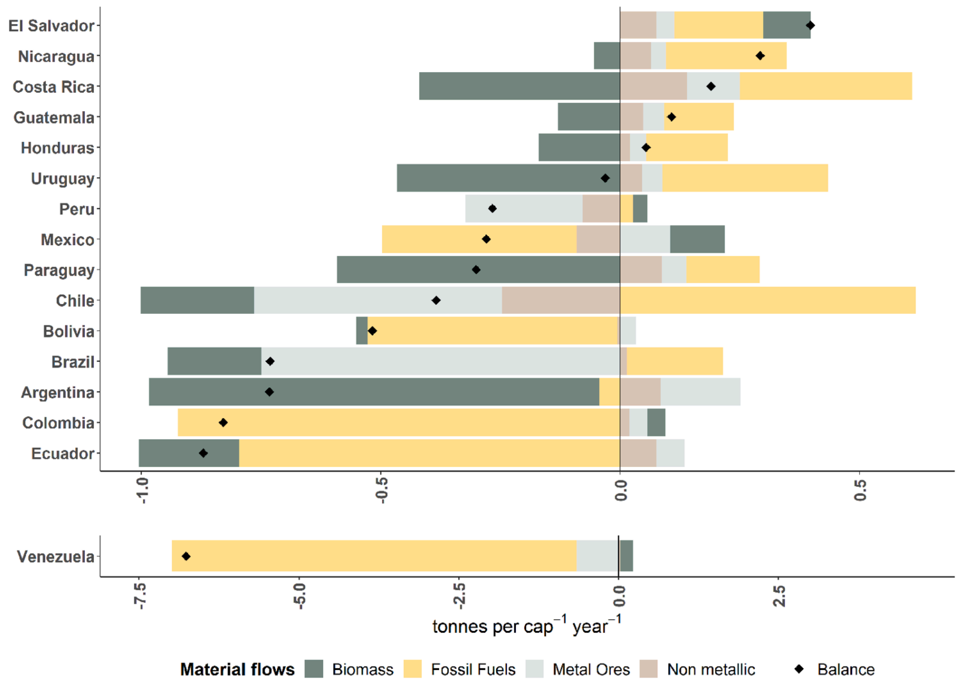

Fig. 3. Cummulative trade balance (imports minus exports) in tonnes per capita (per cap). Data for the 1900–2016 period (estimated as the sum of annual population and annual balance in each country). Note: Data for Uruguay only covers the period 1970–2016.

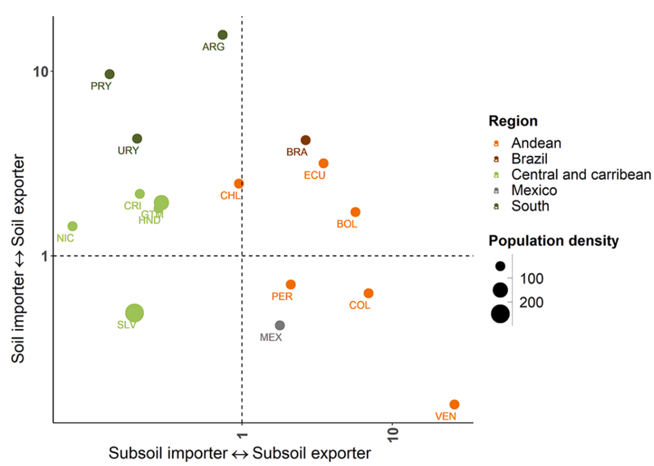

Fig. 4. Export profile of Latin American countries. Data for the 1900–2016 period. The axes measure exports divided by imports. Note: Values above 1 indicate an export profile. Less than one corresponds to an import profile. Soil includes biomass and subsoil includes the rest of the materials.

profile of subsoil, but historically this has not been the case (see Fig. 9 in SM). Worthy of note among this group is Brazil, a country that not only leads the metal exports but also accounts for 60 % of total exports of materials from the region. Eventually, like the agrarian exporters, the total exporters are also specialized in biomass, but mainly since the 1980s (McKay et al., 2021 and Fig. 2 in SM). In historical perspective, these trade patterns have remained stable with the exception of Brazil, which until 1970 was an exporter of subsoil, and Mexico, which until 1970 was a net exporter of both soil and subsoil. The rest of the countries and regions do not show significant changes throughout the entire period studied (see Fig. 9 in SM).

3.3. Global actors

A lesser-known aspect of the material trade is the bilateral relations between countries. Fig. 5 shows the destination of exports and the origin of imports from Latin America as a region in net terms. Europe and North America accounted for almost three-quarters of Latin America's exports by the turn of the 21st century. The flow of resources out of the region is mainly destined to a small group of countries of the Global North, which concentrates less than 10 % of the world population, but accounts for almost half of global GDP (World Bank, 2022). The weight of this group of countries reflects how the hegemonic powers have reigned over the subcontinent for centuries: first, under formal colonial rule and then under informal colonial domination (Ferguson, 2005; Pérez Brignoli, 2018). Independence processes have not given rise to full autonomy. During the so-called First Globalisation (c. 1870–1914), the region was dominated by "an informal empire based on free trade, control of shipping routes, the export of capital and a powerful ideology of superiority" (translation from Pérez Brignoli, 2018). During the interwar period, and after the Second World War, Latin American trade was again conditioned by the United States (US) interference, which, as from the beginning of the twentieth century, expanded its investments and interests in the region (Ferguson, 2005; Fontana, 2011). Thus, well into the twentieth century, most material resources flowed to a small group of industrialised countries that required cheap raw materials to supply local industries.

Today, contrary to what one may expect, the direct relationship with North America has tended to swing. The reason is that US imports accelerated at the turn of the twenty-first century: in 1966, net exports from Latin America to North America were 99 Mt; in 2000, they had fallen to 82 Mt and today account for only 2 Mt. In the case of Europe, they have surged from 57 Mt in 1966 to 155 Mt in 2016.

The apparent reduction in direct material flows to the Global North is linked to one of the most relevant events in recent history: the resurgence of Eastern economies, which has been a turning point in the history of the global biophysical economy. Net exports to the Asia-Pacific axis were already significant in the mid-twentieth century, but they have reached unprecedented levels in recent decades: in 2016 they exceeded 527 Mt. A large part of these exports, however, are utilised by industrial activities. In other words, they represent an intermediate consumption that goes into the production of goods that ultimately flow to a third

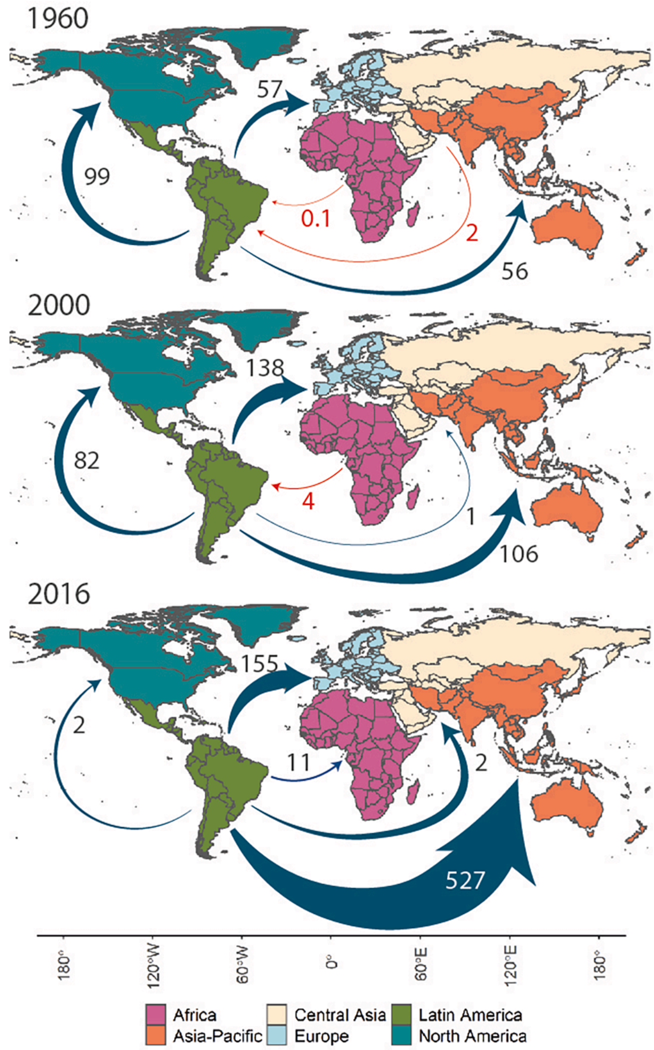

Fig. 5. Latin America's material trade (PTB) in benchmark years (1966, 2000, 2016). Net exports (blue) and net imports (red) in Mt. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

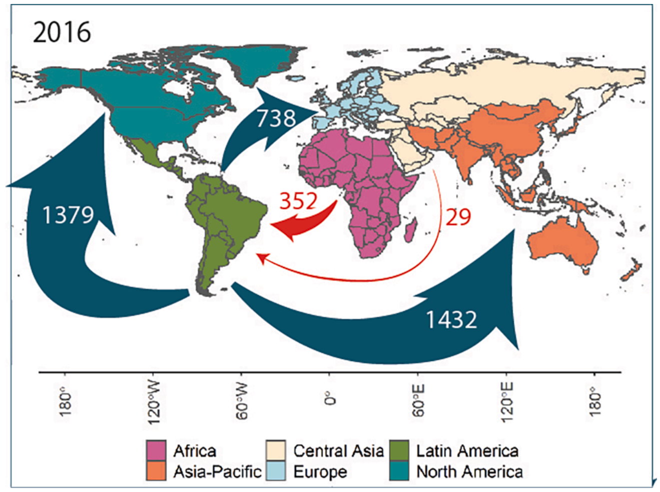

Fig. 6. Latin America's material trade in 'Raw materials equivalents' (RTB) obtained using the MRIO model GLORIA comparing producer and final consumer regions. Net exports (blue) and net imports (red) in Mt. (For interpretation of the references to colour in this figure legend, the reader is referred to the web version of this article.)

country. Fig. 6 shows the estimated net exports from the RME perspective and following a full consumption footprint approach, which transcends the bilateral exchanges and allows identifying the actual origin and destination of extracted materials. The net exports measured from extraction to final consumers in North America and Europe remain very high, suggesting that much of Latin America's exports to China 'end up' in Western economies, since each region accounts for 26 % of the net exports under the RTB, but it can be clearly seen that difference between both accounting logics is much relevant for the former (observe the material flows to North America in Fig. 6 and Fig. 5). The results also show that the level of exports to Eastern countries driven by their final consumption is still very significant, with a 48 % of all Latin America's net exports. China's final consumption is the main driver, accounting for 646 Mt (48 % of the material flow to the region), an amount similar to those of the North America and Europe, although in per capita numbers the level is significantly lower. Lastly, the balance with Africa and the Middle East reverses when upstream connections are considered, suggesting that inputs for producing Latin America's imports originated in these two regions, but these were finally exported from a third region located downstream in the global supply chain.

The Eastern resurgence, as a historical process, is still immature (Muradian et al., 2012). Venturing solid conclusions about its impact, whether generally or on the Global South in particular, is not an easy task. Does China's upsurge correspond to a geographical shift in global hegemonic power that does not create opportunities in peripheral countries? In this sense, it is argued that this country reproduces the same domination practices in the Global South as its predecessors: land grabbing, labour exploitation or the generation of unequal exchange relations, which perpetuate specialisation in commodities (e.g., Campbell, 2008; Ellis, 2009). On the other hand, given the country's relative gap with US military and economic power (Ferguson, 2005), it could be argued that China is still acting only as an intermediary between the traditional centres of global power and the peripheral economies (Story, 2005; Gao, 2012).

3.4. Notes on trade relations and unequal ecological exchange

The trade relationship between two countries expresses the extent to which trade is beneficial to each side. In Ecological Economics' studies, a common way to examine this phenomenon is to compare the average price of exported materials with the average price of imported materials. It is also commonly used to study the relationships of 'unequal ecological exchange' (EUE) (Hornborg, 2012, 2019; Martínez-Alier and Muradian, 2015; Frei et al., 2019). This approach holds that international trade generates an unequal distribution of environmental impacts and economic benefits. Poor countries tend to be net exporters of materials and internalize their environmental impacts, while their exports have lower prices and less added value than their imports (Dorninger et al., 2021). However, other approaches question or nuance the existence of these EUEs (e.g., Moran et al., 2013; Brolin and Kander, 2020a, 2020b). Although a country is a net exporter of resources and the price paid for its exports is less than that paid for its imports, it can still benefit from international trade. As Brolin and Kander (2020a:247) argue: "savings are not incommensurable with unbalanced net flows (meaning imports minus exports). Indeed, theoretically, optimal specialization even requires unbalanced factor flows". In this same direction Williamson (2011) argued that trade and specialization contributed to economic growth during the First Globalization. However, this same author also pointed out that such specialization and price volatility became detrimental to economic development in Latin America in relation to industrialized countries (Williamson, 2011).

In the case of Latin America, we can observe that throughout the period analysed, the price per kg of imports has always been much higher than that of exports: in 1966, the region paid $ 0.5 for each imported kg and sold at $ 0.1, five times less; in 2016, it paid $ 1.6 and sold at $ 0.6, 2.67 times less (Fig. 7a).

Fig. 7b illustrates the trade relationships, distinguishing the world regions that trade with Latin American countries. The most damaging relationship is with Europe: European imports are paid 6 to 8 times more than exports per unit of weight. Exchanges have also been disadvantageous with most world regions, except with Africa and Central Asia until the 1980s. Since then, trade with these regions has also reached a balance. In other words, today, Latin America does not trade in a clearly 'beneficial' way with any region. The latter indicates how the pattern of specialisation has deepened, based on the extraction and export of natural resources, as shown above.

Latin America's trade relationship with the rest of the world have remained relatively stable as a result from the combination of various regional behaviours: while the relationship with Africa and Asia has worsened, the relationship with North America has improved. One can observe, however, how these exchanges slightly improved until well into the 1980s.

Ocampo and Parra (2010) found that on the long-term, the commodities terms of trade stepwise deteriorated in 1920's and in the 1980's. During the period of State-Led Industrialisation (c. 1930–1975), the region depended much less on international markets than during the First Globalisation and during the period of economic openness imposed by the 1980's external debt crisis. From that moment on, not only did the relative prices of raw materials visibly deteriorate (Ocampo and Parra, 2010), but the collapse of the state-led industrialization policies opened the door to a new stage of 'reorientation towards international markets' and export-led growth model (Bértola and Ocampo, 2013). Extractivist *reprimarisation*[7] and the worsening of exchange relations set the tone for the region's trade relations with the world up to early 1990's.

At the dawn of the 21st century, a new stage began marked by a rise in the price of commodities and great demand from Asian markets. During this period, the *reprimarisation* of Latin American trade was consolidated, and imports of manufactured products grew sharply making the way of the detrimental exchange with the Asian countries. Nevertheless, the new transition to Asian markets has brought about big-scale material depletion but, this time, with better monetary trade balances due to the increase in the price of commodities. However, according to our results and that of other works (Samaniego, Vallejo and Martínez-Alier, 2017), this trend seems to have reversed in recent years. A further fall in the prices of primary products is taking place, and it may engender to a *lose-lose* situation that had already been experienced in the 1980s: an increase in the net exports of materials accompanied by negative monetary balances.

In short, our results show that Latin America has been a net exporter of all types of materials throughout the 20th century and that the price of exported products is lower than the price of imported products. Thus, to pay for their imports, the countries of the region have had to export increasingly large volumes of materials. This fact may suggest that Latin American countries have assumed a greater environmental burden than their trading partners. Nevertheless, it is worth noting that we are only considering direct trade flows, while to properly assess the environmental impacts associated to international trade, it would be necessary to account for their embodied impacts (e.g. carbon, land, biodiversity losses). Previous studies have noted that, contrary to what would have been expected, richer countries were net exporters of certain resources and environmental impacts between c. 1870 and 1935, since they specialized in more energy and CO2-intensive manufacturing exports (Kander et al., 2017). Latin American imports (mostly manufactures) were likely more energy-intensive than their exports (mostly primary commodities). Nevertheless, the export of primary commodities, as those exported by Latin America, also might embed significant environmental impacts such as deforestation, land-use change emissions or biodiversity losses (Pendrill et al., 2019; Hong et al., 2022). Our data is not able to provide further information to shed light in this direction. We agree with Brolin and Kander (2020a, 2020b) that more research on embodied impacts in international trade before c. 1990 is necessary to keep enriching these debates.

3.5. *Economic development and physical trade*

Studies based on recent years point out that the level of income in a country correlates negatively with its net exports of materials and positively with net imports. That is, the poor countries tend to be net exporters of materials, while the rich have a greater material dependence on foreign countries (Dittrich and Bringezu, 2010; Bruckner et al., 2012; Wiedmann et al., 2015). Other variables, particularly population density and resources endowment have also been found significant in physical trade patterns (Bruckner et al., 2012; Weinzettel et al., 2013; Brolin and Kander, 2020a).

Fig. 8 shows the relationship between the physical trade balance (net imports) in t cap-1 year^{-1} per capita and the GDP per capita in 2011 US$ for the whole region. We observe that increases in per capita income are negatively correlated with the balance trade throughout the twentieth century. This means that, in the long run, income growth in the region has gone hand in hand with the growth of its material exports. Therefore, this long-term analysis contradicts the idea of increasing material dependence as income rises, as argued in cross-sectional studies for recent years. This correlation, however, is not completely linear and presents historical discontinuities:

The first period (1900–1950) is characterised by the region's outstanding presence in international markets as an exporter of agricultural goods by mean of trade openness in the frame of the First Globalisation (1870–1914/30) and state support during the first stages of the policies of state-led srowth (1930–1950). Although the relative prices of these products evolved positively for Latin American exports during that period (Pinilla and Aparicio, 2015), their volatility limited the region's development, increasing the divergence from industrialised countries (Williamson, 2008).

Between c. 1950–1980 the inward-oriented development policies became the main tool of industrialization of Latin American countries, and as income per capita grew trade became less dynamic than before. The average annual rates of change in the trade balance dropped from 7.9 % up to 0.2 % between 1955–63 and 1964–74 (Table 9 in SM). The material exports went back from 0.9 t cap-1 year^{-1} up to 0.6 t cap-1 year^{-1} in 1980 (Fig. 8), a process which is in accordance to the EUE hypothesis of increasing income and imports, although not yet conclusive. However, the so-called Golden Age of economic growth (c. 1950–1972), went into a crisis by two main reasons: on the one hand, there were external factors such as the oil shocks and the dollar and debt crisis; and on the other hand, certain developmentalist policies failed. Industries in the region became addicted to subsidies that had originally been designed to temporarily help the take off in certain emerging sectors. With the increase in the price of some resources and competition from new Asian countries, industrial production became ever less competitive (Fajnzylber, 1983).

After the crisis of the state-led developmentalist model, a period of commercial openness and economic deregulation opened up in the context of structural reforms, many of them imposed by international financial organisations. In hindsight, the 'neoliberal utopia' years – to use the expression of Héctor Pérez (2018) – were especially tragic: convergence with the rest of the world plummeted to turn-of-the-century levels, economic growth slowed, while physical trade deficit rose at 3.5 % annual rates between 1982 and 1998 almost recovering the level of the previous years (0.8 t cap-1 year^{-1} in 1995). In the late 1990s, a phase similar to that of the early twentieth century finally began with a strong material depletion which has paved the way of economic growth

[7] From the Spanish 'reprimarización', where it is widely used to address the process of refocusing on the production of primary commodities for export in of Latin American economies.

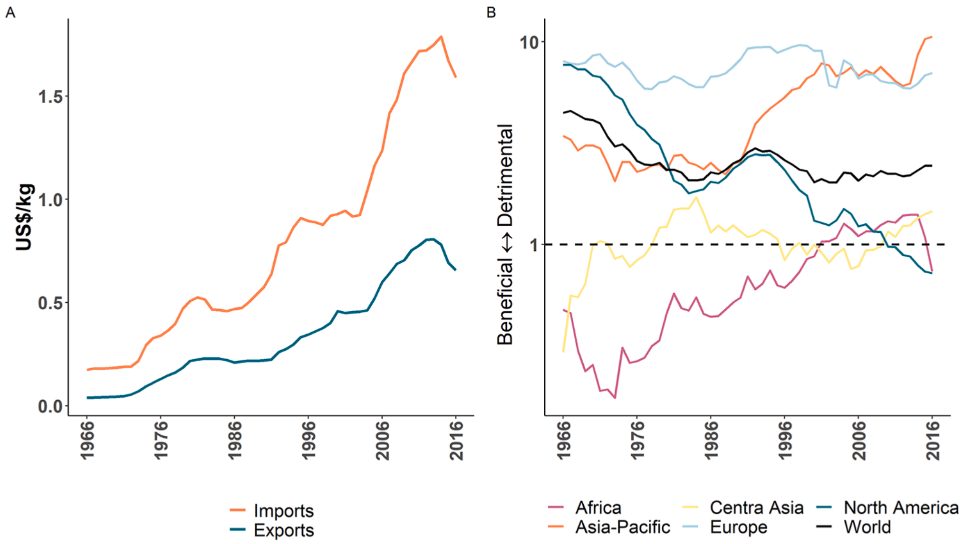

Fig. 7. (a) Price of imports and exports per material unit (current US$ per kg). (b) Exchange relationship with the different world regions. Note: A value greater than one indicates an unfavourable relationship and vice versa.

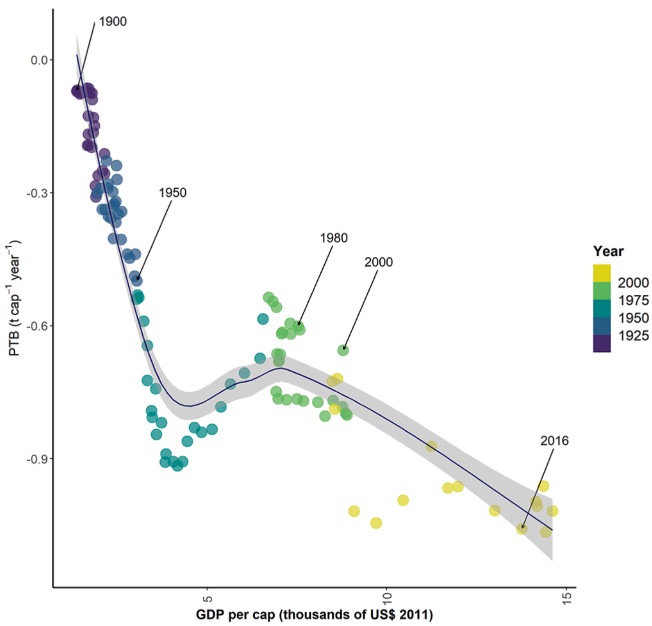

Fig. 8. Relationship between physical trade balance (PTB) and per capita (per cap) income (constant 2011 dollars).

and convergence. Even the volatility of the physical trade balance experienced during the 1900–44 period (12 sd.) came back in this period (10 sd. between 1999 and 2016) (Table 9 in SM). During these years, leftist governments, in many cases of an indigenist origin, rose to power and were critical of the extractivist model and the region's *reprimarisation*. Yet the positive conjunctural evolution of relative prices allowed them to benefit from the income generated by commodity exports and their rising prices (Gudynas, 2009, McKay et al., 2021, Norberg, 2019).

According to our results, and beyond the historical particularities, in the long term there is no evidence of a positive relationship between GDP per capita income and net imports of materials in Latin America. That is, said relationship is a synchronic phenomenon only tested in current times, not a diachronic one. Today, the richest countries tend to externalize their impacts outside their borders, but that does not imply that when a (poor) country gets richer, it stops being a net exporter. This evidence suggests that (i) the poorest countries play a peripheral role even as they get richer over time; and (ii) that it is possible to get richer even as a peripheral country.

A plausible explanation is that net exports are explained by the countries' endowment of resources and not by their income. On a national scale, the countries with the greatest endowment of land and mineral resources, such as Argentina, Paraguay, Uruguay, Bolivia, Brazil, Colombia and Ecuador, present a negative relationship between GDP per capita and the physical trade balance, but being a clear model of economic growth based on the export of materials. Only the Central American countries, with a high population density and scarce mineral resources, have a clear import profile, despite the fact that their per capita income (with the exception of Costa Rica) is at levels similar to or lower than that of Bolivia (6,000 US$ per capita) (Fig. 10 in SM).

4. Concluding remarks

There is a broad consensus regarding the characterisation of Latin America as a Global South region specialised in the provision of energy and materials to global metropolises. The empirical basis supporting this picture remains geographically or historically incomplete. The results obtained in this work corroborate such 'common knowledge': Latin America has always been a net exporter of materials and the remuneration it receives for its exports is lower than what it receives for its imports. Yet, the present study provides new empirical evidence that helps understand the role of Latin America in the global bio-physical economy. Worthy of note are six major conclusions:

1) Latin America's material contribution has not stopped growing throughout the period under study, although the greatest acceleration took place since the World War II. The region has played a decisive role in the second phase of the well-known 'Great Acceleration', sustaining the huge growth in the global consumption of materials. Recent quantities of extraction have reached unprecedented levels: over the last four decades, more materials have likely been extracted for export than during the region's entire history.
2) Among the world's peripheral regions, Latin America's specificity is its high diversification in exported materials: throughout history, it has been a major supplier of agricultural, metal and petroleum products, which explains the wide range of environmental conflicts with local affected communities involved by their extraction.
3) Geographically, Latin America's outflow of resources has shifted substantially throughout history. Until the end of the twentieth

century, the main export flow was directed towards Europe and North America and there was a balanced relationship with the rest of the peripheries. During this period, the direction of export flows has been ruled by a sort of 'informal colonialism' that has reigned over the subcontinent since the nineteenth century. Over the last 20 years, however, the Asia-Pacific axis, led by China, has become the main importer of materials, although a significant part of them are ultimately re-exported to the Global North.

4) Predictably, Latin America presents an unfavourable trade relationship with the rest of the world because it is a net exporter of primary products and a net importer of manufactured products. This relationship has been the most burdensome with Europe and North America. But the terms of trade with Africa and Central Asia have deteriorated since the 1980s, while improved with North America since the 1990s.
5) Both net physical exports and per capita income increased throughout the twentieth century. Yet this relationship was not exactly linear: during the first half of the century and since 2003, the region combined natural depletion with precarious income growth and divergence. Between the mid-twentieth century and the 1980s crisis, an improved situation arose coinciding with the 'import substitution' policies: income and economic convergence increased without material depletion.
6) Unequal Ecological Exchange theorists argue that the poorest countries are net suppliers of materials to the rest of the world. Indeed, our data shows that Latin American countries, which are among the less wealthy in the world, are mostly net exporters of materials. However, this relationship is not linear along time nor always the same within the region: the poorest countries (Central America) are net importers of materials. In this sense, lower land availability due to higher population density seems to play a key role, although this hypothesis needs to be tested by additional studies.

The present work contributes new evidence to the debate on Latin America's 'open veins'. But it is only a first step to properly understand the region's role in the global bio-physical economy and, consequently, in the development of the Anthropocene. In future work, it would be necessary to address not only consumption but also extraction. In this way, the study could be extended to other natural resources (energy, land, etc.) and the embodied effects of international trade could possibly be incorporated.

Declaration of Competing Interest

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Appendix A. Supplementary data

Supplementary data to this article can be found online at https://doi.org/10.1016/j.gloenvcha.2022.102579.

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