Colombian Liberalization and Integration into World Trade Markets: Much Ado about Nothing*

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Abstract

The objective of this article is to study the evolution of Colombian liberalization and integration into world trade from 1996 to 2018. We achieved our objective by measuring

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Colombia's importance in the world trade network through the employment of several types of network centrality metrics and the examination of their dynamics against a set of regional peers. We were able to conclude that Colombia's centrality in the world trade network did not improve, whereas that of some of her regional peers did manifestly. Results highlighted the perils of analyzing a country's trade dynamics in isolation and emphasized the usefulness of examining the world trade network.

Keywords: Colombia; foreign trade; centrality; network analysis; world trade network.
JEL classification: F14, F15, C45, C63.

Apertura e integración de Colombia a la red mundial de comercio: mucho ruido y pocas nueces

Resumen

El objetivo del documento es estudiar la evolución de la liberalización y de la integración de Colombia al comercio mundial entre 1996 y 2018. Para lograrlo, el documento analiza la importancia de Colombia en la red mundial de comercio empleando varias métricas de centralidad en el análisis de redes y evalúa su dinámica, y las compara con las de pares regionales. Se encontró que la posición de Colombia en la red de comercio mundial no mejoró sustancialmente, mientras que la de algunos de sus pares regionales sí lo hizo. Los resultados resaltan los peligros de analizar la dinámica del comercio de un país de forma aislada y resaltan la utilidad de estudiar la red de comercio mundial.

Palabras clave: Colombia; comercio exterior; centralidad; análisis de red; redes de comercio mundial.
Clasificación JEL: F14, F15, C45, C63.

Abertura e integração da Colômbia à rede mundial de comércio: muito barulho por nada

Resumo

O objetivo do documento é estudar a evolução da liberalização e a integração da Colômbia no comércio mundial entre 1996 e 2018. Para atingir seu objetivo, o documento mede a importância da Colômbia na rede mundial de comércio usando vários tipos de métricas de centralidade de rede, e examina sua dinâmica e a compara com a de seus pares regionais. Verifica-se que a posição da Colômbia na rede mundial de comércio não melhorou substancialmente, enquanto a de alguns de seus pares regionais melhorou. Os resultados destacam os perigos de analisar a dinâmica comercial de um país isoladamente e enfatizam a utilidade de estudar a rede mundial de comércio.

Palavras-chave: Colômbia; comércio exterior; centralidade; análise de redes; rede de comércio mundial.
Classificação JEL: F14, F15, C45, C63.

Introduction

Trade liberalization and the fragmentation of production across countries are two fundamental changes that have reshaped world trade in the last decades (Hernández et al., 2014). Regarding trade liberalization, evidence of international trade as one of the engines of economic growth is abundant (Dollar, 1992; Krueger, 1998; Edwards, 1998; Stiglitz, 1998; Frankel & Romer, 1999; Dollar & Kraay, 2004; Arora & Vamvakidis, 2005; Felbermayr, 2005; Kónya, 2006; Awokuse & Christopoulos, 2009; Beaton et al., 2017b). Likewise, there is evidence of a positive relationship between participating in *global value chains*[1] —that result from the transnational fragmentation of production— and higher productivity at the country and firm-level (Gereffi, 1999; Giovannetti et al., 2015; Criscuolo & Timmis, 2018; Del Prete et al., 2017; OECD, 2017).

Colombia, like many other developing countries, embraced the idea of liberalizing trade and integrating its productive sector into world markets. Consequently, in the dawn of the nineties, the country implemented a development plan called "The Peaceful Revolution" (La Revolución Pacífica) that changed the economy's growth strategy from the domestic market to foreign markets and from import substitution to exports (Cardenas et al., 2000; Villar & Esguerra, 2007). It can be claimed that Colombian trade policies, institutional changes, and outsprint of mineral products since the nineties achieved the objective of increasing exports and imports. As exhibited in Figure 1, despite some recent downturn periods (*i. e.*, 2009, 2010, 2016, and 2017), Colombia's trade trend appears to attest that trade liberalization has delivered its most immediate goal: to increase trade and to make it more prominent for the economy.

However, when compared with Latin America or other developing countries, some authors have highlighted that Colombia's trade openness has been modest —even reversed (Villar & Esguerra, 2007; López et al., 2015). Similarly, Ospina (2013) concludes that Colombia's importance in world trade did not improve notably, whereas López et al. (2015) highlight the reduced importance of Colombia in global value chains.

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1 As in Del Prete et al. (2017), the *global value chain* is a concept that entails a vertical fragmentation of the production process in which parts and components are produced in different countries by different firms and then are assembled either sequentially along the chain or in a final location. Alternatively, Grossman and Rossi-Hansberg (2008) describe this fragmentation process as production and specialization in trading *tasks* rather than goods.

The objective of this article is to study the evolution of Colombian liberalization and integration into world trade from 1996 to 2018. As emphasized by Fagiolo et al. (2010), traditional measures of openness (*e. g.,* total trade or total trade to GDP ratios, as in Figure 1) fail to capture how each country is connected within the world trade network (WTN). Consequently, our approach departs from traditional studies that rely on analyzing a country's trade dynamics in isolation. Instead, as world trade is a complex system of countries that are interdependent as they export and import among them, we focus on assessing Colombia's importance in the WTN. As stated by Serrano and Boguñá (2003), the value of the network approach for examining and analyzing the WTN results from its ability to cope with its complexity (see also Fagiolo et al., 2010; Reyes et al., 2010; Kali & Reyes, 2007).

We measure a country's importance in the WTN through its network centrality. To gain further insights about the performance of Colombia in it, our work comprises three main features: first, we compared Colombia's centrality with a set of regional peers (*i. e.,* Brazil, Chile, Mexico, and Peru), the median of countries in the WTN, and with China and the United States as trade leading countries. Second, we built two different WTNs, by value (in US dollars) and volume (in tons), thus, addressing issues related to price effects in our results. Third, by excluding a set of key commodities, we studied how results are dependent on minerals, fuels, and metals —which are particularly contributive to Colombia's and its peers' exports.

Consequently, this article addresses four questions regarding Colombia's liberalization and integration into world trade markets: How has the relative importance of Colombia in the WTN evolved? How does Colombia rank against a benchmark comprising some of its regional peers and other trade-leading countries? How dependent is Colombia's centrality on its key exports? Is the evolution of Colombia's importance in the WTN consistent with the policies and institutional changes implemented for about two decades?

Overall, the main finding is that Colombia increased the number of trading partners and the absolute value of exports and imports but failed to attain a more central role in the WTN. When compared with a group of regional peer countries, Colombia's centrality neither improve substantially nor deteriorated, whereas Chile and Peru improved remarkably. This is even clearer when a set of key commodities is excluded from the WTN. In general, Colombia's importance in the WTN did not increase greatly, but its peers' did manifestly.

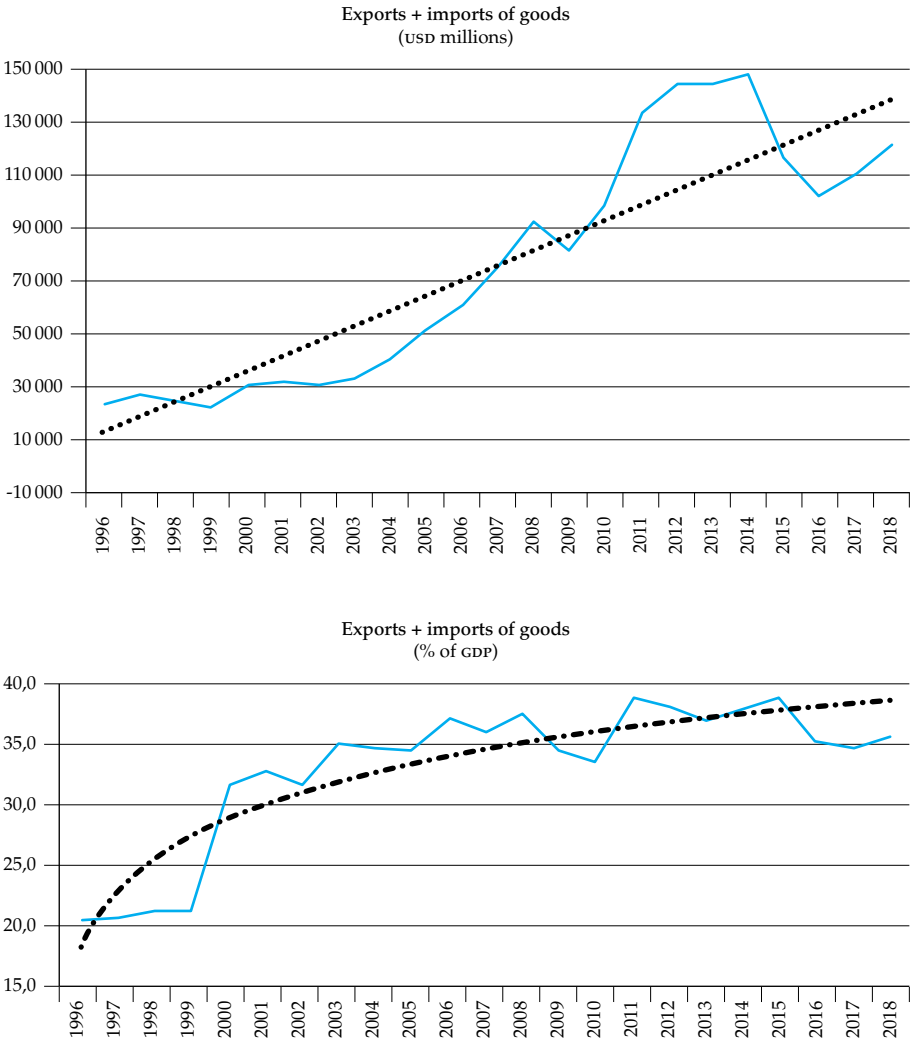

Figure 1. Evolution of Colombian Trade (1996-2018)

The upper panel corresponds to the sum of exports and imports FOB measured in millions of US dollars. The lower panel corresponds to the ratio of exports and imports to Colombia's Gross Domestic Product. The dashed lines correspond respectively to the linear and logarithmic regressions on time series as a representation of their trend; the regression is in its standard form $y = \alpha + \beta t$, where t corresponds to time (horizontal axis) and y to the trade statistic (vertical axis).

Source: Authors' calculations, based on the Colombian Balance of Payments statistics from Banco de la República.

There are several contributions from our work. First, it further exploits network analysis techniques on the WTN. Most literature regarding the WTN examines its main connective features (Serrano & Boguñá, 2003; Kali

& Reyes, 2007; Fagiolo et al., 2010; Reyes et al., 2010; Cassi et al., 2012; De Benedictis et al., 2014; Xu & Qin, 2015; Cepeda-López et al., 2019). We add to the WTN literature by studying how individual countries evolve as elements of the trade network (see also Alongside Fagiolo et al., 2010; Ospina, 2013; Kastelle & Liesch, 2013; Beaton et al., 2017a; Soyyigit & Yavuzaslan, 2018).

Second, as analyzing the WTN allows for a better description of economic integration by considering the various dimensions of connectivity that arise when countries trade among them (see Fagiolo et al., 2010), the results attained an enhanced evaluation of public policies and institutional changes for Colombia's further integration into world trade markets. Third, we work on two versions of the WTN, based on the value (in US dollars) and volume (in tons) of exports and imports, related to price effects in our results. Fourth, taking into account that the emergence of global value chains has accompanied world integration (see Baldwin, 2011; Hernández et al., 2014; Fernández-Stark et al., 2014; Tinta et al., 2018), we measured to what extent Colombia is important as an exporter to (importer from) key global buyers (suppliers) in the WTN. Fifth, based on network centrality measures that capture global importance, we built a Trade Integration Index that enabled us to conveniently measure the evolution of integration. Therefore, we contribute with an enhanced framework for assessing the usefulness of past policies and for envisaging forthcoming policies' goals.

From an economic policy perspective, there is a clear message. It is essential to evaluate past policies and institutions to understand why Colombia, as well as other developing countries, has not been able to achieve a more central role in the WTN and how it can reach it. Colombia's increase in the number of trade partners and the value of trade with determinant markets has been similar or inferior to that experienced by other countries, which results in a sluggish dynamic towards liberalization and integration into world markets. As suggested by the literature on Colombian trade, public goods, such as physical infrastructure, administrative efficiency, regulatory coordination, and reduction of *protectionism*, are required to enhance the competitiveness of the country (Jaramillo, 2004; García et al., 2014; García et al., 2015; López et al., 2015; OECD, 2019; Garavito-Acosta et al., 2020). Furthermore, our results highlight that attaining a better centrality in world trade markets requires trade policies that enable the country to outperform competitor countries; this may be obvious to some extent, yet it may be an overlooked issue when comparing the evolution of trade policies using traditional country-centric trade and openness indicators.

This article consists of four sections aside from the introduction. The second section briefly reviews Colombian and international openness and

integration trade policies. The third section describes the methodology and data. The fourth presents and analyzes the results. The last section summarizes the main findings and discusses policy implications.

1. Colombian regional and international trade policies during the last decades

By the end of the eighties, Colombia started changing its growth strategy from import substitution industrialization or "State-led industrialization" to an exports-oriented strategy (Cardenas et al., 2000). A generalized reduction of tariffs and the elimination of quantitative restrictions for imports at the beginning of the nineties fostered this change (Garay et al., 1998; Villar & Esguerra, 2007). As a consequence, average nominal protection decreased from 44 % to 12 % between 1989 and 1992. Also, export subsidies shrank from 22 % in 1989 to 7 % in 1994 and 4 % in 2006 (Ocampo et al., 2007).[2]

Furthermore, the Ministry of Foreign Trade was established in 1991 to modernize and promote the foreign sector. This changed the orientation of the Colombian Institute of Foreign Trade (Incomex), which, between 1962 and 2000, was in charge of preventing unfair trade practices. Besides, Bancoldex (Banco de Comercio Exterior), a bank aimed at facilitating credit access to Colombian exporters (Garay et al., 1998), was established in 1992. Moreover, trade policies came along with the liberalization of the local financial market (*i. e.*, interest rates and the credit market) and the capital account, privatizations, and the change of the foreign exchange rate regime from crawling peg to free-floating (Ocampo, 1997; Villar & Rincón, 2003).

Regional trade agreements became basic tools for the process of international trade integration worldwide. These agreements pursued integration through a regulated non-tariff trading environment and financial cooperation. Accordingly, bilateral and multilateral trade agreements accompanied Colombian trade liberalization (Table 1). Interestingly, it reveals that these agreements usually ratify existing ties between members as they are signed between traditional regional partners, and they have little effect on the productive structure of the export sector with limited expansion to new markets (Dingemans & Ross, 2012).

2 Nevertheless, two of the most important exceptions were agriculture and livestock and agroindustry and the automobile sectors. The first two sectors were protected with *price bands* that were adjusted according to foreign competition (Circa, 1993). In the automobile sector, the tariff for finished cars was set at 35 % compared with a zero tariff for vehicles to assemble.

Nevertheless, these efforts toward an export-oriented growth strategy encountered two main problems. First, the tariff reduction process established at the beginning of the nineties was concomitant with significant growth of non-tariff regulations and measures that affected about 70 % of the tariff universe for the next two decades (García et al., 2014). Therefore, concurrent with García et al. (2014), notwithstanding the attempts to liberalize trade and promote exports other than coffee, *protectionism* seems to be the word that describes Colombian trade policy between 1950 and 2013 the best.

Table 1. Colombian Bilateral and Multilateral Trade Agreements

Agreement	Countersigner(s)	Signed/Expiration
Andean Free Trade Zonea	Bolivia, Ecuador, and Peru (Chile and Venezuela abandoned the Trade Zone)	1969/1993
Andean Trade Preference Act	United States	1991/2001
Group of Three	Mexico and Venezuela	1994/2006
Andean Trade Promotion Drug Eradication Act	United States	2002/2011
Free Trade Agreementb	Chile	2006
Free Trade Agreement	Guatemala, Honduras, and Salvador	2007
Free Trade Agreement	Canada	2008c
Free Trade Agreement	Switzerlandc, Liechtensteinc, Norwayd, and Icelandd	2008
Free Trade Agreement	United States	2011e
Free Trade Agreement	European Union and Peru	2012f
Pacific Alliance	Chile, Mexico, and Peru	2012g
Free Trade Agreement	South Korea	2013h
Free Trade Agreement	Costa Rica	2013h

[a] Formerly, Andean Community. [b] Formerly, Acuerdo de Complementación Económica, signed in 1994. [c] Valid from 2011. [d] Valid from 2014. [e] Valid from 2012. [f] Valid from 2013. [g] Valid from 2015. [h] Valid from 2016.

Second, the quality of institutions and infrastructure was an obstacle to trade. The foreign trade survey conducted by Banco de la República (the central bank of Colombia) to trade operators in 2013 documented that public entities intervening in foreign trade processes lack coordination, whereas their rules impose a hurdle to trade because they lack clarity and simplicity, they are difficult to access and not timely disclosed (García et al., 2015).

Moreover, Colombian infrastructure (roads, ports, airports, electricity, and telecommunications) fails in coverage and quality considerably (Jaramillo, 2004; Montezuma, 2008; Yepes et al., 2013). World Bank's Logistics Performance Index (LPI) provides a fair relative measure of how both institutional and infrastructural obstacles impose a burden on Colombian trade.[3] As exhibited in Figure 2, Colombia's LPI scores from 2007 to 2018 are below those of all other countries in the figure —except Peru at the end of the sample. Therefore, concurrent with Jaramillo (2004) and García et al. (2015), institutional and infrastructural issues have been an important barrier to Colombian trade and integration into world markets.

Furthermore, the World Bank's Doing Business project records the time and cost (excluding tariffs) associated with the logistical process of exporting and importing goods. According to this database, the ease of trading across borders ranking placed Colombia in the 133rd position within a sample of 190 economies in 2019.[4] For instance, while the average Colombian border compliance time is 112 hours, in Brazil, Chile, Mexico, and Peru is 49, 60, 20, and 48 hours, respectively. Regarding the border compliance costs to export, Colombia has an average cost of US$630, whereas Chile, Mexico, and Peru have costs of US$290, US$400, and US$630, respectively. Brazil's is the highest, at US$862.

Even though Colombian trade policies and regulatory changes seemed to have met the objective of increasing exports and imports, the network analysis carried out by Ospina (2013) revealed that the country did not improve notably its position in the WTN. Moreover, this author argued that while trade agreements increased trade channels, they did not imply larger flows or higher productivity transfers because of their scarce implementation with key global importers and exporters —with the notable exception of the United States, which concentrated a large amount of Colombian imports and exports.

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3 World Bank's LPI analyzes countries through six indicators: (1) Efficiency of customs and border management clearance; (2) Quality of trade- and transport-related infrastructure; (3) Easiness of arranging competitively priced international shipments; (4) Competence and quality of logistics services; (5) Ability to track and trace consignments; (6) Frequency with which shipments reach consignees within the scheduled or expected delivery time. The higher the index, the higher the performance in trade logistics.

4 Brazil, Chile, Mexico, and Peru ranked 108, 73, 69, and 102, respectively. The database is available at https://www.doingbusiness.org

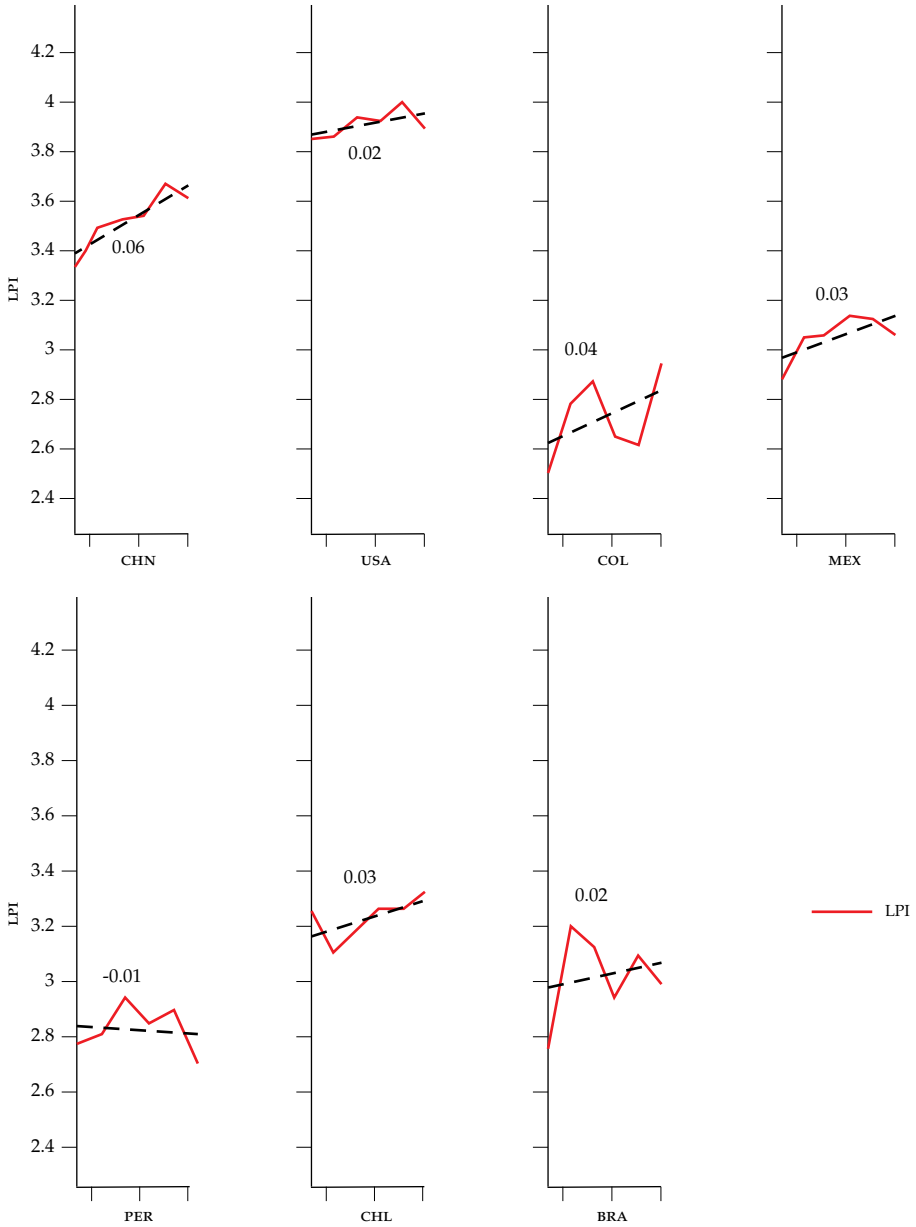

Figure 2. Logistics Performance Index (LPI), 2007-2018

Due to availability limitations, data corresponds to 2007, 2010, 2012, 2014, 2016, and 2018 (in the horizontal axis). The dashed lines correspond to the linear regression on time series as a representation of their overall trend; the regression is in its standard form $y = \alpha + \beta x$, where x and y correspond to time (horizontal axis) and LPI (vertical axis), respectively, and the slope (β) is reported for comparison purposes.

Source: Based on World Bank data.

Based on López et al. (2015), these facts may have manifested in Colombian exports of high and medium technology industrial goods, contributing with about 2 and 13 % of total exports, respectively, whereas those of primary products —mostly minerals, fuels, and metals— and manufactured goods based on natural resources representing about 70 %.[5] These authors also report that, between 1992 and 2012, Colombia was the fifth country (among 71) with the highest degree of sectorial concentration —mostly on commodities and manufactures based on natural resources. This may explain "the reduced importance of the country in global value chains" (López et al., 2015, p. 32). Further, Colombia's notable dependence on the performance of the oil sector (see Garavito-Acosta et al., 2020) exposed the country to volatility shocks (see Giri et al., 2019).

2. Methodology and Data

First, we present network notation and centrality measures. We emphasize why those measures matter for assessing and analyzing the evolution of Colombia's importance in the WTN and, thus, its integration into world markets. Then, we describe the datasets.

2.1. Network Centrality Analysis

Network analysis aims at describing and understanding an underlying system, focused on capturing the system's structure (see Börner et al., 2007). As countries and their exports and imports conform to a system, the use of network analysis furthers understanding of the international trade system.

If there are n countries, a traditional representation of the WTN is A, an $n \times n$ adjacency matrix with elements A_{ij} such that

$$A_{ij} = \begin{cases} 1 \text{ if there is an export from } i \text{ to } j, \\ 0 \text{ otherwise.} \end{cases} \quad (1)$$

If A_{ij} is equal to 1, there is an export from i to j, regardless of the value of exports. The weighted adjacency matrix W, with elements Wij, displays the monetary value of the exports from i to j (in US dollars) or their volume (in tons). To avoid issues related to the units, we transformed W into $\bar{W}$ (2),

5 The percentage participation of minerals, fuels, and metals is reported in Appendix A1.

with elements $\bar{W}_{ij}$ containing the contribution of each *ij* trade relation to the total value or volume of trade. For visualization purposes, comparisons of centrality measures based on $\bar{W}_{ij}$ will employ a logarithmic transformation.

$$\bar{W}_{ij} = W_{ij} / \left(\sum_{i=1}^{n} \sum_{i=1}^{n} W_{ij} \right) \quad (2)$$

Related literature studies the structure and evolution of the WTN —as previously referenced. Instead, we studied how countries' importance in the WTN has evolved. We focused on Colombia and a set of benchmark countries.

Centrality quantifies how important nodes (*i. e.*, countries) are in a networked system (see Newman, 2010). As a network is composed of nodes and their linkages, any change in the number of nodes or in the number or weight of their links will affect the structure of the network and the relative importance of all other nodes in it.

There are different centrality measures (see Newman, 2010). In our case, the centrality of a country in the WTN is a function of the number and intensity of its trade relations with other countries, along with the importance of those countries for the WTN. Therefore, we focused on three centrality algorithms, which yield six different centrality measures (*i. e.*, in-degree, out-degree, in-strength, out-strength, hub, and authority) that are convenient for studying countries' importance in the WTN.[6] The three algorithms are presented next —their formulae are exhibited in Appendix A2.

- *Degree:* Based on the adjacency matrix A_{ij}, it corresponds to the number of links (*i. e.*, trading counterparties) connected to the node (country) *i*. We calculated in-degree $\left(k_i^{in}\right)$ and out-degree $\left(k_i^{out}\right)$ to quantify incoming (imports) and departing (exports) links, respectively. The degree has two main shortcomings. First, it does not consider the intensity of the linkages (*i. e.*, the value of exports and imports). Second, it does not contemplate the importance of adjacent nodes as an importance factor; thus, it is regarded as a *local* centrality measure.

6 We discarded centrality measures based on the in-between role of nodes in a network (*i. e., betweenness centrality*), the distance between nodes (*i. e., closeness centrality*), or *random walk betweenness centrality* (see Fagiolo et al., 2010). As the majority of countries in the WTN display a large number of linkages to other countries and low distances among them (see Cepeda-López et al., 2019), most betweenness measures tend to be of limited informational value about cross-section differences between countries; moreover, most of them —in their standard formulation— overlook the weighted nature of the WTN. Our choice of algorithms is analogous to that of Ospina (2013).

- *Strength:* Based on the weighted adjacency matrix $\overline{W}_{ij}$, it measures the intensity of trade for node *i*. We calculate in-strength $\left(s_i^{in}\right)$ and out-strength $\left(s_i^{out}\right)$ to quantify the intensity of the incoming (imports) and departing (exports) linkages. In our case, the intensity comes in two distinct forms: the value (in US dollars) and the volume (in tons) of trade. Because trade flows are normalized by total world trade, strength represents market shares irrespective of whether the original data are values or quantities. Akin in degree, strength is a local measure —the importance of adjacent nodes was neglected.
- HITS *(Hypertext Induced Topic Search):* It is a centrality algorithm designed by Kleinberg (1999) to surmount the main drawbacks of eigenvector centrality —designed by Bonacich (1972). Following Langville and Meyer (2012), HITS yields two separate but interdependent centrality measures: hub and authority, which correspond to the importance as global originators of links (*i. e.*, exporter) and as global receivers of links (*i. e.*, importer). Hub centrality of node *i* was defined to be proportional to the weighted sum of the authority of the countries it exports to, whereas the authority centrality of node *i* was defined to be proportional to the weighted sum of the hub centrality of the countries it imports from. When using the weighted adjacency matrix $\overline{W}_{ij}$, the intensity of the linkages serves as weights for this weighted sum. As HITS is based on eigenvector centrality, hub and authority centrality measure the importance of exporter and importer at a global scale, not only taking into account the importance of all direct and indirect (*i. e.*, adjacent and non-adjacent) counterparties but also the topology of the entire WTN. In our case, the HITS algorithm works on a circular thesis: a central exporter (a good hub) exports to central importers (good authorities), whereas a central importer (a good authority) imports from central exporters (good hubs). This circular thesis is particularly valuable for preliminarily assessing a country's role in global value chains, in which connecting with global buyers and global suppliers in value-added production networks is key to economic integration.[7] In our view, hub and authority centrality

7 As global value chains are related to the fragmentation of production across countries (De Backer & Miroudot, 2014), hub and authority centrality may serve to capture the extent to which a country trades directly and indirectly with dominant global buyers and suppliers (*i. e.*, important) in the production of certain goods. Under an analogous approach, Criscuolo and Timmis (2018) use Katz centrality (see Newman, 2010) to identify central nodes in European global value chains based on the World Trade Organization Trade in Value-Added (TiVA) indicators. From a methodological viewpoint,

fit Fagiolo et al. (2010) claim for an integration measure that not only captures how much a country trades but also the specific distribution of trade across direct and indirect trading partners.[8]

Our choice of algorithms and centrality measures enable us to cover three important dimensions of a country in the WTN. First, the degree measures how many connections a country has and how contributive those are to the total relations in the WTN. A country pursuing an integrated economy will increase its in- and out-degree as a result of new trade relations. Second, strength measures how intense the connections are and how contributive they are to world trade. A country pursuing an integrated economy will not only increase trade counterparties but also the strength of those connections by value and volume —otherwise, the contribution of new connections may be dubious. Third, hub and authority centrality measure a country's importance as an exporter to global buyers and as an importer from global suppliers, respectively. A country pursuing an integrated economy not only will increase the number (*i. e.*, degree) and intensity (*i. e.*, strength) of its trade relations but also its overall importance for the WTN as a participant of global value chains —as an exporter to key importers, importer from key exporters, or both.[9] As reported by Criscuolo and Timmis (2018), this is remarkably important because becoming more central as a customer or a supplier in the global value chains is associated with faster productivity growth (of firms).

Therefore, we used these three dimensions for assessing Colombia's WTN integration. Absolute improvements in these three dimensions would reflect that trade policies attained a more open economy. However, relative improvements with respect to the WTN and peers would reflect those trade policies were successful in attaining a better integration into the WTN.

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using trade flows (instead of TiVA indicators or input-output data) has some obvious analytical limitations but may provide some preliminary insights about the role of a country in global value chains.

8 Other authors have used authority and hub centrality (*i. e.*, HITS algorithm) to study the importance of countries in trade networks (see Ospina, 2013; Soyyigit & Yavuzaslan, 2018) and global input-output networks (see Soyyigit & Boz, 2017). Also, they have been used to study network importance in interbank cross-border flows (see Eren & Soyyigit, 2017) and interbank networks (see León et al., 2018).

9 As reported by Criscuolo and Timmis (2018), this is remarkably important because becoming more central as a customer or a supplier in the global value chains is associated with faster productivity growth (of firms).

2.2. Data

We used the free-on-board (FOB) value of exports of the BACI dataset, an international trade database at the product-level, which covers more than 200 countries and 5,000 products annually between 1995 and 2018. BACI is the French acronym of *Base pour l'Analyse du Commerce International*, and it is constructed by the CEPII (*Centre d'études prospectives et d'informations internationales*), the French center for research and expertise on the world economy. BACI reconciles the annual trade data reported to the United Nations Statistics Division, which distributes them via the Comtrade database.[10] We used the dataset starting in 1996 and ending in 2018. We excluded countries that do not have trade data reported for a given year.[11] We did not filter trade data based on its contribution to world trade or a country's economic size (as in Kali & Reyes, 2007).

After we processed the data from BACI, we attained one adjacency matrix (A) and two weighted adjacency $\left(\overline{W}\right)$ matrices —by value and volume.[12] Each of these three matrices has three dimensions (209 x 209 x 23), corresponding to 209 countries and 23 periods (*i. e.,* years).

3. Main results

We reported results according to the three algorithms presented before (*i. e.,* degree, strength, and HITS), which correspond to the three importance dimensions mentioned: the number of connections, their intensity, and the weighted importance of countries at the end of those connections.

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10 The BACI database is available for free upon request at http://cepii.fr/CEPII/en/bdd_modele/download.asp. It classifies products by the 6-digit Harmonized System (HS), which allows participating countries to classify traded goods on a common basis for customs purposes. At the international level, HS is a six-digit code system revised in 1992, 1996, 2002, 2007, 2012, and 2017, and BACI is furnished in each of those 6 revisions. For our purposes, we used the 1996's revision, which provides the longest and more complete dataset.

11 Excluded countries were American Samoa, the State of Palestine, Guam, Montenegro, the Netherlands Antilles, Curaçao, Saint Maarten, Bonaire, Saint Barthelemy, San Marino, Serbia, South Sudan, Sudan, and Serbia and Montenegro.

12 Regarding trade by volume, most customs statistics report quantities in tons. However, about 15 % are detailed in other units of measure (units, meters, square meters, watts, etc.). The BACI estimates the rates of conversion into tons using mirror flows reported in tons by a country and in another unit by the other trading partner; the rate of conversion is applied if a minimum of 10 mirror flows have been used in its computation and if the standard deviation is inferior to 2.5 (see Gaulier & Zignago, 2010).

We discussed the importance of Colombia in the WTN and its evolution from 1996 to 2018. We compared Colombia's degree, strength, and hub and authority centrality with a set of countries that are interesting because they lead the WTN in terms of network importance and size (*i. e.*, the United States and China) or because they are Colombia's regional peers. Among those regional peers, we considered countries that are similar in size (Chile), larger (Mexico and Brazil), and smaller (Peru).[13] Additionally, we compared Colombia's importance with the median of all countries in the WTN.

3.1. Degree centrality

In-degree $\left(k_i^{in}\right)$ and out-degree $\left(k_i^{out}\right)$ quantify the number of countries a country imports from and exports to, respectively. As portrayed in Figure 3, Colombia's centrality measured by its in-degree in the WTN shows the countries exporting to Colombia has increased along the period, albeit decreases in 1998 and 2003. Colombia's exports and imports counterparties have been higher than that of Peru and Chile and the median of countries in the WTN. This number has increased but at a slower pace than its peers —as evident from the linear trend's slope.

Comparatively, at the end of the period under analysis, Colombia's in-degree was below that of Brazil and Mexico and slightly higher than that of Chile and Peru. The upward trend in the number of countries Colombia imports from was visibly slower than that of its peers and the median of all countries. As expected, the in-degree of China and the United States were higher.

Regarding the countries Colombia exports to, there was an evident upward trend in out-degree, but less pronounced than for in-degree. Brazil, Mexico, and Chile shared this difference in trend, whereas Peru displayed a steeper out-degree trend. Peru exhibited the strongest upward trend in out-degree, along with the median of all countries in the WTN. Both China and the United States presented an almost flat trend for out-degree.

Overall, it was noticeable that Colombia increased the number of countries it exports to and imports from. This is consistent with the quest for a more open and integrated economy. Yet, Colombia was not the only country

13 Based on World Bank figures, as of 2018, Chile's GDP (U$ 298 billion) was about 0.89 times Colombia's (US $334 billion); Peru's (US $222 billion) was about 0.66 times; Mexico's (US $1221 billion) was about 3.7 times, and Brazil's (US $1885 billion) was about 5.6 times. Argentina and Venezuela were discarded because of their extreme macroeconomic behavior during the period under analysis.

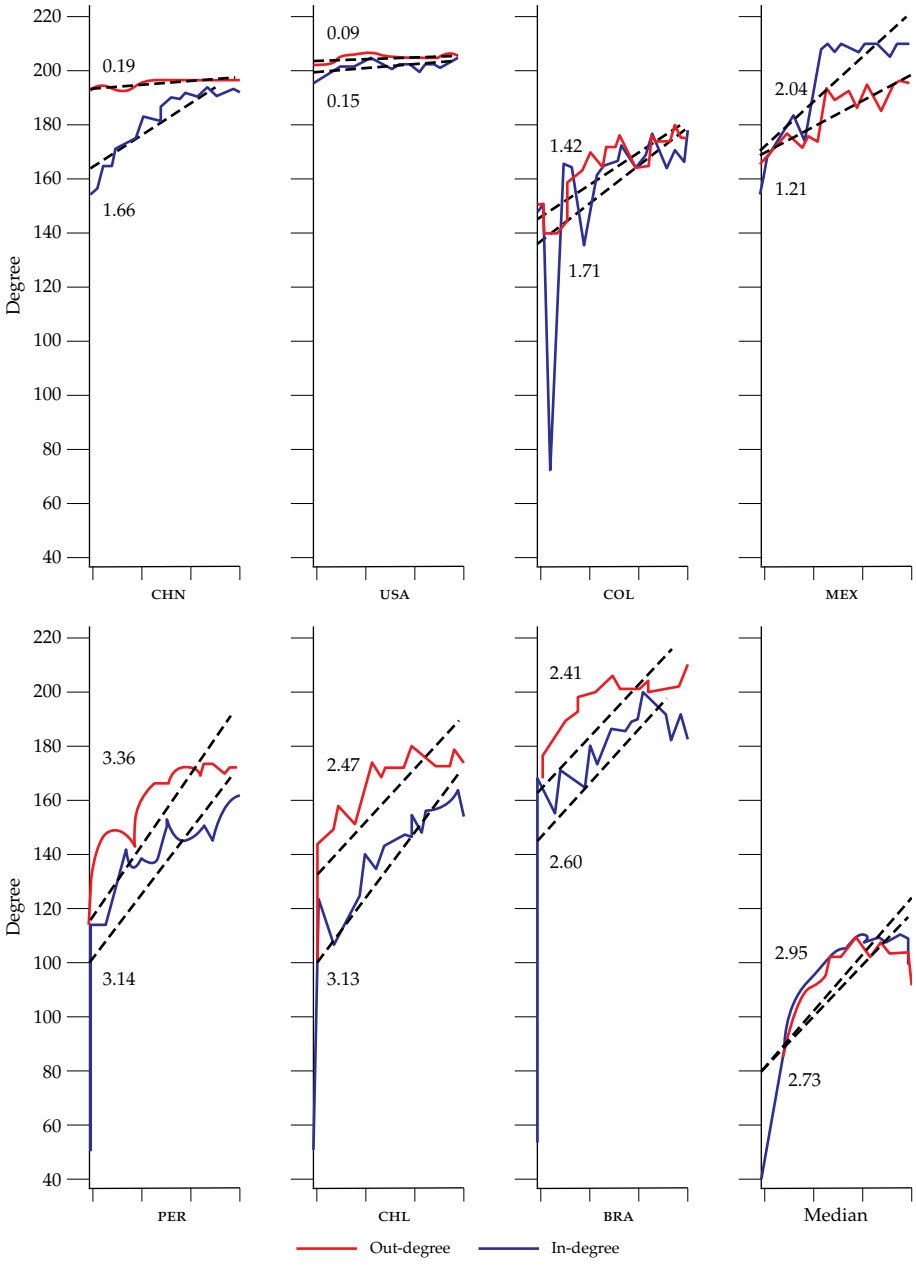

Figure 3. Evolution of Out- and In-Degree, in US Dollars (or tons) from 1996 to 2018

Note: The dashed line corresponds to the linear regression on time series as a representation of their trend; the regression is in its standard form $y = \alpha + \beta t$, where t corresponds to time (horizontal axis) and y to the centrality measure (vertical axis), and the slope (β) is reported for comparison purposes. The median is calculated on the 209-country sample.

Source: Based on BACI.

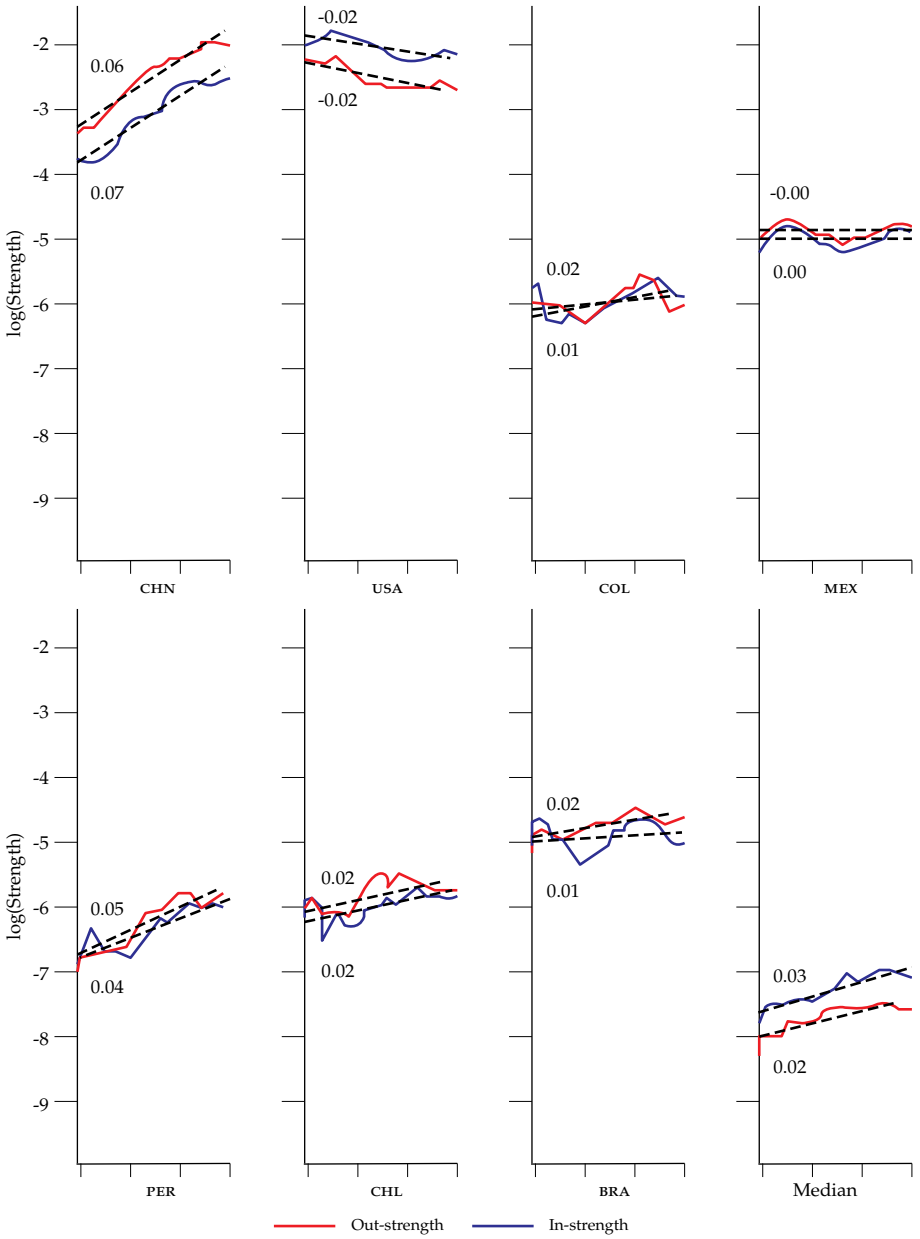

Figure 4. Evolution of Out- and In-Strength in US Dollars from 1996 to 2018

The dashed line corresponds to the linear regression on time series as a representation of their trend; the regression is in its standard form $y = \alpha + \beta t$, where t corresponds to time (horizontal axis) and t to the centrality measure (vertical axis), and the slope (β) is reported for comparison purposes. The vertical axis has been transformed into its logarithm for readability issues. The median was calculated on the 209-country sample.

Source: Based on BACI.

to achieve more trading partners amid the trade liberalization process, prevalent among many developing countries since the late eighties and early nineties. For instance, Peru, Chile, Brazil, and the median of countries in the WTN were able to increase the number of export counterparts faster. Interestingly, relative to its peers, Colombia displayed a slight increase in the countries from which it imports (*i. e.*, in-degree).

3.2. Strength Centrality

In-strength $\left(s_i^{in}\right)$ and out-strength $\left(s_i^{out}\right)$ quantify the contribution of countries to total imports and exports in the WTN, respectively. As portrayed in Figure 4, Colombia's contribution to the WTN's exports and imports by value (in US dollars) displayed a minor upward trend. Nevertheless, the upward trend in out-strength hinders, from the beginning to the end of the period analysed, the contribution to the total value of exports declined. By the end of the set period, the contribution of Colombian exports and imports to global trade by value was similar to that of Peru. All other regional peers (Chile, Mexico, and Brazil) had contributions to the WTN higher than that of Colombia. Well above Colombia and its regional peers, China exhibited a remarkable increase in its contribution to total imports and exports, whereas that of the United States remained high despite its declining trend.

Since these measures are relative to the total WTN, it is possible to affirm that, in most years, the benchmark countries, as well as China, behaved as net exporters since the out-strength measure exceeded the in-strength measure. This pattern was not fulfilled for Colombia's case, which reveals for the last years an important trade deficit. For the United States, it reflects its role as a net importer throughout the sample.

From a policy perspective, the minor increase in Colombia's contribution to total trade by value was somewhat inconsistent with the increase in trade counterparties and with the quest for a more open and integrated economy. Overall, it was apparent that Colombia did worse than most of its regional peers during the period under analysis. In fact, the upward trend in exports —*i. e.*, out-strength— of Peru, Chile, Brazil, and the median of countries in the WTN surpassed that of Colombia.

Figure 5 exhibits the out- and in-strength based on the WTN by volume (in tons). Although Colombia's contribution to the WTN's exports displayed a negligible upward trend, its contribution throughout the sample was higher than that of Chile and Peru. Colombia's contribution to the WTN's imports portrayed a notable increasing trend. However, its contribution to total imports by volume was lower than that of its peers —except Peru.

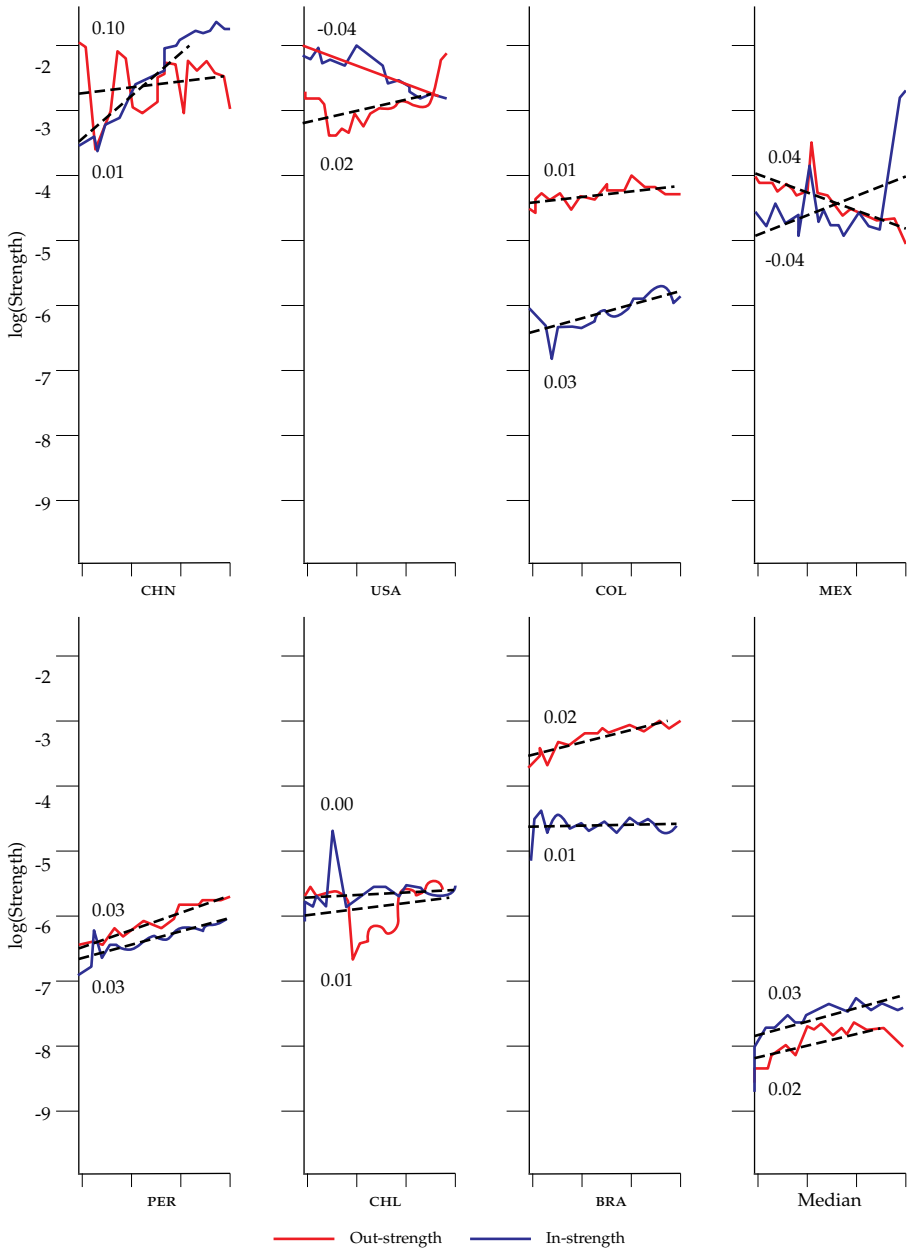

Figure 5. Evolution of Out- and In-Strength in Tons from 1996 to 2018

The dashed line corresponds to the linear regression on time series as a representation of their trend; the regression is in its standard form $y = \alpha + \beta t$, where t corresponds to time (horizontal axis) and y to the centrality measure (vertical axis), and the slope (β) is reported for comparison purposes. The vertical axis has been transformed into its logarithm for readability issues. The median is calculated on the 209-country sample.

Source: Based on BACI.

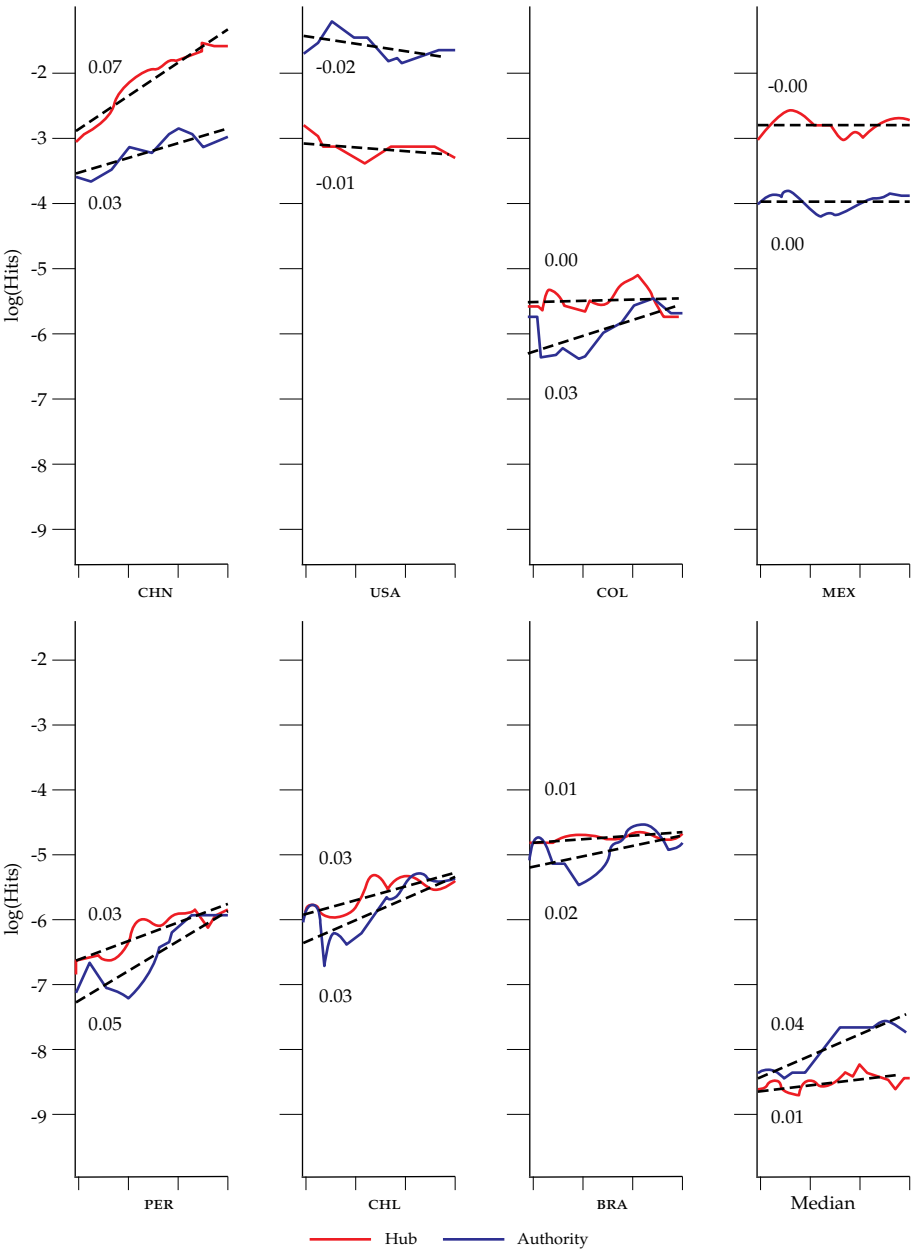

Figure 6. Evolution of Hub and Authority Centrality in US Dollars from 1996 to 2018

The dashed line corresponds to the linear regression on time series as a representation of their trend; the regression is in its standard form $y = \alpha + \beta t$, where t corresponds to time (horizontal axis) and y to the centrality measure (vertical axis), and the slope (β) is reported for comparison purposes. The vertical axis has been transformed into its logarithm for readability issues. The median is calculated on the 209-country sample.

Source: Based on BACI.

China exhibited a significant upward trend in its total contribution to global imports, whereas the United States' had a declining trend.

Contrary to the results obtained by value (in US dollars), in most years, China and Chile behaved as net importers, while Mexico reflected its role as a net importer at the end of the sample. Colombia, Peru, and Brazil behaved as net exporters by volume. Although the United States was a net importer in most years, this pattern changed at the end of the sample.

Therefore, although the trade counterparties increased, Colombia's contribution to the WTN by value and volume has not improved manifestly. Also, Colombia exhibited a remarkably large surplus by volume combined with slight differences between exports and imports by value; this suggests that Colombia's exports are mainly low-value and high-volume products. Possibly, this fact reflects the reduced importance of Colombia in global value chains. Exporting high-value and low-volume products could improve the contribution of Colombia to the WTN as an exporter while reducing the trade deficit by value.

3.3. HITS: Authority and hub centrality

Authority (a) and hub (h) centrality quantify the network importance of countries as importers from key global exporters and exporters to central global importers, respectively. Regarding the WTN by value (in US dollars), Figure 6 shows that Colombia's hub centrality tends to be higher than authority centrality; that is, it tends to be more important as an exporter to dominant global importers than as an importer from key global exporters. This feature is shared by all of Colombia's regional peers, except for the median of countries in the WTN.

Overall, Colombia's hub centrality was similar to Chile's; lower than Mexico's and Brazil's, and higher than Peru's and the median of countries in the WTN. Regarding the evolution of Colombia's hub centrality, it displayed a flat trend similar to that of Mexico, Brazil, and the median of countries in the WTN. By the end of the sample, a distinctive positive trend enabled Peru to close the gap with respect to Colombia and allowed Chile to surpass Colombia. The steepest hub centrality upward trend corresponded to China; this discloses the protracted increase in the importance of China as a key global exporter, concurrent with the decline of the United States. Regarding authority centrality, Colombia displayed a clear upward trend similar to that of Chile, Brazil, China, and the median of countries, but weaker than that of Peru; as in the case of hub centrality, Peru's stronger upward trend in authority centrality enabled closing the gap with respect to Colombia.

Considering the WTN by volume, Figure 7 shows that Colombia's hub centrality displayed a flat trend, whereas Peru, Chile, Brazil, and the median of countries in the WTN displayed a clear upward trend; that is, the importance of Colombia as an exporter to key global importers worsened with respect to that of most of its regional peers. The downward hub centrality trend of China contrasted with that of the United States. Regarding authority centrality, Colombia exhibited an upward trend similar to that of Chile and Peru but weaker than that of Mexico. While China displayed an increasing authority centrality trend by volume, the United States exhibited a downward trend. Overall, by volume, Colombia tended to be more important as an exporter to key global importers than an importer from key world exporters. However, this pattern reversed at the end of the sample.

Consequently, it is possible to conclude that Colombia's importance as an exporter to global key importers —by value and volume— has not improved, whereas that of Peru and Chile has increased manifestly. Likewise, Colombia's importance as an importer from key global exporters by value has not improved as much as that of Peru and Chile. That is, the relative position of Colombia in the WTN has not improved as expected.

3.4. A Trade Integration Index from HITS

HITS' hub and authority centrality measure countries' number and intensity of trade connections while gauging the importance of countries at the other end of those connections. Therefore, hub and authority centrality are comprehensive measures of how central a country is as a global exporter and importer within the WTN, respectively. However, to measure how integrated a country is into the WTN, it is convenient to attain a single index out from hub and authority centrality. A judicious conjecture is that a well-integrated country should be simultaneously central as an exporter and an importer. That is, trade integration is not a one-way path but results from countries' importance as buyers and sellers of goods and services for the entire WTN.

Based on that conjecture, we calculated a Trade Integration Index (TII) from HITS' hub and authority centrality. As suggested by León et al. (2018), such an index may be attained by multiplying and normalizing hub and authority centrality (see Appendix A2).[14] The choice of the product of both centrality measures is consistent for identifying those countries that simultaneously fulfill a central role as exporters and importers for the WTN.

14 Instead of the product, the min(·) operator may be used. The average is inconvenient as it may fail to filter countries with a central position as exporters and importers simultaneously.

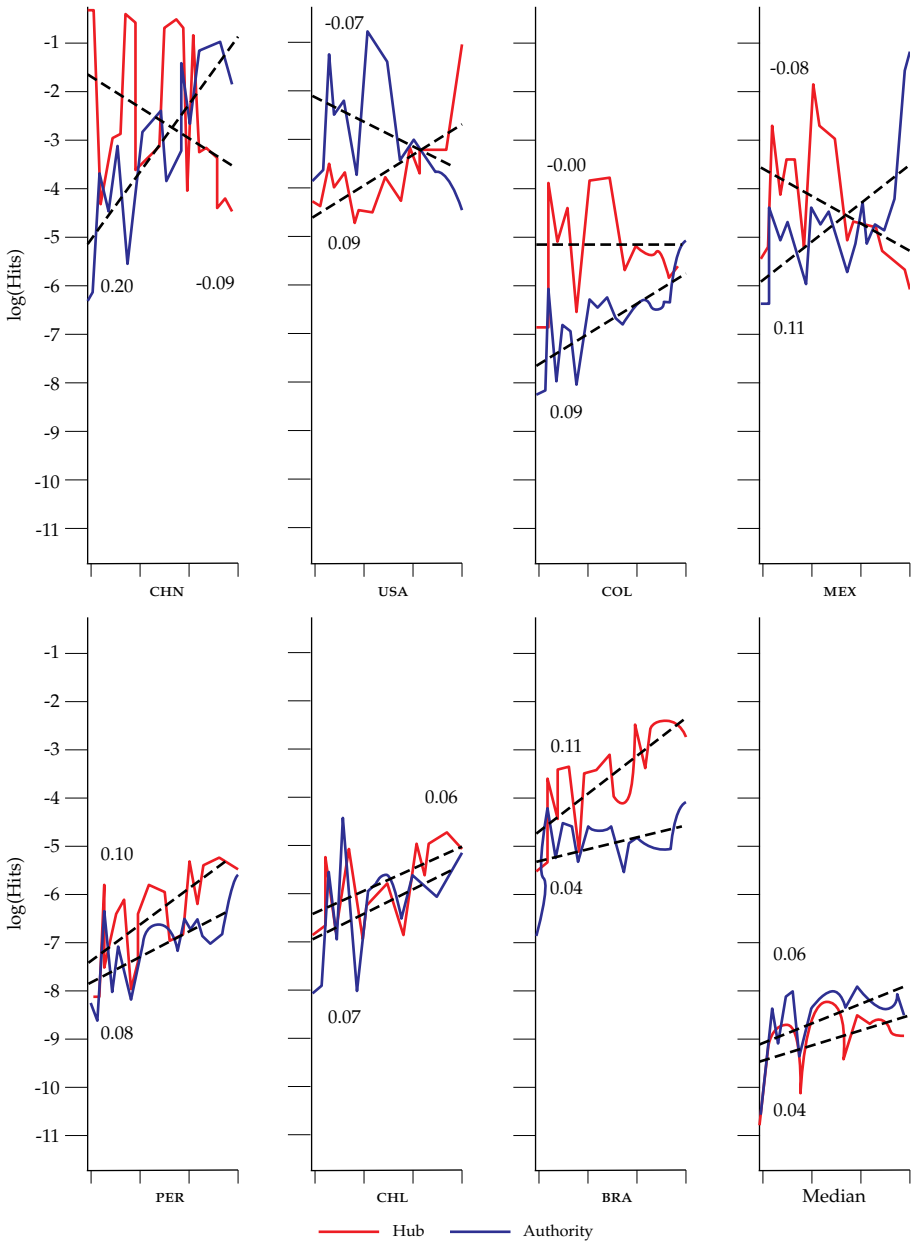

Figure 7. Evolution of Hub and Authority Centrality in Tons from 1996 to 2018

The dashed line corresponds to the linear regression on time series as a representation of their trend; the regression is in its standard form $y = \alpha + \beta t$, where t corresponds to time (horizontal axis) and y to the centrality measure (vertical axis), and the slope (β) is reported for comparison purposes. The vertical axis has been transformed into its logarithm for readability issues. The median is calculated on the 209-country sample.

Source: Based on BACI.

Congruent with the three dimensions of centrality previously studied, Figure 8 exhibits Colombia's TII for the WTN by value. It shows a positive slope, corresponding to an increasing trend in its integration into the WTN. Additionally, all regional peers showed a positive slope in their TII. Peru and Chile exhibited the strongest increasing trends out of the set of regional peers. Peru's slope was almost three-times Colombia's —and the same as China's. Chile's increasing trend was twice as strong as that of Colombia. Interestingly, during the period under analysis, Chile surpassed Colombia, whereas Peru closed the gap with Colombia noticeably. Mexico and Brazil showed a higher level of TII than Colombia, Chile, and Peru, but Mexico displayed a slight negative trend, whereas Brazil showed a slow positive one. China and the United States exhibited the highest TII in the figure, with China displaying a strong upward trend that differs substantially from the United States' decreasing trend.

Figure 9 exhibits the TII for the WTN by volume of trade. Colombia displayed an increasing trend in its integration into the WTN. As with the TII by value, all regional peers showed a positive slope in their TII. Peru exhibited the strongest increasing trend out of its regional peers, which was more than twice Colombia's. Remarkably, Peru's performance surpassed China's. Chile's TII displayed an upward trend of about 1.6 times that of Colombia. Mexico and Brazil showed a higher level of TII than Colombia, Peru, and Chile, but Mexico displayed a moderate improvement. The United States and China exhibited the highest TII. In the case of the United States, the evolution of integration into the WTN has been almost stagnant.

Again, consistent with the three dimensions of centrality, Colombia's TII trend by value and volume confirmed that Colombia's integration into the WTN has improved. However, improvement was subpar to that of Peru and Chile. Colombia has not been able to close the gap with Mexico and Brazil —even though their integration into the WTN has lingered stationary during the period analyzed.

It is well-known that the primary sector is of utmost importance for Chile, Colombia, and Peru. As shown in Appendix A1, as of 2018, about 55, 62, and 55 % of Chilean, Colombian, and Peruvian exports correspond to minerals, fuels, and metals. Therefore, it is judicious to study the level and evolution of TII excluding across the WTN a set of key minerals, fuels, and metals that are critical for Chile, Colombia, and Peru.[15] This enabled us to filter out the effect of commodities-dependence and to draw additional conclusions from the integration of Colombia into world trade.

15 For brevity, we focused on TII. Degree, strength, and hub and authority centrality after excluding key minerals, fuels, and metals are exhibited in Appendix A3. The main analytical inferences overlap with those drawn from focusing on TII.

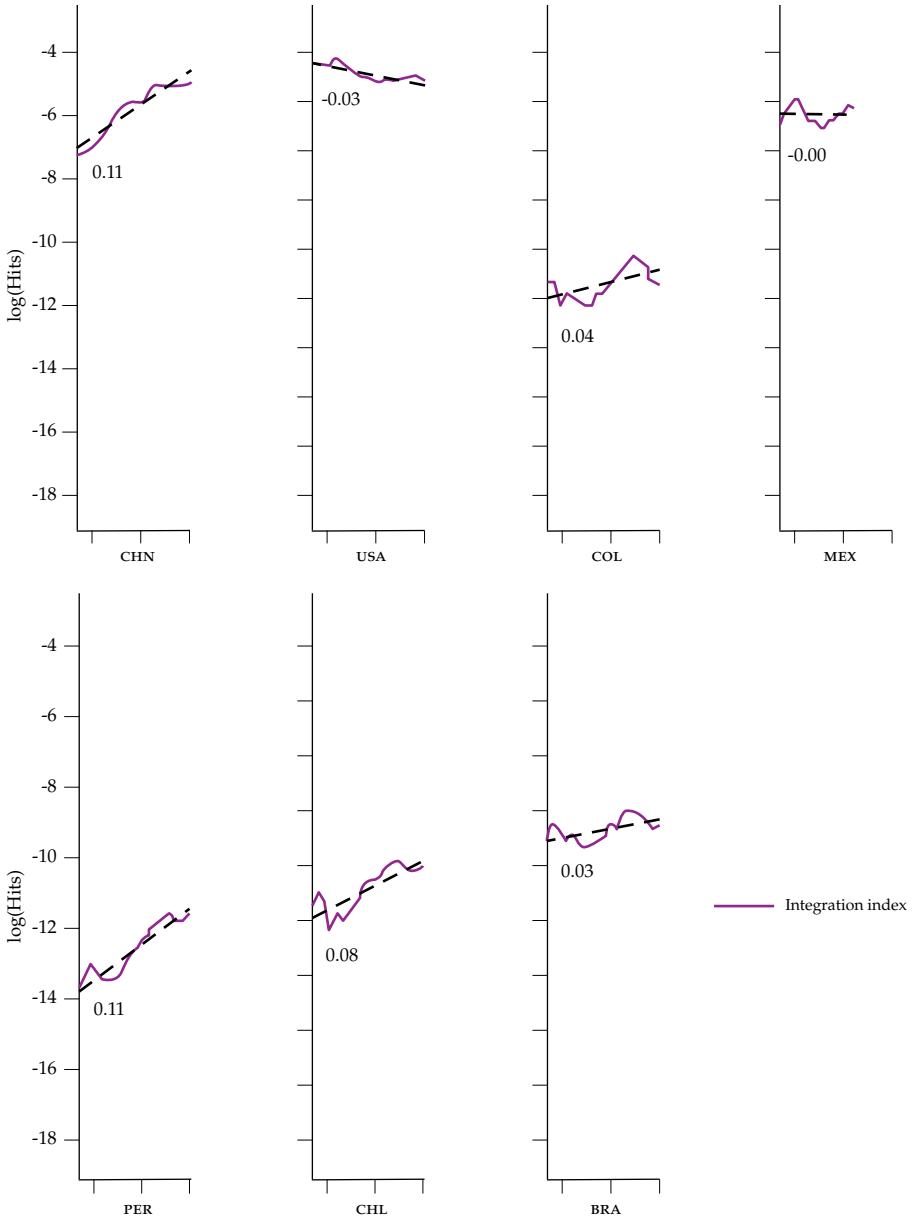

Figure 8. Evolution of Trade Integration Index (TII), in US Dollars, from 1996 to 2018

The dashed line corresponds to the linear regression on time series as a representation of their trend; the regression is in its standard form $y = \alpha + \beta t$, where t corresponds to time (horizontal axis) and y to the centrality measure (vertical axis), and the slope (β) is reported for comparison purposes. The vertical axis has been transformed into its logarithm for readability issues.

Source: Based on BACI.

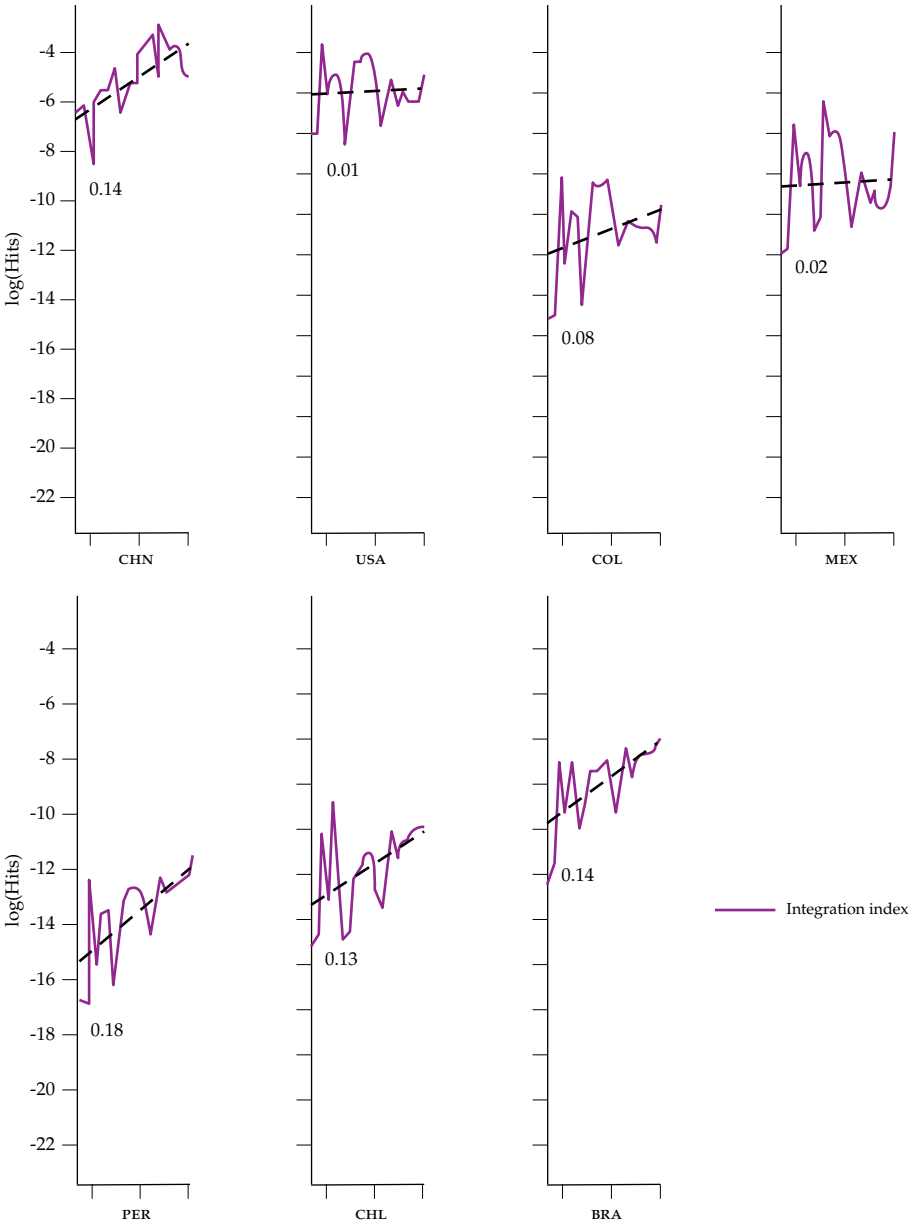

Figure 9. Evolution of Trade Integration Index (TII) in Tons from 1996 to 2018

The dashed line corresponds to the linear regression on time series as a representation of their trend; the regression is in its standard form $y = \alpha + \beta t$, where t corresponds to time (horizontal axis) and y to the centrality measure (vertical axis), and the slope (β) is reported for comparison purposes. The vertical axis has been transformed into its logarithm for readability issues.

Source: Based on BACI.

Figure 10 exhibits the TII based on the WTN by value (in US dollars) after excluding key minerals, fuels, and metals.[16] Interestingly, although excluded products were chosen because they are the most contributive to exports of Colombia, Chile, and Peru, Colombia was particularly affected. With respect to results on the entire WTN (Figure 8), the slope of Colombia's TII was halved when key minerals, fuels, and metals were excluded, whereas that of Peru and Chile showed a slight increase and decrease in slope, respectively. Further, the level of Colombia's TII diminished. In the case of the United States, China, Brazil, and Mexico, the TII and its slope did not change noticeably.

Figure 11 exhibits the TII based on the WTN by volume (tons) after excluding key minerals, fuels, and metals. With respect to TII on the entire WTN (in Figure 9), Colombia, Mexico, and the United States were notably affected as their slopes turned sharply negative. Interestingly, the slope of TII for Peru and China did not change, whereas that of Brazil and Chile decreased but remained positive.

Therefore, the results by value and volume, excluding minerals, fuels, and metals, showed that Colombian exports are highly dependent on those commodities. Unlike Peru and Chile, achieving a higher centrality in the WTN was not dependent on minerals, fuels, and metals. Further, the sharp change in slope in the TII by volume for Colombia confirmed the dependence on low-value and high-volume exports. Even though trade integration has improved, such dependence on key commodities has negatively affected the process of integration into the WTN compared with other regional peers, such as Peru and Chile.

16 We excluded key minerals, fuels, and metals by removing the corresponding Harmonized System (HS) Nomenclature codes in the dataset. After studying the main minerals and metals exported by Colombia, Chile, and Peru, the HS codes excluded were #27 (mineral fuels, mineral oils, and products of their distillation; bituminous substances; mineral waxes), #72 (iron and steel), #74 (copper and articles thereof), #75 (nickel and articles thereof), #76 (aluminum and articles thereof), and #79 (zinc and articles thereof).

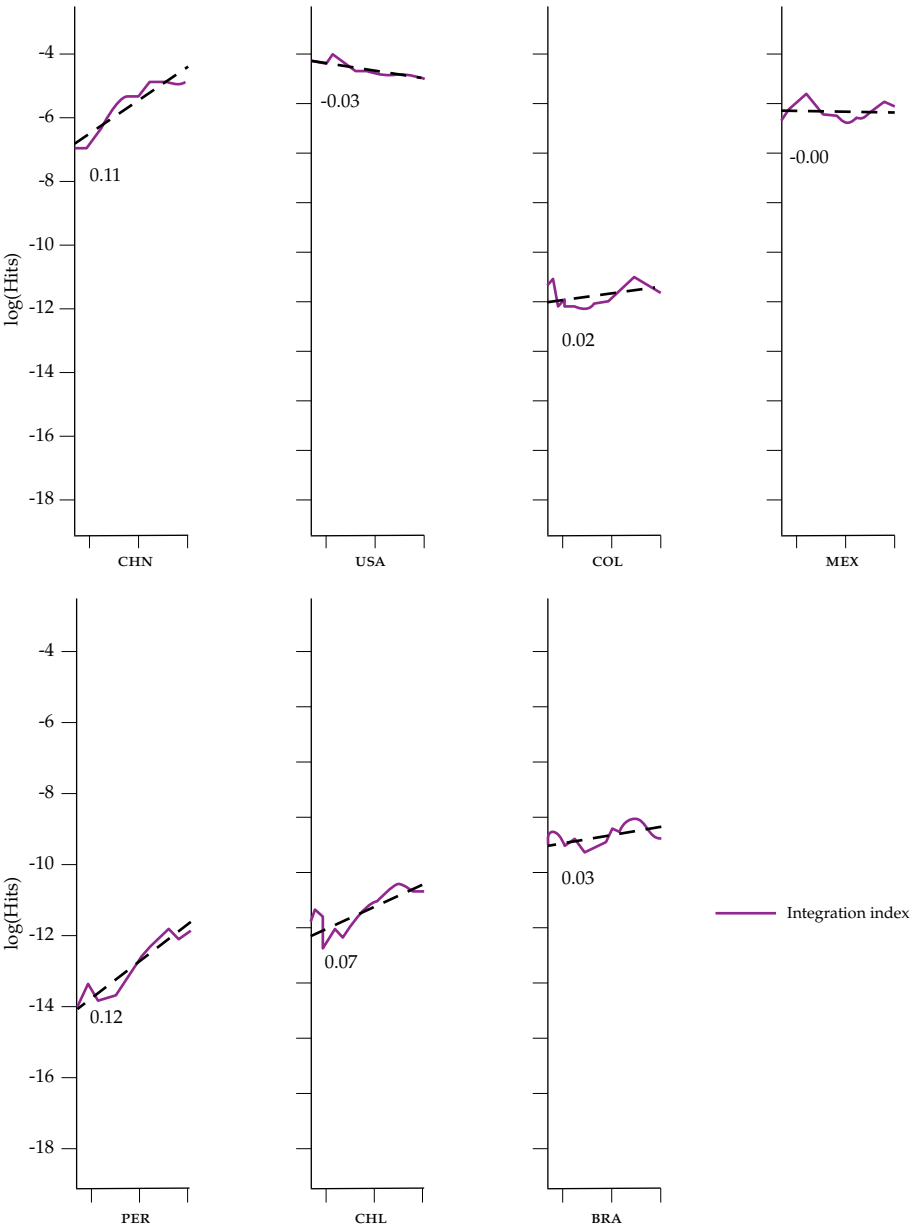

Figure 10. Evolution of Trade Integration Index (TII) in US Dollars from 1996 to 2018, excluding Key Minerals, Fuels, and Metals

The dashed line corresponds to the linear regression on time series as a representation of their trend; the regression is in its standard form $y = \alpha + \beta t$, where t corresponds to time (horizontal axis) and y to the centrality measure (vertical axis), and the slope (β) is reported for comparison purposes. The vertical axis has been transformed into its logarithm for readability issues.

Source: Based on BACI.

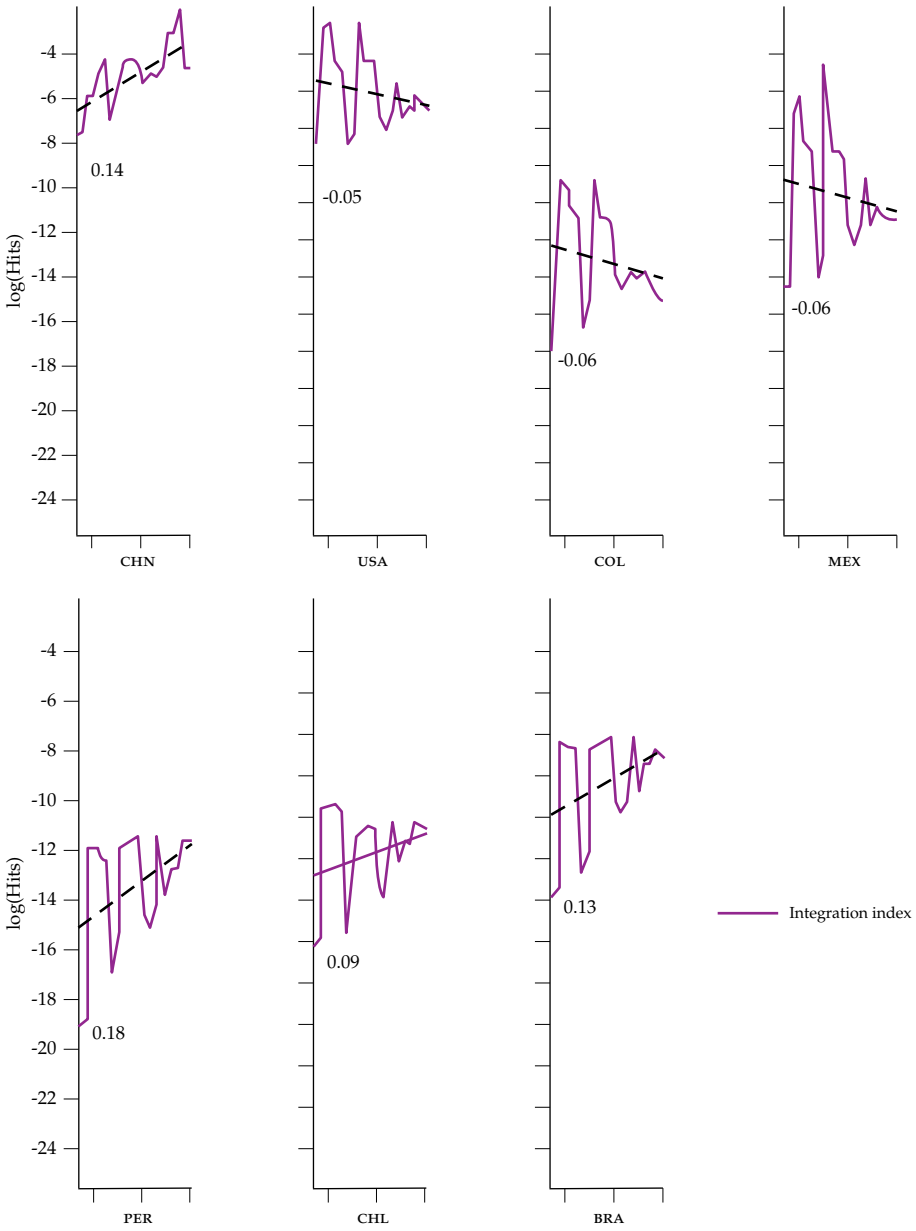

Figure 11. Evolution of Trade Integration Index (TII) in Tons from 1996 to 2018, excluding Key Minerals, Fuels, and Metals

The dashed line corresponds to the linear regression on time series as a representation of their trend; the regression is in its standard form $y = \alpha + \beta t$, where t corresponds to time (horizontal axis) and y to the centrality measure (vertical axis), and the slope (β) is reported for comparison purposes. The vertical axis has been transformed into its logarithm for readability issues.

Source: Based on BACI.

Conclusions

Amid the worldwide trade liberalization process of the late eighties and early nineties, Colombia changed its economy's growth strategy from domestic to foreign markets and from import substitution to exports. This article studied the evolution of Colombian liberalization and integration into world trade from 1996 to 2018 from a comprehensive viewpoint. Instead of relying on traditional country-centric measures of trade openness and integration (*e. g.*, contribution of trade to GDP and growth of exports and imports), we analyzed Colombia's trade dynamics with respect to the WTN and a set of regional peers (*i. e.*, Brazil, Chile, Mexico, and Peru). For completeness, we also compared Colombia with China and the United States as trade leading countries.

Our methodological choice required implementing network analysis basics and three different measures (*i. e.*, dimensions) of network importance: the number of connections, the intensity of those connections, and the network importance of the countries at the other end of the connections. These three correspond to three network centrality algorithms, namely degree centrality, strength centrality, and HITS centrality. For methodological convenience, we also built a Trade Integration Index based on the two outcomes of the HITS algorithm —*i. e.*, authority and hub centrality. We used the BACI International trade database reported by CEPII to build a 209-country and 23-year WTN by value (in US dollars) and by volume (in tons).

The results showed that Colombia increased the number of connections as an exporter and an importer during the sample period. However, with respect to the WTN, the increase in the exports and imports partners was subpar. Regarding the intensity of export and import connections, they both showed a weak, increasing trend below that of most of Colombia's regional peers. Finally, the importance of Colombia as an exporter to key global importers showed a negligible increasing trend that does not imply a substantial improvement with respect to other countries in the WTN, whereas other regional peers (*i. e.*, Peru and Chile) did improve manifestly. As an importer from key global exporters, Colombia showed an increasing trend that is similar to its peers'. The Trade Integration Index, which measures the extent to which a country is simultaneously a key global exporter and a key global importer, confirms the rather modest improvement in Colombia's integration into the WTN. Excluding a set of key minerals, fuels and metals revealed that the modest improvement in Colombia's integration is due to a limited number of commodities, whereas the substantial improvement of its peers is not. After excluding that central set of commodities, it is evident

that Colombia's integration into the WTN has not improved materially —unlike that of its peers.

All in all, the three dimensions of network importance share a common outcome: although Colombia's openness increased, its integration into world trade markets did not improve noticeably. This is clear as Colombia increased its trade partners, the value and volume of trade, and the importance of its trade partners, but other countries in the WTN increased even more. Compared with the set of selected regional peers, Chile and Peru improved their integration substantially, whereas Mexico and Brazil maintained their already high levels of integration. Moreover, taking into account Colombia's centrality as a key global exporter and importer, our results support López et al. (2015) and Garavito-Acosta et al. (2020) statements about its reduced importance in global value chains.

From an economic policy perspective, results highlighted the challenges ahead to liberalize and better integrate into world markets and achieve long-term economic growth from trade. Colombia's trade authorities need to revise to what extent past policies and institutional changes can be amended to correct the meager improvement in integration when compared with its peers and the WTN. Besides, it is of utmost importance to revise how successful peers (*i. e.*, Peru and Chile) attained such improvements and evaluate whether it is feasible and desirable to replicate their strategies. There are many factors to be considered in this revision and evaluation, such as differences in institutions, infrastructure, and the costs associated with border compliance. Also, dissimilarities across trade sectors may explain differences in integration into the WTN; we are well aware of the importance of analyzing trade sectors individually and their value chains, and we plan to undertake that research path in the near future.

References

Arora, V., & Vamvakidis, A. (2005). Economic spillovers. *Finance and Development, 42*(3). https://www.imf.org/external/pubs/ft/fandd/2005/09/arora.htm

Awokuse, T. O., & Christopoulos, D. K. (2009). Nonlinear dynamics and the exports: output growth nexus. *Economic Modelling, 26*(1), 184-190. https://doi.org/10.1016/j.econmod.2008.06.009

Baldwin, R. (2011). *Trade and industrialisation after globalisation's 2nd unbundling: how building and joining a supply chain are different and why it matters*.. https://doi.org/10.3386/w17716

Beaton, K., Cebotari, A., & Komaromi, A. (2017a). *Revisiting the link between trade, growth, and inequality: lessons for Latin America and the Caribbean*. International Monetary Fund. https://www.imf.org/en/Publications/WP/Issues/2017/03/09/Revisiting-the-Link-between-Trade-Growth-and-Inequality-Lessons-for-Latin-America-and-the-44732

Beaton, K., Cebotari, A., Ding, X., & Komaromi, A. (2017b). *Trade integration in Latin America: a network perspective*. International Monetary Fund. https://www.imf.org/en/Publications/WP/Issues/2017/06/29/Trade-Integration-in-Latin-America-44971

Bonacich, P. (1972). Factoring and weighting approaches to status scores and clique identification. *Journal of Mathematical Sociology, 2*(1), 113-120. https://doi.org/10.1080/0022250X.1972.9989806

Börner, K., Sanyal, S., & Vespignani, A. (2007). Network science. *Annual Review of Information Science and Technology, 41*(1), 537-607. https://doi.org/10.1002/aris.2007.1440410119

Cardenas, E., Ocampo, J. A., & Thorp, R. (2000). *Industrialization and the state in Latin America: the post war years. An economic history of twentieth-century Latin America. Vol. 3*. Palgrave.

Cassi, L., Morrison, A., & Ter Wal, A. L. (2012). The evolution of trade and scientific collaboration networks in the global wine sector: a longitudinal study using network analysis. *Economic Geography, 88*(3), 311-334. https://doi.org/10.1111/j.1944-8287.2012.01154.x

Cepeda-López, F., Gamboa-Estrada, F., León, C., & Rincón-Castro, H. (2019). The evolution of world trade from 1995 to 2014: a network approach. *The Journal of International Trade & Economic Development, 28*(4), 1-34. https://doi.org/10.1080/09638199.2018.1549588

Criscuolo, C., & Timmis, J. (2018). The changing structure of global value chains: are central hubs key for productivity? *International Productivity Monitor,* (34), 64-80. https://EconPapers.repec.org/RePEc:sls:ipmsls:v:34:y:2018:4

De Backer, K., & Miroudot, S. (2014). Mapping global value chains. In R. A. Hernández, J. M. Martínez-Piva & N. Mulder (Eds.), *Global value chains and world trade* (pp. 43-78). ECLAC. https://repositorio.cepal.org/bitstream/handle/11362/37041/S2014061_en.pdf?sequence=1&isAllowed=y

De Benedictis, L., Nenci, S., Santoni, G., Tajoli, L., & Vicarelli, C. (2014). Network analysis of world trade using the BACI-CEPII dataset. *Global Economy Journal, 14*(3-4), 287-343. https://doi.org/10.1515/gej-2014-0032

Del Prete, D., Giovannetti, G., & Marvasi, E. (2017). Global value chains participation and productivity gains for North African firms. *Review of World Economics, 153*, 675-701. https://doi.org/10.1007/s10290-017-0292-2

Dingemans, A., & Ross, C. (2012). Free trade agreements in Latin America since 1990: an evaluation of export diversification. *CEPAL Review, 108*, 27-48. http://hdl.handle.net/11362/11602

Dollar, D. (1992). Outward-oriented developing economies really do grow more rapidly: evidence from 95 LDCs, 1976-85. *Economic Development and Cultural Change, 40*(3), 523-544. https://www.jstor.org/stable/1154574

Dollar, D., & Kraay, A. (2004). Trade, growth, and poverty. *The Economic Journal, 114*(4), 22-49. https://www.jstor.org/stable/3590109

Edwards, S. (1998). Openness, productivity and growth: what do we really know? *The Economic Journal, 108*(447), 383-398. https://www.jstor.org/stable/2565567

Eren, E., & Soyyigit, S. (2017). Network analysis of interbank cross-border flows at country level (2006-2015). *Press Academia. Procedia, 4*, 171-187. https://doi.org/10.17261/Pressacademia.2017.532

Fagiolo, G., Reyes, J., & Schiavo, S. (2010). The evolution of the world trade web: a weighted-network analysis. *Journal of Evolutionary Economics, 20*(4), 479-514. https://doi.org/10.1007/s00191-009-0160-x

Felbermayr, G. J. (2005). Dynamic panel data evidence on the trade-income relation. *Review of World Economics, 141*(4), 583-611. https://doi.org/10.1007/s10290-005-0046-4

Fernández-Stark, K., Bamber, P., & Gereffi, G. (2014). Global value chains in Latin America: a development perspective for upgrading. In R. A. Hernández, J. M. Martínez-Piva & N. Mulder (Eds.), *Global value chains and world trade* (pp. 79-106). ECLAC. https://repositorio.cepal.org/bitstream/handle/11362/37041/S2014061_en.pdf?sequence=1&isAllowed=y

Frankel, J. A., & Romer, D. (1999). Does trade cause growth? *American Economic Review, 89*(3), 379-399. https://doi.org/10.1257/aer.89.3.379

Garavito-Acosta, A., Montes-Uribe, E., Toro Córdoba, J. H., Agudelo-Rivera, C., Alfonso-Corredor, A. A., Carmona-Duarte, A. D., Collazos-Gaitán, M. M., González-Sabogal, C., Hernández-Bejarano, M. D., López-Valenzuela, D. C., Martínez-Osorio, A:, Rodríguez-Niño, N., Salamanca-Gil, S. I., Santos-Pena, J. C., & Zárate-Solano, H. M. (2020). Ingresos externos corrientes de Colombia: desempeño exportador, avances y retos. *Revista Ensayos sobre Política Económica, 95,* 1-81. https://doi.org/10.32468/espe.95

Garay, L. J., Quintero, L. F., Villamil, J. A., Tovar, J., Fatat, A., Gómez, S., Restrepo, E., & Yemail, B. (1998). *Colombia: estructura industrial e internacionalización 1967-1996*. Departamento Nacional de Planeación.

García, J., Collazos, M. M., & Montes, E. (2015). *Las instituciones en el sector externo colombiano: ¿apoyo o escollo al comercio?* Banco de la República.

https://www.banrep.gov.co/sites/default/files/publicaciones/archivos/be_889.pdf

García, J., López, C., Montes, E., & Esguerra, P. (2014). *Una visión general de la política comercial colombiana entre 1950 y 2012*. Banco de la República. https://www.banrep.gov.co/sites/default/files/publicaciones/archivos/be_817.pdf

Gaulier, G., & Zignago, S. (2010). *BACI: international trade database at the product-level, the 1994-2007 version*. CEPII. http://www.cepii.fr/PDF_PUB/wp/2010/wp2010-23.pdf

Gereffi, G. (1999). International trade and industrial upgrading in the apparel commodity chain. *Journal of International Economics, 48*(1), 37-70. https://doi.org/10.1016/S0022-1996(98)00075-0

Giovannetti, G., Marvasi, E., & Sanfilippo, M. (2015). Supply chains and the internationalization of small firms. *Small Business Economics, 44*, 845-865. https://doi.org/10.1007/s11187-014-9625-x

Giri, R., Quayyum, M. S. N., & Yin, R. (2019). *Understanding export diversification: key drivers and policy implications*. International Monetary Fund. https://www.imf.org/en/Publications/WP/Issues/2019/05/14/Understanding-Export-Diversification-Key-Drivers-and-Policy-Implications-46851

Grossman, G. M., & Rossi-Hansberg, E. (2008). Trading tasks: a simple theory of offshoring. *American Economic Review, 98*(5), 1978-1997. https://www.princeton.edu/~grossman/TradingTasks.pdf

Hernández, R. A., Martínez-Piva, J. M., & Mulder, N. (2014). *Global value chains and world trade: prospects and challenges for Latin America*. ECLAC. https://repositorio.cepal.org/bitstream/handle/11362/37041/S2014061_en.pdf?sequence=1&isAllowed=y

Jaramillo, L. F. (2004). El estado de la infraestructura en Colombia frente al reto de la globalización. *Poliantea, 1(2)*, 129-152. https://doi.org/10.15765/plnt.v1i2.362

Kali, R., & Reyes, J. (2007). The architecture of globalization: a network approach to international economic integration. *Journal of International Business Studies, 38*(4), 595-620. https://www.jstor.org/stable/4540445

Kastelle, T., & Liesch, P. W. (2013). The importance of trade in economic development: Australia in the international trade network. *International Studies of Management & Organization, 43*(2), 6-29. https://doi.org/10.2753/IMO0020-8825430201

Kleinberg, J. M. (1999). Authoritative sources in a hyperlinked environment. *Journal of the ACM (JACM), 46*(5), 604-632. https://doi.org/10.1145/324133.324140

Kónya, L. (2006). Exports and growth: Granger causality analysis on OECD countries with a panel data approach. *Economic Modelling, 23*(6), 978-992. https://doi.org/10.1016/j.econmod.2006.04.008

Krueger, A. (1998). Why trade liberalisation is good for growth. *The Economic Journal, 108*(450), 1513-1522. https://www.jstor.org/stable/2566196

Langville, A. N., & Meyer, C. D. D. (2012). *Google's pagerank and beyond: the science of search engine rankings*. Princeton University Press.

León, C., Machado, C., & Sarmiento, M. (2018). Identifying central bank liquidity super-spreaders in interbank funds networks. *Journal of Financial Stability, 35,* 75-92. https://doi.org/10.1016/j.jfs.2016.10.008

López, C., López, E., & Montes, E. (2015). *Colombia en el comercio mundial (1992-2012): desempeño de las exportaciones colombianas.* Banco de la República. https://www.banrep.gov.co/sites/default/files/publicaciones/archivos/be_885.pdf

Montezuma, R. (2008). Infraestructura: los retos de Colombia. *Documentos de política pública: Piensa Colombia, 1.*

Newman, M. E. J. (2010). *Networks: an introduction*. Oxford University Press.

Ocampo, J. A. (1997). Una década de grandes transformaciones, 1986-1995. *Ibero-amerikanisches Archiv, 23*(1/2), 183-211. https://www.jstor.org/stable/43392756

Ocampo, J. A., Romero, A., & Parra, M. (2007). La búsqueda, larga e inconclusa, de un nuevo modelo (1981-2006). En J. A. Ocampo (Comp.), *Historia económica de Colombia* (pp. 341-418). Planeta-Fedesarrollo.

Organization for Economic Cooperation and Development (OECD). (2017). *Sectoral analysis of global value chains and developing countries*. OECD.

Organization for Economic Cooperation and Development (OECD). (2019). *OCDE economic surveys: Colombia 2019*. https://doi.org/10.1787/e4c64889-en

Ospina, B. (2013). *Impacto de la apertura en la conectividad e integración de Colombia en la red mundial del comercio* [tesis de grado, Universidad del Rosario]. https://doi.org/10.48713/10336_4545

Reyes, J., Schiavo, S., & Fagiolo G. (2010). Using complex networks analysis to assess the evolution of international economic integration: the cases of East Asia and Latin America. *Journal of International Trade and Economic Development, 19(2)*, 215-239. https://doi.org/10.1080/09638190802521278

Serrano, A., & Boguñá, M. (2003). Topology of the world trade web. *Physical Review E, 68*(1), 015101. https://doi.org/10.1103/PhysRevE.68.015101

Soyyigit, S., & Yavuzaslan, K. (2018). Complex network analysis of international olive oil market. *Turkish Journal of Agricultural Economics, 24*(2), 117-129. https://doi.org/10.24181/tarekoder.453488

Soyyigit, S., & Boz, C. (2017). Global input-output analysis: a network approach. *Yildiz Social Science Review, 24*(2), 89-102. https://yssr.yildiz.edu.tr/article/22

Stiglitz, J. E. (1998). *Towards a new paradigm for development: strategies, policies, and processes*. UNCTAD.

Tinta, A. A., Sarpong, D. B., Ouedraogo, I. M., Al Hassan, R., Mensah-Bonsu, A., & Ebo Onumah, E. (2018). The effect of integration, global value chains and international trade on economic growth and food security in ECOWAS. *Cogent Food & Agriculture, 4*(1). https://doi.org/10.1080/23311932.2018.1465327

Villar, L., & Esguerra, P. (2007). El comercio exterior colombiano en el siglo XX. En J. Robinson & M. Urrutia, *Economía colombiana del siglo XX: un análisis cuantitativo* (pp. 1-53). Banco de la República-Fondo de Cultura Económica.

Villar, L., & Rincón, H, (2003). Capital flows and foreign exchange regimes in the Colombian economy. In A. Berry & G. Indart (Eds.), *Critical issues in international financial reform*. Transaction Publishers.

Xu, H., & Qin, J. (2015). The structure and nodes' role of the world coal trade network. *Journal of Chinese Economic and Business Studies, 13*(1), 33-49. https://doi.org/10.1080/14765284.2014.994848

Yepes, T., Ramírez J. M., Villar, L., & Aguilar, J. (2013). Infraestructura de transporte en Colombia. *Cuadernos de Fedesarrollo, 46*. https://www.repository.fedesarrollo.org.co/bitstream/handle/11445/153/CDF_No_46_Julio_2013.pdf?sequence=3&isAllowed=y

Appendix A1. Total Exports and Exports of Minerals, Fuels, and Metals, 2018

(USD million)

Country	Minerals	Fuels	Metals	Total
Brazil	24366	31756	17609	**239888**
Chile	21419	666	19202	**75482**
China	4975	46630	186291	**2494230**
Colombia	80	24225	1494	**41832**
Mexico	6307	29706	19214	**450532**
Peru	18169	4268	3926	**47894**
United States	10388	192681	73520	**1665303**

Source: The World Bank and authors' calculations.

(Percentage of total exports)

Country	Minerals	Fuels	Metals	Total
Brazil	10.2	13.2	7.3	**30.7**
Chile*	28.4	0.9	25.4	**54.7**
China	0.2	1.9	7.5	**9.5**
Colombia**	0.2	57.9	3.6	**61.7**
Mexico	1.4	6.6	4.3	**12.3**
Peru***	37.9	8.9	8.2	**55.0**
United States	0.6	11.6	4.4	**16.6**

* Mainly copper, molybdenum, gold, iron, manganese, lead, and zinc.
** Mainly oil, coal, gold, and ferronickel.
*** Mainly copper, gold, and zinc.

Source: The World Bank and authors' calculations.

Appendix A2. Network Centrality Analysis Formulae

Network centrality analysis formulae

$k_i^{in} = \sum_{j=1}^{n} A_{ji}$	$k_i^{out} = \sum_{j=1}^{n} A_{ji}$
In-degree	Out-degree
$s_i^{in} = \sum_{j=1}^{n} W_{ji}$	$s_i^{out} = \sum_{j=1}^{n} W_{ji}$
In-strength	Out-strength
$a = \Gamma^1 (W^T W)$	$h = \Gamma^1 (W W^T)$
Authority	Hub

$$TII_i \frac{\frac{a_i}{\sum_{i=1}^{n} a_i} \times \frac{h_i}{\sum_{i=1}^{n} h_i}}{\sum_{i=1}^{n} \left(\frac{a_i}{\sum_{i=1}^{n} a_i} \times \frac{h_i}{\sum_{i=1}^{n} h_i} \right)}$$

Trade Integration Index

Where,

1. A_{ij} is a directed adjacency matrix, $A_{ij} = \begin{Bmatrix} 1 \text{ if there is an export from } i \text{ to } j, \\ 0 \text{ otherwise.} \end{Bmatrix}$
2. W_{ij} is a directed and weighted adjacency matrix
3. n is the number of participants in the network
4. Γ^1 is the first (principal) eigenvector (*i. e.*, column vector) of matrix Σ, in which $\Sigma = \Gamma \Lambda \Gamma^T$
5. $0 \leq TII_i \leq 1$
6. $\sum_{i=1}^{n} TII_i = 1$

Source: Authors' design, based on Bonacich (1972), Newman (2010), and León et al. (2018).

Appendix A3. Degree, Strength, and Hub and Authority Centrality after Excluding Minerals, Fuels, and Metals

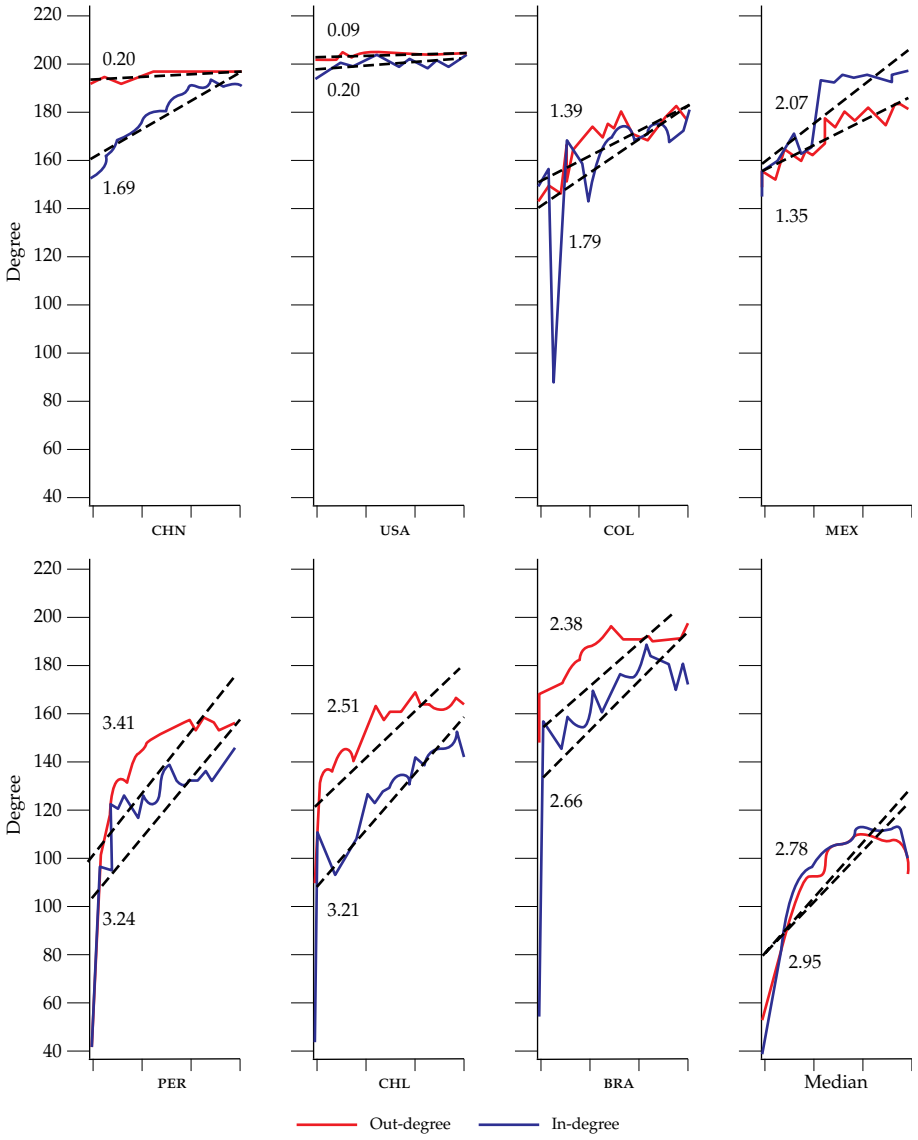

Figure A1. Evolution of Out- and In-Degree in US Dollars (or Tons) from 1996 to 2018, Excluding Minerals, Fuels, and Metals

The dashed line corresponds to the linear regression on time series as a representation of their trend; the regression is in its standard form $y = \alpha + \beta t$, where t corresponds to time (horizontal axis) and y to the centrality measure (vertical axis), and the slope (β) is reported for comparison purposes. The median is calculated on the 209-country sample.

Source: Based on BACI.

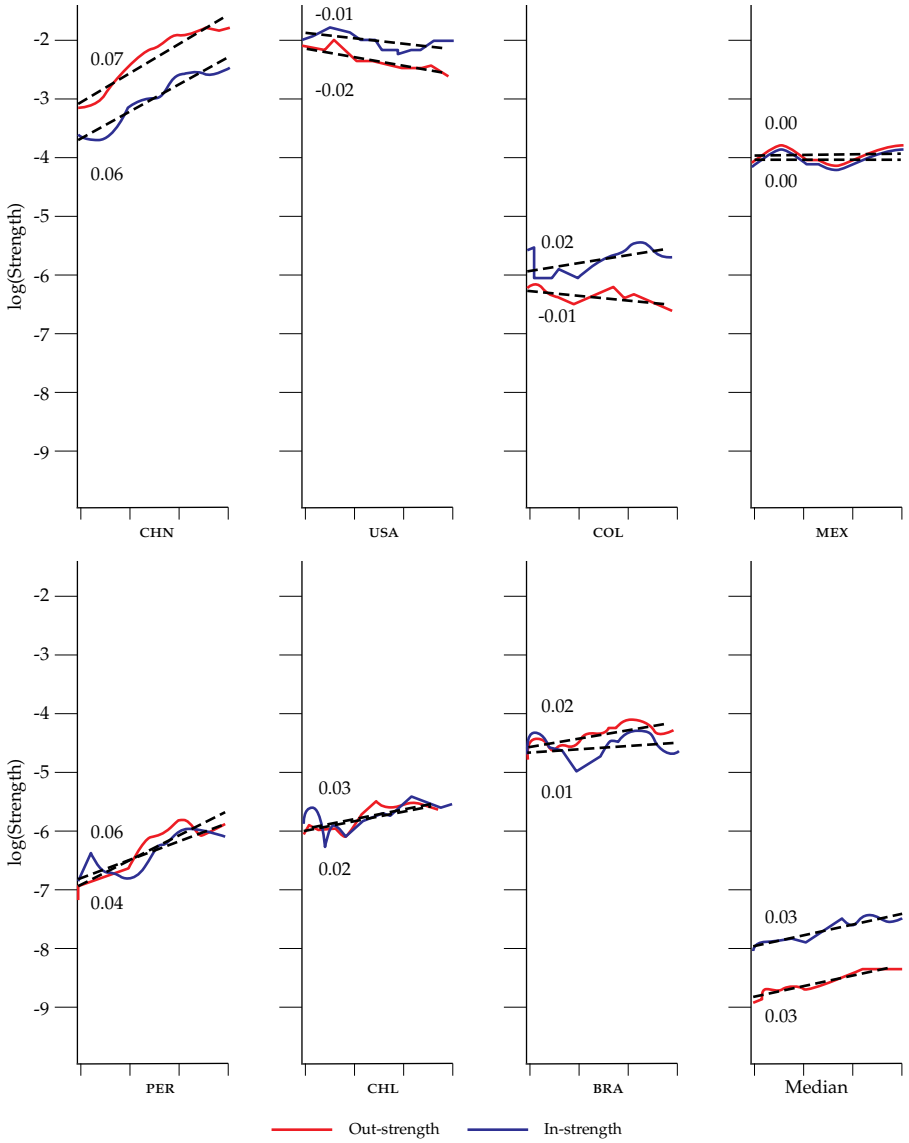

Figure A2. Evolution of Out- and In-Strength in US Dollars from 1996 to 2018, Excluding Key Minerals, Fuels, and Metals

The dashed line corresponds to the linear regression on time series as a representation of their trend; the regression is in its standard form $y = \alpha + \beta t$, where t corresponds to time (horizontal axis) and y to the centrality measure (vertical axis), and the slope (β) is reported for comparison purposes. The vertical axis has been transformed into its logarithm for readability issues. The median is calculated on the 209-country sample.

Source: Based on BACI.

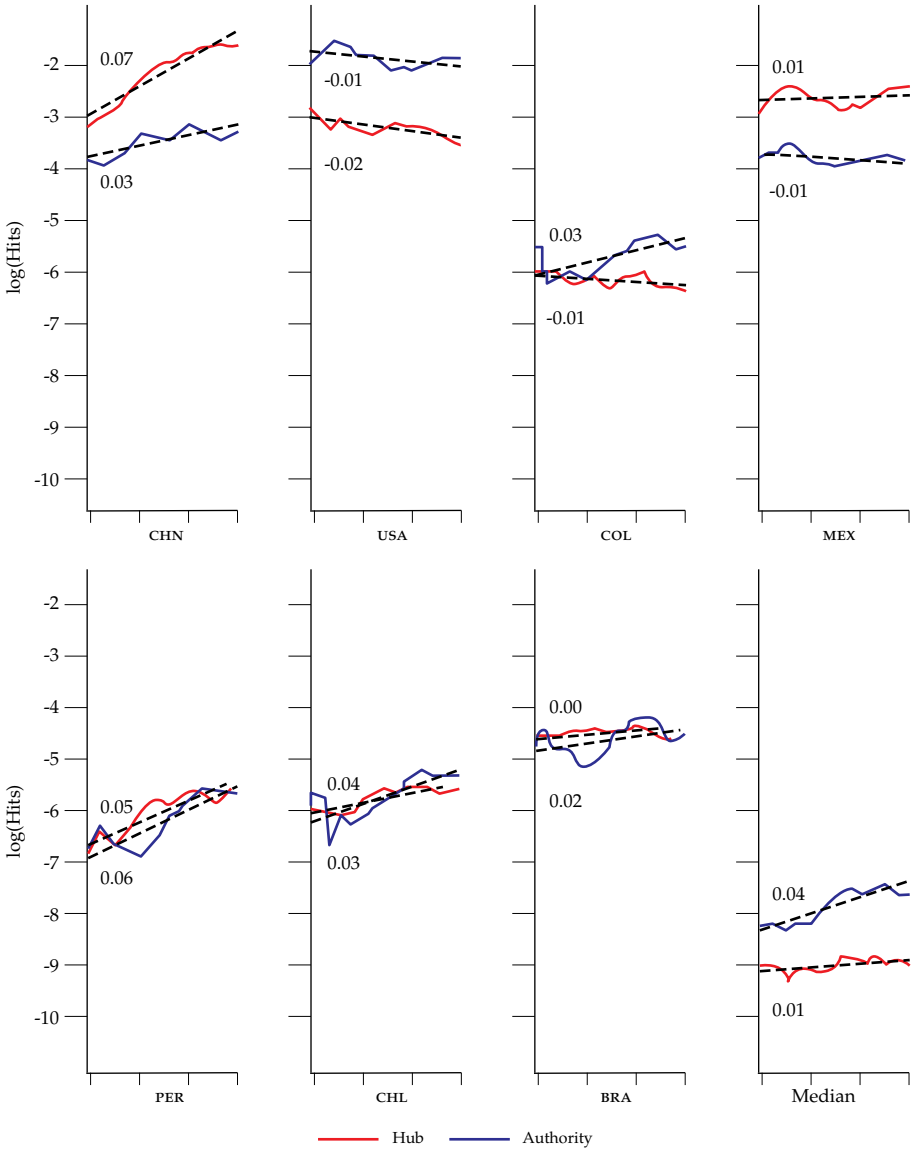

Figure A3. Evolution of Hub and Authority Centrality in US Dollars from 1996 to 2018, Excluding Key Minerals, Fuels, and Metals

The dashed line corresponds to the linear regression on time series as a representation of their trend; the regression is in its standard form $y = \alpha + \beta t$, where t corresponds to time (horizontal axis) and y to the centrality measure (vertical axis), and the slope (β) is reported for comparison purposes. The vertical axis has been transformed into its logarithm for readability issues. The median is calculated on the 209-country sample.

Source: Based on BACI.

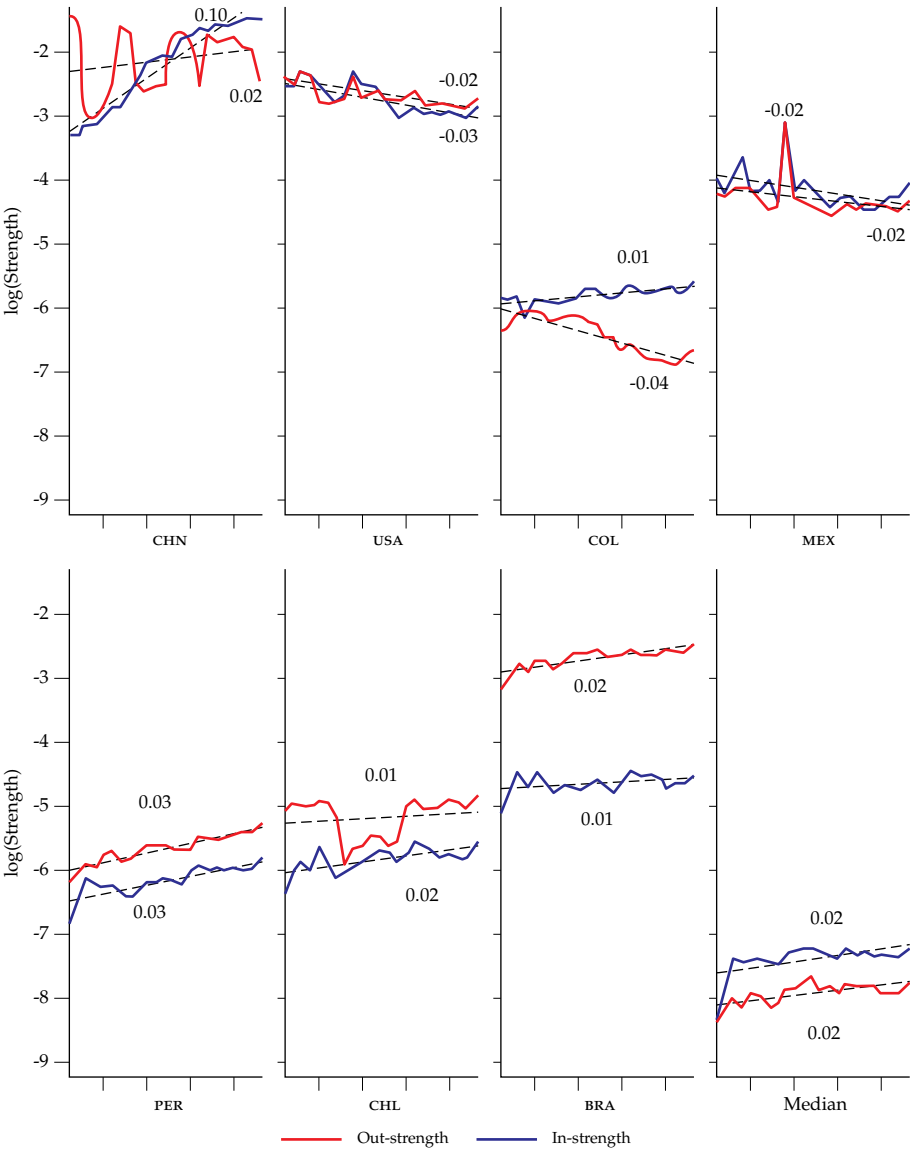

Figure A4. Evolution of Out- and In-Strength in Tons from 1996 to 2018, Excluding Minerals, Fuels, and Metals

The dashed line corresponds to the linear regression on time series as a representation of their trend; the regression is in its standard form $y = \alpha + \beta t$, where t corresponds to time (horizontal axis) and y to the centrality measure (vertical axis), and the slope (β) is reported for comparison purposes. The vertical axis has been transformed into its logarithm for readability issues. The median is calculated on the 209-country sample.

Source: Based on BACI.

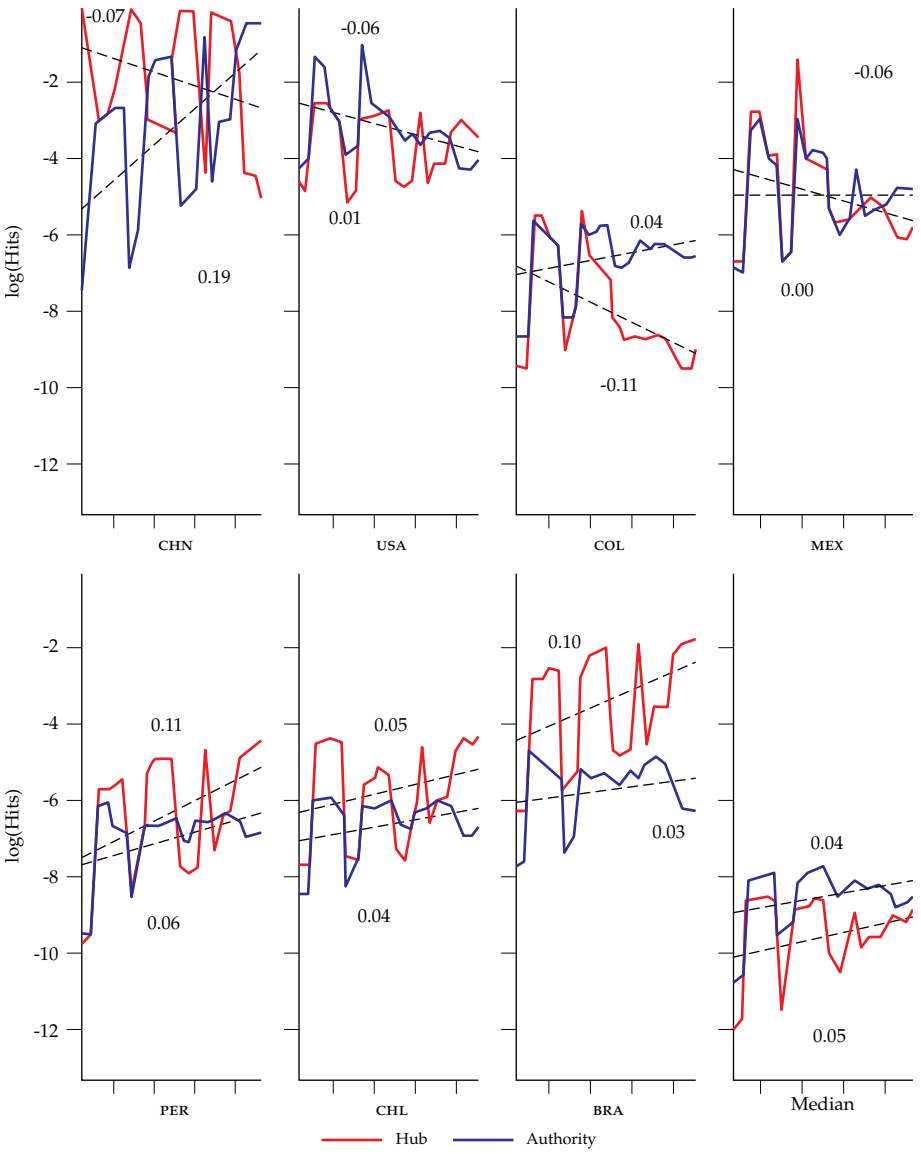

Figure A5. Evolution of Hub and Authority Centrality in Tons from 1996 to 2018, Excluding Minerals, Fuels, and Metals

The dashed line corresponds to the linear regression on time series as a representation of their trend; the regression is in its standard form $y = \alpha + \beta t$, where t corresponds to time (horizontal axis) and y to the centrality measure (vertical axis), and the slope (β) is reported for comparison purposes. The vertical axis has been transformed into its logarithm for readability issues. The median is calculated on the 209-country sample.

Source: Based on BACI.