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Colombian liberalization and integration into world trade markets: Much ado about nothing

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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 achieve our objective by measuring Colombia's importance in the world trade network—by value (US dollars) and volume (tons). We employ several types of network centrality metrics to measure importance (i.e. degree, strength, hub, authority), and examine their dynamics against a set of regional peers that serve as benchmark countries. Consistent with previous literature, more than two decades of dedicated trade policies and institutional changes resulted in increased value and volume of exports and imports. However, when compared with regional peers such as Chile, Brazil, Mexico, and Peru, and China and the United States as trade leading countries, Colombia's centrality in the world trade network did not improve accordingly. Further, excluding a set of key commodities across the world trade network (i.e. minerals, fuels, and metals) resulted in a noticeable worsening in Colombia's centrality. We conclude that Colombia's centrality in the world trade network did not improve, whereas that of some of her regional peers did manifestly (i.e. Peru and Chile). Results highlight the perils of analyzing a country's trade dynamics in isolation and emphasizes the usefulness of examining the world trade network. From the economic policy and institutional perspectives, results underscore the challenges ahead to better integrate into world markets and to achieve long-term economic growth from trade.

Classification JEL. F14, F15, C45, C63.

Keywords. Colombia, foreign trade, centrality, network analysis, world trade network.

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

Resumen

El objetivo del artículo es estudiar la evolución de la apertura e integración de Colombia al comercio mundial entre 1996 y 2018. Logramos el objetivo al medir la importancia del país en la red de comercio mundial en valores (dólares de los Estados Unidos) y volúmenes (toneladas). Empleamos varios tipos de métricas de centralidad de red (grado, valor de los flujos de comercio, centro, autoridad) y examinamos su dinámica en comparación con las de pares regionales que sirven como países de referencia. De acuerdo con la literatura colombiana previa, más de dos décadas de políticas comerciales y cambios institucionales resultaron en un aumento del valor y volumen de las exportaciones e importaciones. Sin embargo, en comparación con Brasil, Chile, México y Perú, y China y Estados Unidos como países líderes en el comercio mundial, la centralidad de Colombia en la red mundial no mejoró de manera acorde. Más aún, si se excluye un grupo selecto de bienes primarios (minerales, combustibles y metales), la centralidad de Colombia se deteriora. Concluimos que la centralidad del país en la red mundial de comercio no mejoró, mientras que la de algunos de sus pares regionales lo hizo de manera notable (Perú y Chile). Los resultados también resaltan los inconvenientes de analizar aisladamente la dinámica de comercio de un país y enfatizan la utilidad de examinarlos a la luz de la red mundial de comercio. Desde la perspectiva de la política comercial y el marco institucional, los resultados revelan los desafíos de Colombia para integrarse mejor en los mercados mundiales y lograr un mayor crecimiento económico de largo plazo que tenga como fuente el comercio internacional.

Código JEL. F14, F15, C45, C63.

Palabras clave. Colombia, comercio exterior, centralidad, análisis de redes, red de comercio mundial.

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Introduction

Trade liberalization and the fragmentation of production across countries are two fundamental changes that have reshaped world trade in the last decades (Hernández, Martínez Piva, & Mulder, 2014). Regarding trade liberalization, evidence on international trade as one of the engines of economic growth is abundant.[1] Likewise, there is evidence of a positive relationship between participating in *global value chains*[2]—that result from the transnational fragmentation of production—and higher productivity at the country and firm-level.[3]

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, Colombia 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, Ocampo, & Thorp, 2000; Villar & Esguerra, 2007).

It can be claimed that Colombian trade policies, institutional changes, and outsprint of the mineral products since the nineties, achieved the objective of increasing exports and imports. As exhibited in Figure 1, despite some recent periods of downturn (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 achieve a more prominent role of trade for the economy.

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

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[1] See Dollar (1992), Krueger (1998), Edwards (1998), Stiglitz (1998), Frankel and Romer (1999), Dollar and Kraay (2004), Arora and Vamvakidis (2005), Felbermayr (2005), Kónya (2006), Awokuse and Christopoulos (2009), and Beaton, Cebotari, and Komaromi (2017).

[2] As in Del Prete, Giovannetti, and Marvasi (2017), *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 assembled either sequentially along the chain or in a final location. Alternatively, Grossman & Rossi-Hansberg (2008) describe this fragmentation process as the production and specialization in trading *tasks* rather than goods.

[3] See Gereffi (1999), Giovannetti, Marvasi, and Sanfilippo (2015), Criscuolo and Timmis (2018), Del Prete et al. (2017), and OECD (2017).

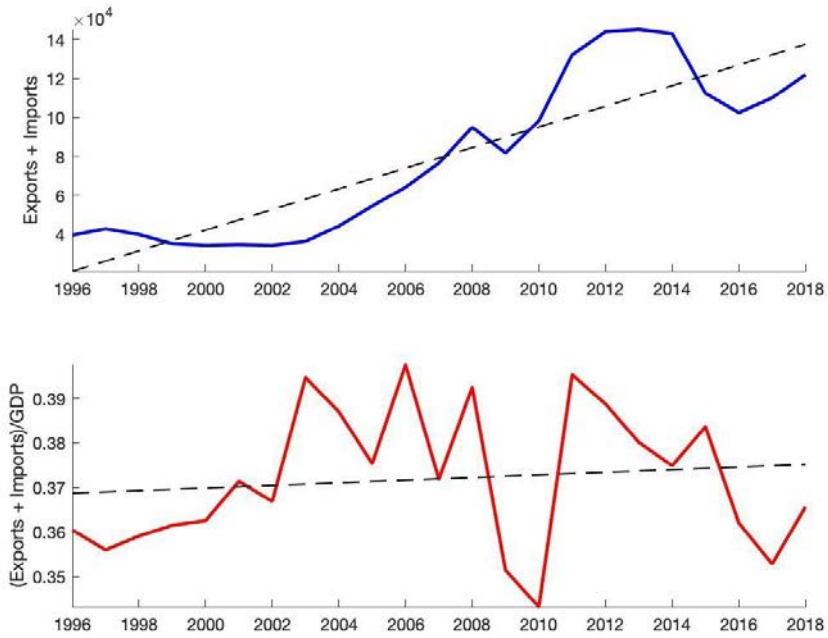

Figure 1. Evolution of Colombian trade, 1996-2018. The upper panel corresponds to the sum of exports and imports FOB measured in millions of US dollars. The lower panel corresponds to the ratio of exports and imports to Gross Domestic Product. The dashed lines correspond to the linear regression on time 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 trade statistic (vertical axis). Source: authors' calculations, based on DANE.

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, Reyes, and Schiavo (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.[4] We measure a country's importance in the WTN through calculating its network centrality. To gain further insights about the performance of Colombia in the WTN, our work comprises three main features: first, we compare Colombia's centrality with a set of regional peers (i.e. Brazil, Chile, Mexico, Peru), the median of countries in the WTN, and with China and the United States as trade

[4] 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. Fagiolo et al. (2010), Reyes, Schiavo, and Fagiolo (2010), and Kali and Reyes (2007) argument other benefits of applying network analysis to study world trade.

leading countries. Second, we build two different WTNs, namely by value (in US dollars) and by volume (in tons)—thus addressing issues related to price effects in our results. Third, by excluding a set of key commodities, we study how results are dependent on minerals, fuels, and metals—which are particularly contributive to Colombia's and her peers' exports.

Thus, this article addresses four questions regarding Colombia's liberalization and integration into world trade markets. First, how has the relative importance of Colombia in the WTN evolved? Second, how does Colombia rank against a benchmark comprising some of her regional peers and other trade-leading countries? Third, how dependent Colombia's centrality is on her key exports? Fourth, 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 in the WTN did not improve substantially or even deteriorated, whereas Chile and Peru improved remarkably. This is even clearer when a set of key commodities is excluded from the WTN. Consequently, not only the importance of Colombia in the WTN did not increase greatly but also that from her peers did manifestly.

There are several contributions from our work. First, it further exploits network analysis techniques on the WTN. Most literature on the analysis of the WTN examines its main connective features.[5] We add to the WTN literature by studying how individual countries evolve as elements of the trade network.[6] 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), our results attain an enhanced evaluation of the public policies and institutional changes implemented to further integrate Colombia 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; this counters issues related to price effects in our results. Fourth, taking into account that the emergence of global value chains has accompanied the integration of the world, we measure to what extent Colombia is important as an exporter to (importer from) key global buyers (suppliers) in the WTN.[7] Fifth, based on network centrality measures that capture global importance,

[5] See Serrano and Boguñá (2003), Kali and Reyes (2007), Fagiolo et al. (2010), Reyes et al. (2010), Cassi, Morrison, and Ter Wal (2012), De Benedictis, Nenci, Santoni, Tajoli, and Vicarelli (2014), Xu and Qin (2015), Cepeda-López, Gamboa-Estrada, León, and Rincón-Castro (2018).
[6] Alongside Fagiolo et al. (2010), Ospina (2013), Kastelle and Liesch (2013), Beaton, Cebotari, Ding, and Komaromi (2017), and Soyyigit and Yavuzaslan (2018).
[7] On the importance of global value chains on nowadays trade, see Baldwin (2011), Hernández et al. (2014), Fernández-Stark, Bamber, and Gereffi (2014), and Tinta et al. (2019).

we build a Trade Integration Index that enables 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 key 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 she can reach it. Colombia's increase in the number of trade partners and the value of trade with key 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.[8] 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 trade policies towards openness and integration in the last decades. 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, Ocampo, & Thorp, 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).[9] As a consequence, average nominal protection decreased from 44 percent to 12 percent

[8] See Jaramillo (2004), García, López, Montes, and Esguerra (2014), García, Collazos, and Montes (2015), López et al. (2015), OECD (2019), and Garavito-Acosta et al. (2020).

[9] The first wave of Colombian trade openness dates back to the end of the sixties until the beginning of the seventies. It was reverted from 1982 to 1986. Thus, at the end of the eighties, the average nominal protection on potential imports reached 44 percent (Ocampo, Romero, & Parra, 2007).

between 1989 and 1992. Also, export subsidies shrank from 22 percent in 1989 to 7 percent in 1994 and 4 percent in 2006 (Ocampo, Romero, & Parra, 2007).[10]

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, as exhibited in Table 1.[11]

Nevertheless, these efforts towards 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 percent 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.

[10] Nevertheless, two of the most important exceptions were agriculture and livestock, agroindustry and automobile sectors. Circa 1993, the first two sectors were protected with *price bands* that were adjusted depending on foreign competition. In the automobile sector, the tariff for finished cars was set at 35 percent compared with a zero tariff for vehicles to assemble.

[11] Empirical evidence regarding world trade integration of Latin America reveals that these agreements usually ratify existing ties between members as they are signed between traditional regional partners, and they had little effect on the productive structure of the export sector with limited expansion to new markets (Dingemans & Ross, 2012).

Agreement	Countersigner(s)	Signed / Expiration
Andean Free Trade Zone[a]	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 Agreement[b]	Chile	2006
Free Trade Agreement	Guatemala, Honduras, and Salvador	2007
Free Trade Agreement	Canada	2008[c]
Free Trade Agreement	Switzerland[c], Liechtenstein[c], Norway[d], and Iceland[d]	2008
Free Trade Agreement	United States	2011[e]
Free Trade Agreement	European Union and Peru	2012[f]
Pacific Alliance	Chile, México, and Peru	2012[g]
Free Trade Agreement	South Korea	2013[h]
Free Trade Agreement	Costa Rica	2013[h]

Table 1. Colombian bilateral and multilateral trade agreements. [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. Source: authors' elaboration.

Second, the quality of institutions and infrastructure was an obstacle to trade.[12] 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, Ramírez, Villar, & Aguilar, 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.[13] 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

[12] By *institution* we refer to the "system of rules, beliefs, norms, and organizations that together generate a regularity of (social) behavior" (Greif, 2006, p. 30).

[13] 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.

and infrastructural issues have been an important barrier to Colombian trade and integration into world markets.

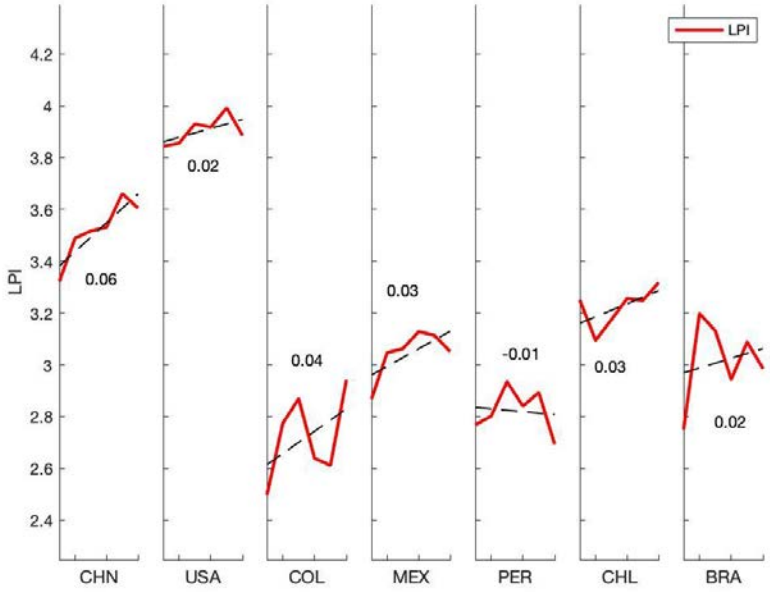

Figure 2. Logistics Performance Index (LPI), 2007-2018. Due to availability limitations, data corresponds to the years 2007, 2010, 2012, 2014, 2016, 2018 (in the horizontal axis). The higher the index, the higher the performance in trade logistics. The dashed lines correspond to the linear regression 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: authors' elaboration, based on World Bank data.

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.[14] For instance, while the average border compliance time to export in Colombia is 112 hours, in Brazil, Chile, Mexico, and Peru it is 49 hours, 60 hours, 20 hours, 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.

[14] Brazil, Chile, Mexico, and Peru ranked in the 108th place, the 73rd place, the 69th place, and the 102th position, respectively. The database is available in https://www.doingbusiness.org.

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 his position in the WTN. Moreover, this author argued that while trade agreements increased trade channels, they did not imply large flows or higher productivity transfers, because they were scarcely implemented with key global importers and exporters—with the notable exception of the United States, which concentrated a large amount of Colombian imports and exports.

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 percent and 13 percent of total exports, respectively, whereas those of primary products—mostly minerals, fuels and metals—and manufactured goods based on natural resources representing about 70 percent.[15] 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, Quayyum, & Yin, 2019).

2 Methodology and data

First, we present network notation and centrality measures. We emphasize on why those measures matter for assessing and analyzing the evolution of Colombia's importance in the WTN and—thus—her 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, Sanyal, & Vespignani, 2007). As countries and their exports and imports conform to a system, network analysis has been used to further understand the system of international trade.

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

[15] The percentage participation of minerals, fuels, and metals is reported in Appendix A.1.

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

If A_{ij} is equal to 1, there is an export from i to j, irrespective of the value of exports. The weighted adjacency matrix W, with elements W_{ij}, 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 $\overline{W}$ (2), with elements $\overline{W}_{ij}$ 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 $\overline{W}_{ij}$ will employ a logarithmic transformation.

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

Related literature studies the structure and evolution of the WTN—as previously referenced. Instead, we study how countries' importance in the WTN has evolved. We focus our study 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 and/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 the network.

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 focus 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.[16] The three algorithms are presented next—their formulae are exhibited in Appendix A.2.

- 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 calculate in-degree (k_i^{in}) and out-degree

[16] We discarded centrality measures based on the in-between role of nodes in a network (i.e. *betweenness centrality*), distance between nodes (i.e. *closeness centrality*) or *random walk betweenness centrality* (see Fagiolo, Reyes, & Schiavo, 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, Gamboa-Estrada, León, & Rincón-Castro, 2018), 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).

(k_i^{out}) to quantify the number of 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 consider the importance of adjacent nodes as an importance factor –thus, it is regarded as a *local* centrality measure.

- Strength: Based on the weighted adjacency matrix $\overline{W}_{ij}$, it measures the intensity of trade for node *i*. We calculate in-strength (s_i^{in}) and out-strength (s_i^{out}) to quantify the intensity of the incoming (imports) and departing (exports) linkages. In our case, the intensity comes in two distinct forms, namely the value (in US dollars) and the volume (in tons) of trade. Akin to degree, strength is a local measure—the importance of adjacent nodes is 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 originator of links (i.e. as exporter) and as global receiver of links (i.e. as importer). Hub centrality of node *i* is defined to be proportional to the weighted sum of the authority of the countries it exports-to, whereas authority centrality of node *i* is 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 as 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 to global buyers and global suppliers in value-added production networks is key to economic integration.[17] In our view, hub and authority centrality fits Fagiolo, Reyes, and Schiavo (2010) claim for an integration measure

[17] 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 global buyers and global suppliers that are dominant (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 World Trade Organization Trade in Value-Added (TiVA) indicators. From a methodological viewpoint, 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.

that not only captures how much a country trades but also the specific distribution of trade across direct and indirect- trading partners.[18]

Our choice of algorithms and centrality measures enable us to cover three important dimensions of a country in the WTN. First, degree measures how many connections a country has, and how contributive those connections are to the total connections 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 are those connections to world trade. A country pursuing an integrated economy will not only increase the number of 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 how important a country is 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 exporter to key importers, importer from key exporters, or both.[19]

Therefore, we use these three dimensions to assess whether Colombia is more integrated to the WTN or not. 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.

2.2 Data

We use the free-on-board (FOB) value of exports of the BACI dataset. It is 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 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 their COMTRADE database.[20] We use the dataset starting in 1996 and ending in 2018. We exclude

[18] 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, Machado, & Sarmiento, 2018).
[19] As reported in 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).
[20] BACI database is available for free upon request (http://cepii.fr/CEPII/en/bdd_modele/download.asp). BACI classifies products by the 6-digit Harmonized System (HS), which allows participating countries to classify

countries that do not have trade data reported for a given year.[21] We do not filter trade data based on its contribution to world trade or country's economic size (as in Kali & Reyes, 2007).

After we process the data from BACI, we attain one adjacency matrix (A) and two weighted adjacency ($\overline{W}$) matrices—by value and volume.[22] 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 report results according to the three algorithms presented before (i.e. degree, strength, and HITS). They correspond to the three importance dimensions aforementioned, namely the number of connections, their intensity, and the weighted importance of countries at the end of those connections.

We discuss the importance of Colombia in the WTN and its evolution from 1996 to 2018. We compare 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. United States and China) or because they are regional peers of Colombia. Among those regional peers, we consider countries that are similar in size (Chile), larger (Mexico and Brazil), and smaller (Peru).[23] Besides, we compare Colombia's importance with the median of all countries in the WTN.

3.1 Degree centrality

In-degree (k_i^{in}) and out-degree (k_i^{out}) quantify the number of countries a country imports from and exports to, respectively. As portrayed in Figure 3, Colombia's centrality measured by her in-degree in the WTN shows that the number of countries exporting to Colombia has increased along the period

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 use the 1996's revision, which provides the longest and more complete dataset.

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

[22] Regarding trade by volume, most customs statistics report quantities in tons. However, about 15 percent are detailed in other units of measure (units, meters, square meters, watts, etc). 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).

[23] Based on World Bank figures, as of 2018, Chile's GDP (U$ 298 billion) was about .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.

albeit marked decreases in 1998 and 2003. Colombia's number of exports and imports counterparties has 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 her peers—as evident from the linear trend's slope.

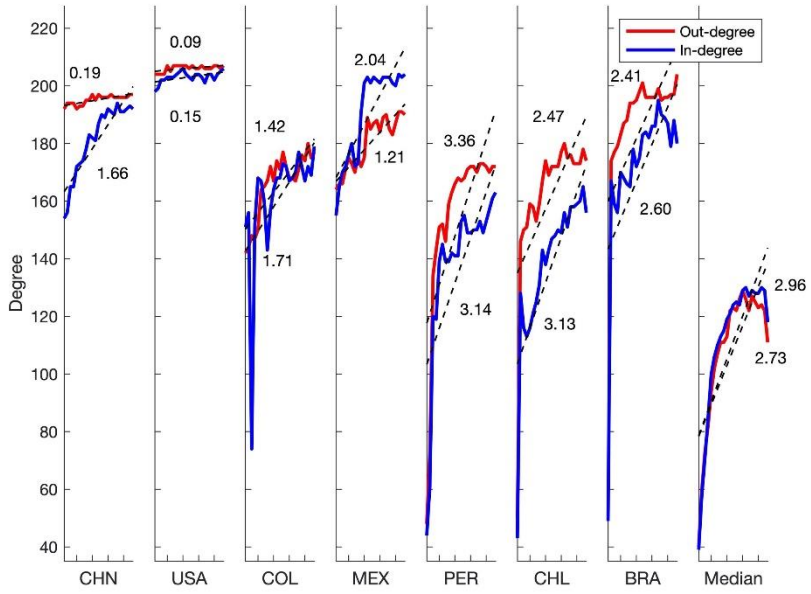

Figure 3. Evolution of out- and in-degree, in US dollars (or tons) from 1996 to 2018. The dashed line corresponds to the linear regression on time series as a representation of their trend; the regression is in its standard form $y = \alpha + \beta t$, where t corresponds to time (horizontal axis) and y to the centrality measure (vertical axis), and the slope (β) is reported for comparison purposes. The median is calculated on the 209-country sample. Source: authors' calculations, based on BACI.

Comparatively, at the end of the period under analysis, Colombia's in-degree is 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 is visibly slower than that of her peers and the median of all countries. As expected, in-degree of China and the United States is higher.

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

Overall, it is noticeable that Colombia did increase the number of countries that she 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 to achieve more trading partners amid the trade liberalization

process that has been 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 her peers, Colombia, displays the slightest increase in the number of countries from which she imports from (i.e. in-degree).

3.2 Strength centrality

In-strength (s_i^{in}) and out-strength (s_i^{out}) 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) both display a minor upward trend. Nevertheless, the upward trend in out-strength hinders that from beginning to end of the period under analysis the contribution to the total value of exports declined. By the end of the period under analysis, the contribution of Colombian exports and imports to global trade by value is similar to that of Peru. All other regional peers (Chile, Mexico, and Brazil) have contributions to the WTN higher than that of Colombia. Well above Colombia and her regional peers, China exhibits a remarkable increase in her contribution to total imports and exports, whereas that of the United States remains high despite it has a 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 for China, behaved as net exporters since the out-strength measure exceeded the in-strength measure. In the case of Colombia, this pattern is not fulfilled and reveals for the last years an important trade deficit. For the United States, it reflects its role as a net importer throughout the sample.

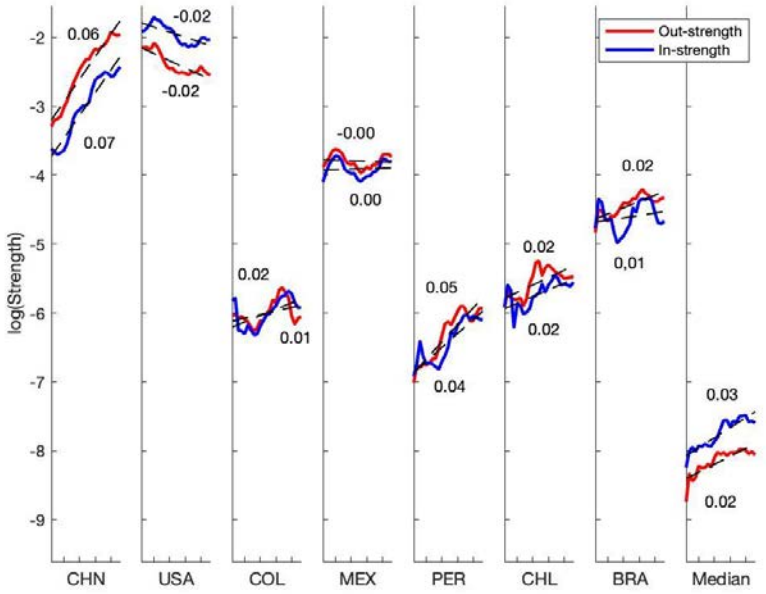

Figure 4. Evolution of out- and in-strength, in US dollars, from 1996 to 2018. The dashed line corresponds to the linear regression on time series as a representation of their trend; the regression is in its standard form $y = \alpha + \beta t$, where t corresponds to time (horizontal axis) and y to 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: authors' calculations, based on BACI.

From a policy perspective, the minor increase in Colombia's contribution to total trade by value is somewhat inconsistent with the increase in trade counterparties, and with the quest for a more open and integrated economy. Overall, it is apparent that Colombia did worse than most of her 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 surpasses 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 displays a negligible upward trend, her contribution throughout the sample is higher than that of Chile and Peru. Colombia's contribution to the WTN's imports displays a notable increasing trend. However, her contribution to total imports by volume is lower than that of her peers—except Peru. China exhibits a significant upward trend in her total contribution to global imports, whereas that of the United States has 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 reflects its role as 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.

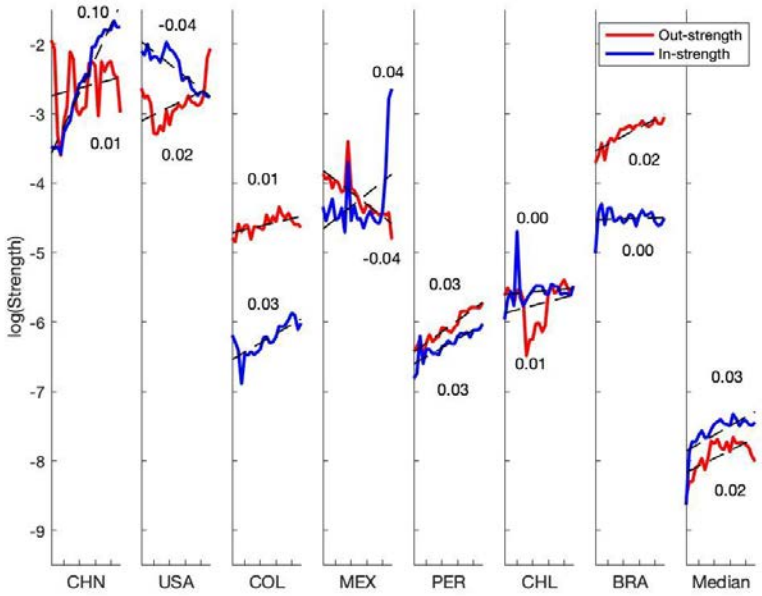

Figure 5. Evolution of out- and in-strength, in tons, from 1996 to 2018. The dashed line corresponds to the linear regression on time series as a representation of their trend; the regression is in its standard form $y = \alpha + \beta t$, where t corresponds to time (horizontal axis) and y to the centrality 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: authors' calculations, based on BACI.

Therefore, although the number of trade counterparties has increased, Colombia's contribution to the WTN by value and volume has not improved manifestly. Also, Colombia exhibits 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 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 key 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 key global importers than as importer from key global exporters. This is a feature shared by all Colombia's regional peers in the figure, except for the median of countries in the WTN.

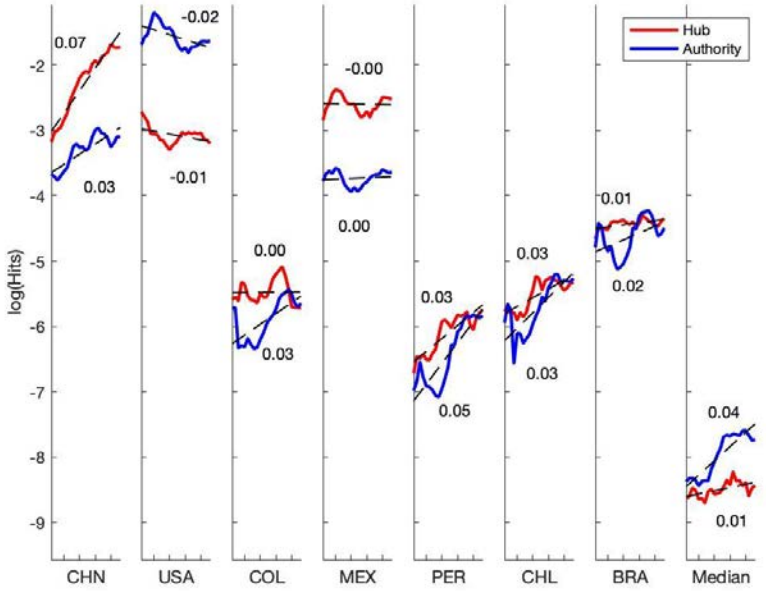

Figure 6. Evolution of hub and authority centrality, in US dollars, from 1996 to 2018. The dashed line corresponds to the linear regression on time series as a representation of their trend; the regression is in its standard form $y = \alpha + \beta t$, where t corresponds to time (horizontal axis) and 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: authors' calculations, based on BACI.

Overall, Colombia's hub centrality is 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 displays 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 corresponds 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 displays 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.

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

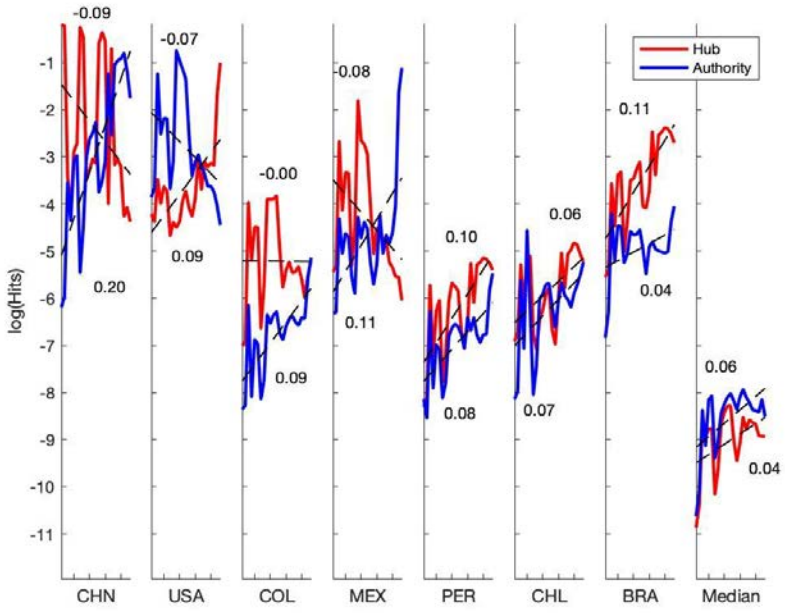

Figure 7. Evolution of hub and authority centrality, in tons, from 1996 to 2018. The dashed line corresponds to the linear regression on time series as a representation of their trend; the regression is in its standard form $y = \alpha + \beta t$, where t corresponds to time (horizontal axis) and y to 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: authors' calculations, based on BACI.

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 as an importer. That is, trade integration is not a one-way path, but results from countries' importance as buyer and seller of goods and services for the entire WTN.

Based on that conjecture, we calculate a Trade Integration Index (TII) from HITS' hub and authority centrality. As suggested in León, Machado, and Sarmiento (2018), such an index may be attained by multiplying and normalizing hub and authority centrality (see Appendix A.2).[24] The choice of the product of both centrality measures is consistent to identify those countries that simultaneously fulfill a central role as exporters and importers for the WTN.

Consistent 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 her integration into the WTN. It is also consistent to find that all regional peers show a positive slope in their TII. Peru and Chile exhibit the strongest increasing trends out of the set of regional peers. Peru's slope is almost three-times Colombia's—and the same as China's. Chile's increasing trend is twice as strong as that of Colombia. Interestingly, during the period under analysis, Chile surpasses Colombia, whereas Peru closes the gap with Colombia noticeably. Mexico and Brazil show a higher level of TII than Colombia, Chile, and Peru, but Mexico displays a slight negative trend, whereas Brazil shows a slow positive one. China and the United States exhibit the highest TII in the figure, with China displaying a strong upward trend that differs substantially from the United States' decreasing trend.

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

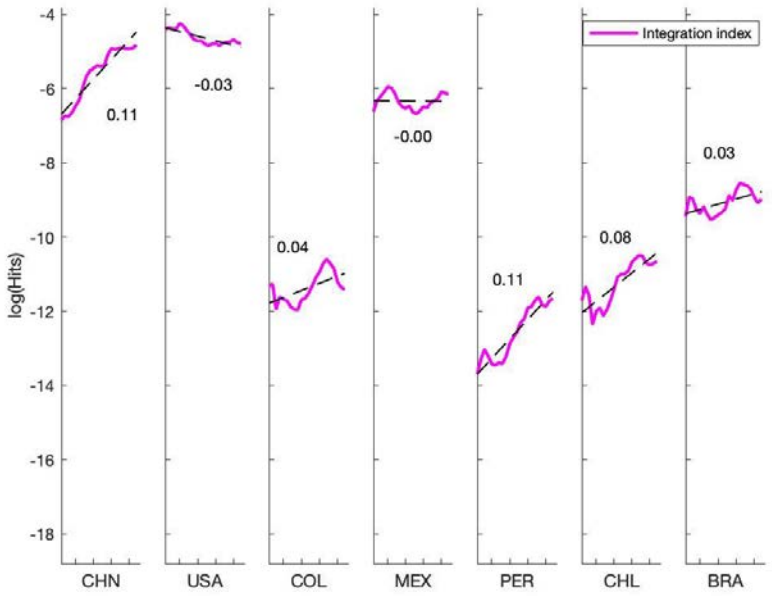

Figure 8. Evolution of Trade Integration Index (TII), in US dollars, from 1996 to 2018. The dashed line corresponds to the linear regression on time series as a representation of their trend; the regression is in its standard form $y = \alpha + \beta t$, where t corresponds to time (horizontal axis) 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: authors' calculations, based on BACI.

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

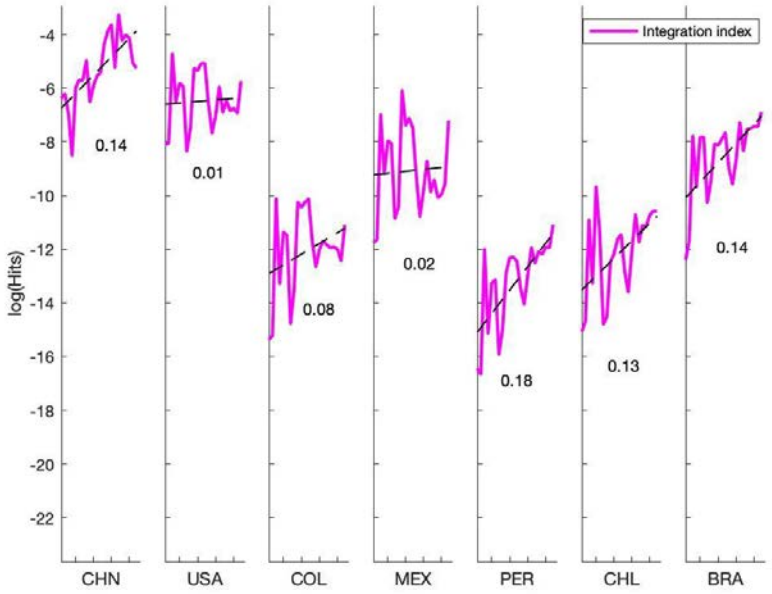

Figure 9. Evolution of Trade Integration Index (TII), in tons, from 1996 to 2018. The dashed line corresponds to the linear regression on time series as a representation of their trend; the regression is in its standard form $y = \alpha + \beta t$, where t corresponds to time (horizontal axis) and y 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: authors' calculations, based on BACI.

Again, consistent with the three dimensions of centrality, Colombia's TII trend by value and volume confirms that Colombia's integration into the WTN has improved. However, improvement is 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 A.1, as of 2018, about 55, 62, and 55 percent of Chilean's, Colombian's and Peruvian's 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.[25] This will enable us to filter out the effect of commodities-dependence and to draw additional conclusions about the integration of Colombia to world trade.

[25] For brevity, we focus on TII. Degree, strength, and hub and authority centrality after excluding key minerals, fuels, and metals are exhibited in Appendix A.3. The main analytical inferences overlap with those drawn from focusing on TII.

Figure 10 exhibits the TII based on the WTN by value (in US dollars) after excluding key minerals, fuels, and metals.[26] Interestingly, although excluded products were chosen because they are the most contributive to exports of Colombia, Chile, and Peru, Colombia is particularly affected. With respect to results on the entire WTN (Figure 8), the slope of Colombia's TII is halved when key minerals, fuels, and metals are excluded, whereas that of Peru and Chile shows a slight increase and decrease in slope, respectively. Further, the level of Colombia's TII diminishes. In the case of the United States, China, Brazil, and Mexico, the TII and its slope do not change noticeably.

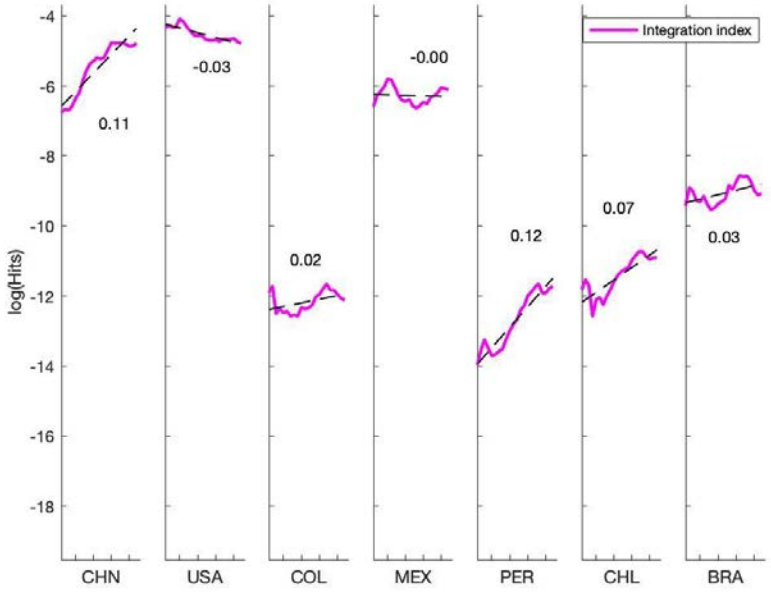

Figure 10. Evolution of Trade Integration Index (TII), in US dollars, from 1996 to 2018, excluding key minerals, fuels, and metals. The dashed line corresponds to the linear regression on time series as a representation of their trend; the regression is in its standard form $y = \alpha + \beta t$, where 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: authors' calculations, based on BACI.

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 are notably affected as their slopes turned sharply negative. Interestingly, the slope of

[26] We exclude 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).

TII for Peru and China did not change, whereas that of Brazil and Chile decreased but remained positive.

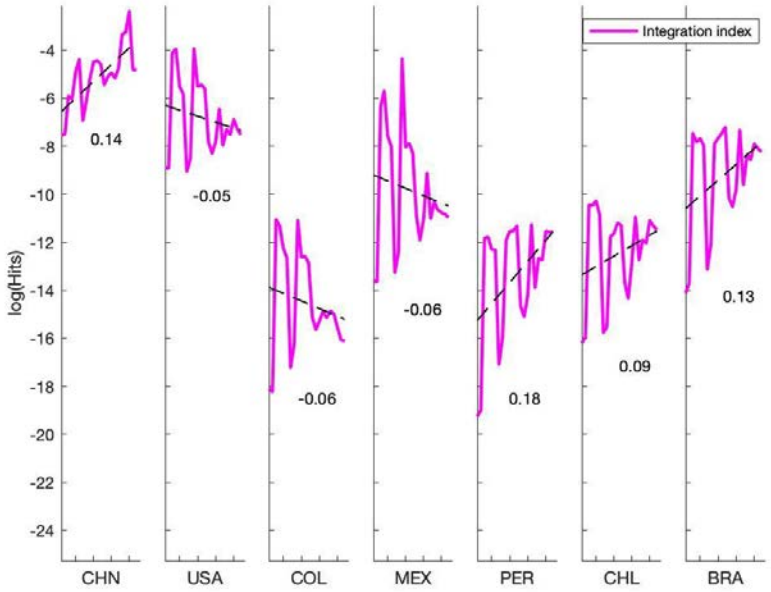

Figure 11. Evolution of Trade Integration Index (TII), in tons, from 1996 to 2018, excluding key minerals, fuels, and metals. The dashed line corresponds to the linear regression on time series as a representation of their trend; the regression is in its standard form $y = \alpha + \beta t$, where t 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: authors' calculations, based on BACI.

Therefore, the results by value and volume excluding minerals, fuels, and metals show that Colombian exports are highly dependent on those commodities. Unlike Peru and Chile, achieving a higher centrality in the WTN is not dependent on minerals, fuels, and metals. Further, the sharp change in slope in the TII by volume for Colombia confirms 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.

4 Conclusions

Amid the worldwide trade liberalization process of the late eighties and early nineties, Colombia changed her 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, 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, Peru). For completeness, we also compare 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, namely 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 show that Colombia increased the number of connections as exporter and importer during the sample period. However, with respect to the WTN, the increase in the number of exports and imports partners was subpar. Regarding the intensity of export and import connections, they both show 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 shows 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 importer from key global exporters, Colombia shows an increasing trend that is similar to her 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 her peers is not. After excluding that key set of commodities, it is evident that Colombia's integration into the WTN has not improved materially—unlike that of her peers.

All in all, the three dimensions of network importance share a common outcome: although Colombia openness increased, her integration into world trade markets did not improve noticeably. This is clear as Colombia increased the number of trade partners, the value and volume of trade, and the importance of her 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 level 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) about her reduced importance in global value chains.

From an economic policy perspective, results highlight the challenges ahead to liberalize and better integrate into world markets and to 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 her peers and the WTN. Besides, it is of utmost importance to revise how successful peers (i.e. Peru and Chile) attained such improvement and to evaluate whether it is feasible and desirable to replicate their strategy. 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.

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Appendix A.1 Total exports and exports of minerals, fuels, and metals, 2018

(USD million)

Country	Minerals	Fuels	Metals	Total
Brazil	24,366	31,756	17,609	**239,888**
Chile	21,419	666	19,202	**75,482**
China	4,975	46,630	186,291	**2,494,230**
Colombia	80	24,225	1,494	**41,832**
Mexico	6,307	29,706	19,214	**450,532**
Peru	18,169	4,268	3,926	**47.894**
United States	10,388	192,681	73,520	**1,665,303**

Source: World Bank. 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**

Source: The World Bank. Authors' calculations.

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

** Mainly oil, coal, gold, and ferronickel.

*** Mainly copper, gold, and zinc.

Appendix A.2 Network centrality analysis formulae

Network centrality analysis formulae	
$\mathcal{k}_i^{in} = \sum_{j=1}^{n} A_{ji}$ In-degree	$\mathcal{k}_i^{out} = \sum_{j=1}^{n} A_{ij}$ Out-degree
$\mathcal{s}_i^{in} = \sum_{j=1}^{n} W_{ji}$ In-strength	$\mathcal{s}_i^{out} = \sum_{j=1}^{n} W_{ij}$ Out-strength
$a = \Gamma^1(W^T W)$ Authority	$\mathcal{h} = \Gamma^1(W W^T)$ Hub

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

Trade Integration index

Where,

1. A_{ij} is a directed adjacency matrix, $A_{ij} = \begin{Bmatrix} 1 \text{ if there is an edge from } i \text{ to } j, \\ 0 \text{ otherwise} \end{Bmatrix}$
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 A.3 Degree, strength, and hub and authority centrality after excluding minerals, fuels, and metals.

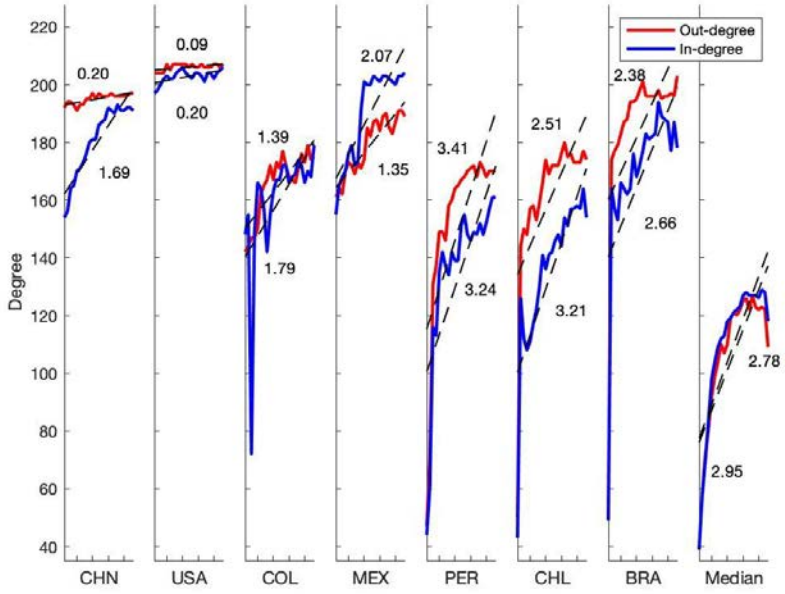

Figure A1. Evolution of out- and in-degree, in US dollars (or tons), from 1996 to 2018, excluding minerals, fuels, and metals. The dashed line corresponds to the linear regression on time series as a representation of their trend; the regression is in its standard form $y = \alpha + \beta t$, where t 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: authors' calculations, based on BACI.

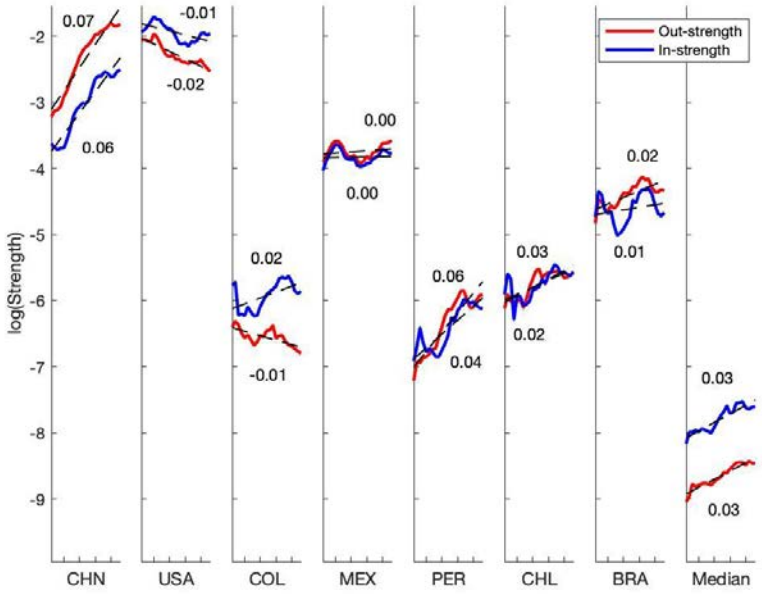

Figure A2. Evolution of out- and in-strength, in US dollars, from 1996 to 2018, excluding key minerals, fuels, and metals. The dashed line corresponds to the linear regression on time series as a representation of their trend; the regression is in its standard form $y = \alpha + \beta t$, where t corresponds 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: authors' calculations, based on BACI.

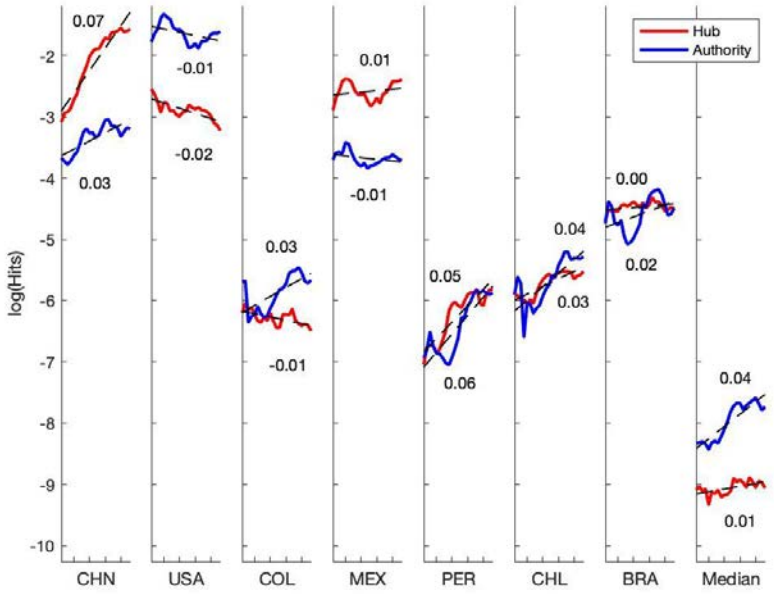

Figure A3. Evolution of hub and authority centrality, in US dollars, from 1996 to 2018, excluding key minerals, fuels, and metals. The dashed line corresponds to the linear regression on time series as a representation of their trend; the regression is in its standard form $y = \alpha + \beta t$, where 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: authors' calculations, based on BACI.

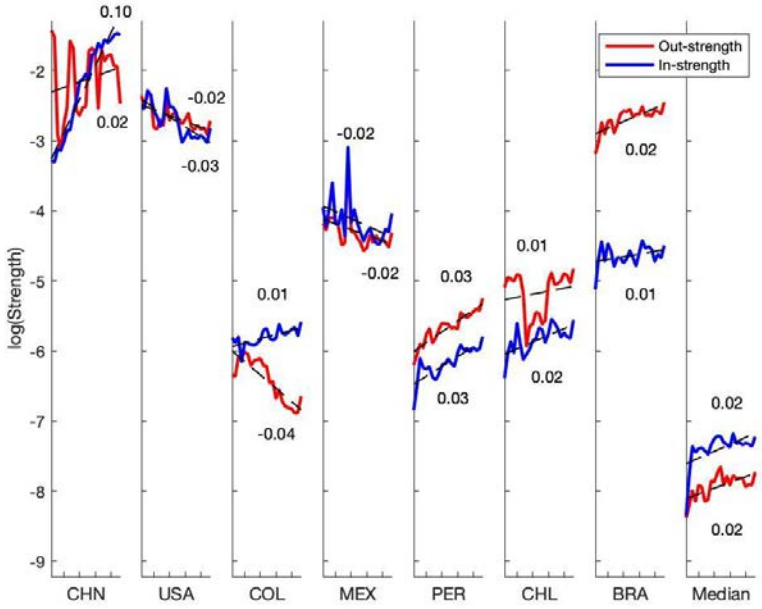

Figure A4. Evolution of out- and in-strength, in tons, from 1996 to 2018, excluding minerals, fuels, and metals. The dashed line corresponds to the linear regression on time series as a representation of their trend; the regression is in its standard form $y = \alpha + \beta t$, where t corresponds to 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: authors' calculations, based on BACI.

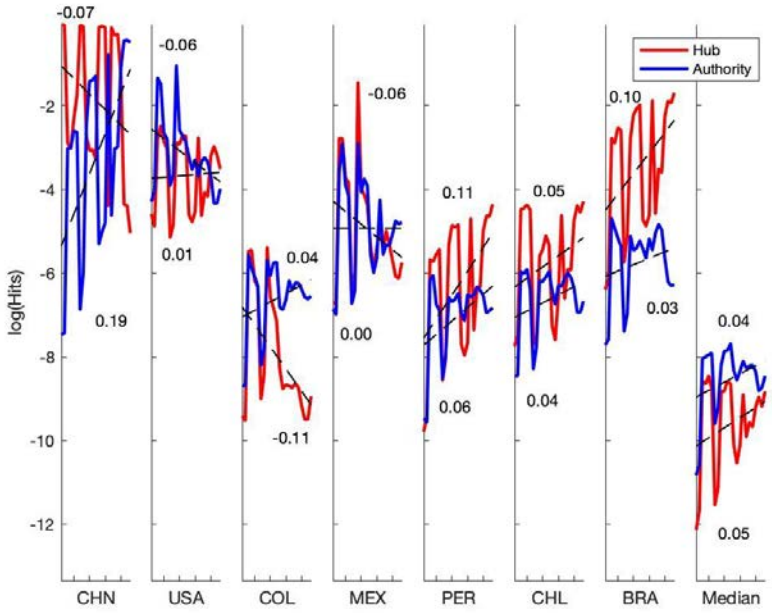

Figure A5. Evolution of hub and authority centrality, in tons, from 1996 to 2018, excluding minerals, fuels, and metals. The dashed line corresponds to the linear regression on time series as a representation of their trend; the regression is in its standard form $y = \alpha + \beta t$, where t corresponds 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: authors' calculations, based on BACI.


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