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## TRADE INTEGRATION IN LATIN AMERICA: A NETWORK PERSPECTIVE

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# TRADE INTEGRATION IN LATIN AMERICA: A NETWORK PERSPECTIVE<sup>1</sup>

*This paper considers the integration of Latin American and Caribbean (LAC) countries in the world and regional trade networks on the basis of the network analysis framework. It compares alternative network centrality measures for LAC with other regions and contrasts them against fundamentals-based benchmark trade networks. The paper finds that LAC countries are relatively well integrated in terms of links to diversified markets, but the strength of those links is weak. The extra-regional concentration of LAC's trade and weak integration in global value chains leaves scope for the more central role of larger LAC countries that is predicted by benchmark networks for both world and regional networks.*

## A. Introduction

**1. Faltering growth after the global financial crisis has left many countries in search of new drivers of economic growth.** At the same time, traditional domestic engines of growth like countercyclical fiscal policy and expansionary monetary policy have reached their limits. While trade has weakened alongside domestic demand, with the weakness exacerbated by the waning pace of trade liberalization and a decline in the growth of global value chains (WEO, 2016), higher trade could still help increase economic efficiency, productivity and overall activity. Like other regions, Latin America and the Caribbean (LAC) has struggled to overcome the economic fallout from the global financial crisis, especially the end of the commodity super-cycle. Against these considerations, the paper considers the extent to which Latin America is integrated into global markets, with a view to determining whether the trade channels can provide further scope for integration into the world and regional networks for LAC.

**2. Traditional measures of integration, such as trade openness, suggest that Latin America is less integrated into the world trade network (WTN) than other regions.** Most economies in the region have also been found to under-trade relative to fundamentals drawn from gravity models (IMF, 2015). We consider alternative measures from the network analysis literature to examine the overall topology of the WTN and explore the centrality of the LAC region in it (section II). In particular, we look at the degree to which LAC countries have already integrated into the WTN and how this integration evolved over time, whether LAC's under-trading is primarily a result of the paucity of trade links or weak trade flows, and how central or important are LAC countries to the world and regional trade networks.

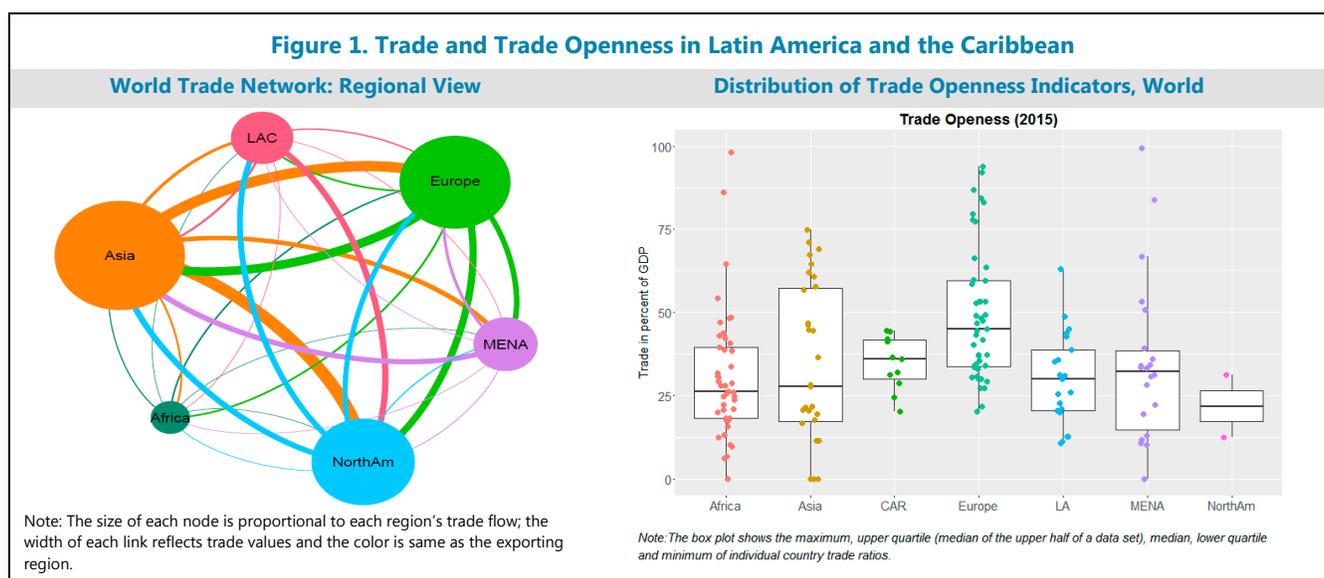
<sup>1</sup> Prepared by Kimberly Beaton, Aliona Cebotari, Andras Komaromi and Xiaodan Ding. The authors would like to thank Valerie Cerra for helpful comments and suggestions. This paper was prepared as a background study for the Western Hemisphere Department's Cluster Report on Trade Integration in Latin America and the Caribbean. This paper describes research in progress by the authors and is published to elicit comments and to encourage debate. The views expressed in this paper are those of the authors and do not necessarily represent the views of the IMF, its Executive Board, or IMF management.

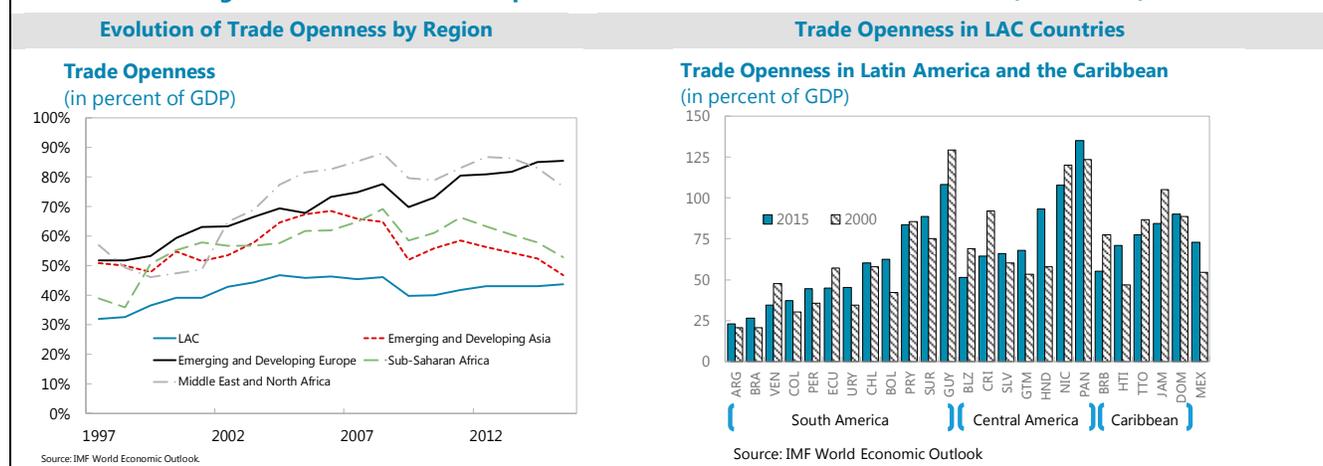
**3. We also compare LAC’s integration in the WTN against fundamentals-based benchmark networks.** We estimate two models of trade network formation (binary and weighted) and compare the actual degree of integration to the predictions of these models. In addition to the standard gravity model that is used to estimate weighted networks, we also apply gravity variables to simulate a binary network formation. This approach asks how differences in economic development and trade costs, among other variables, affect the likelihood of countries trading with each other and the intensity of the trading link (section III). Section IV concludes.

## B. How Integrated is Latin America in the World Trade Network?

**4. By traditional measures, the Latin American region appears weakly integrated into the WTN.** Despite accounting for about 8 percent of global economic activity in 2015, the region accounted for only about 5.1 percent of global exports of goods and services. In 2015, LAC’s trade (exports and imports) represented only 44 percent of regional GDP, well below that of other emerging market economies in all regions of the world (Figure 1). While the region liberalized trade and benefited from increased trade openness in the late 1980s and early 1990s, its openness has remained relatively stable since the beginning of the 2000s.

**5. The large economies of South America drive LAC’s low average trade openness.** There are significant cross-country differences in the region’s openness to trade, with openness ranging from 25 to 125 percent of GDP. The large economies of South America are the least open to trade, especially Brazil and Argentina, where trade accounts for only 27½ percent and 24 percent of GDP respectively. Central American and Caribbean economies are much more open to trade, reflecting the relatively small size of these economies and related limited domestic production, which increases their reliance on imported goods and services. Mexico is also relatively more open compared to South America, despite its large size, due to its proximity to the United States and the low barriers to its trade with the United States after the North American Free Trade Agreement (NAFTA) came into force in 1994.



**Figure 1. Trade and Trade Openness in Latin America and the Caribbean (Concluded)**


## Overview of the Trade Network

### 6. The network analysis literature provides a useful visualization of the world trade links.

Both the geographical and the centrality representations of the WTN suggest that the LAC region is integrated but not very central to the world network when the size of the trade flows is taken into account.<sup>2</sup> Under the centrality representation— where countries that receive most of the top flows are the ones pulled closer to the center of the network— the US, China and EU are clearly the most central to the trade network. The clustering of the world network roughly around regional boundaries is also evident. Latin America clusters closer to the US, as trade has traditionally been concentrated with this northern neighbor, but more recently China has gained particular prominence as an important export market for LAC's commodity exporters as commodity exports to Asia have increased and as the cost of trade has declined. In other regions, North Africa is closely integrated into the European networks, while Middle East, Africa and Asia are closely interlinked with each other. The Caribbean region remains on the periphery of the WTN, but given the small size of many of these economies, the prospects to occupy a more central role in the global network are likely limited.

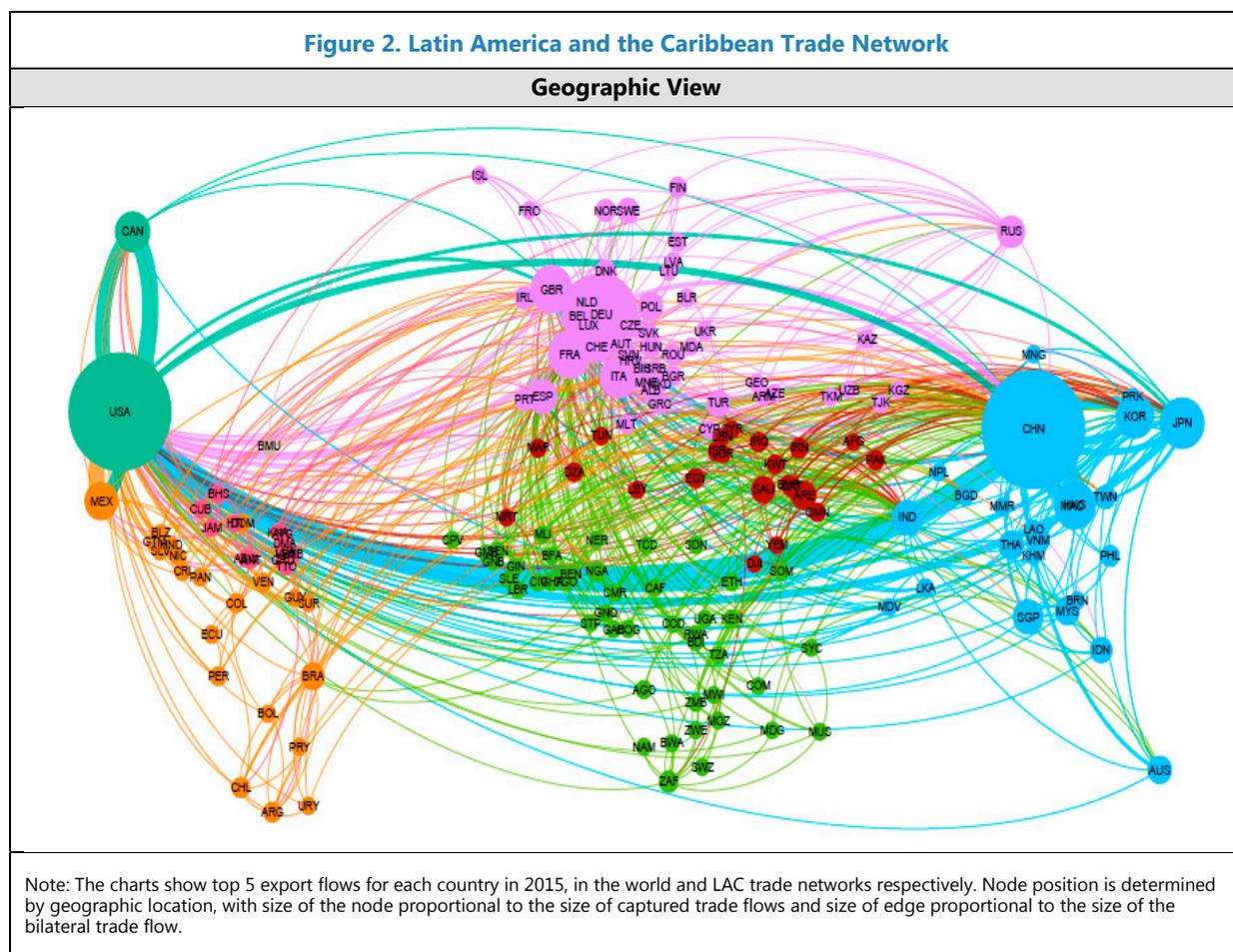
**7. In addition to the network visualization, network analysis relies on a number of indicators of connectivity within the networks.** We construct two types of networks from the IMF's Directions of Trade Statistics (DOTS) database, which reports annual data on bilateral exports for about 184 countries over the 1948 to 2015 period.<sup>3</sup> The first is a binary (or unweighted) network, which is based on the export-import matrix whose entries reflect only the existence or not of a trade

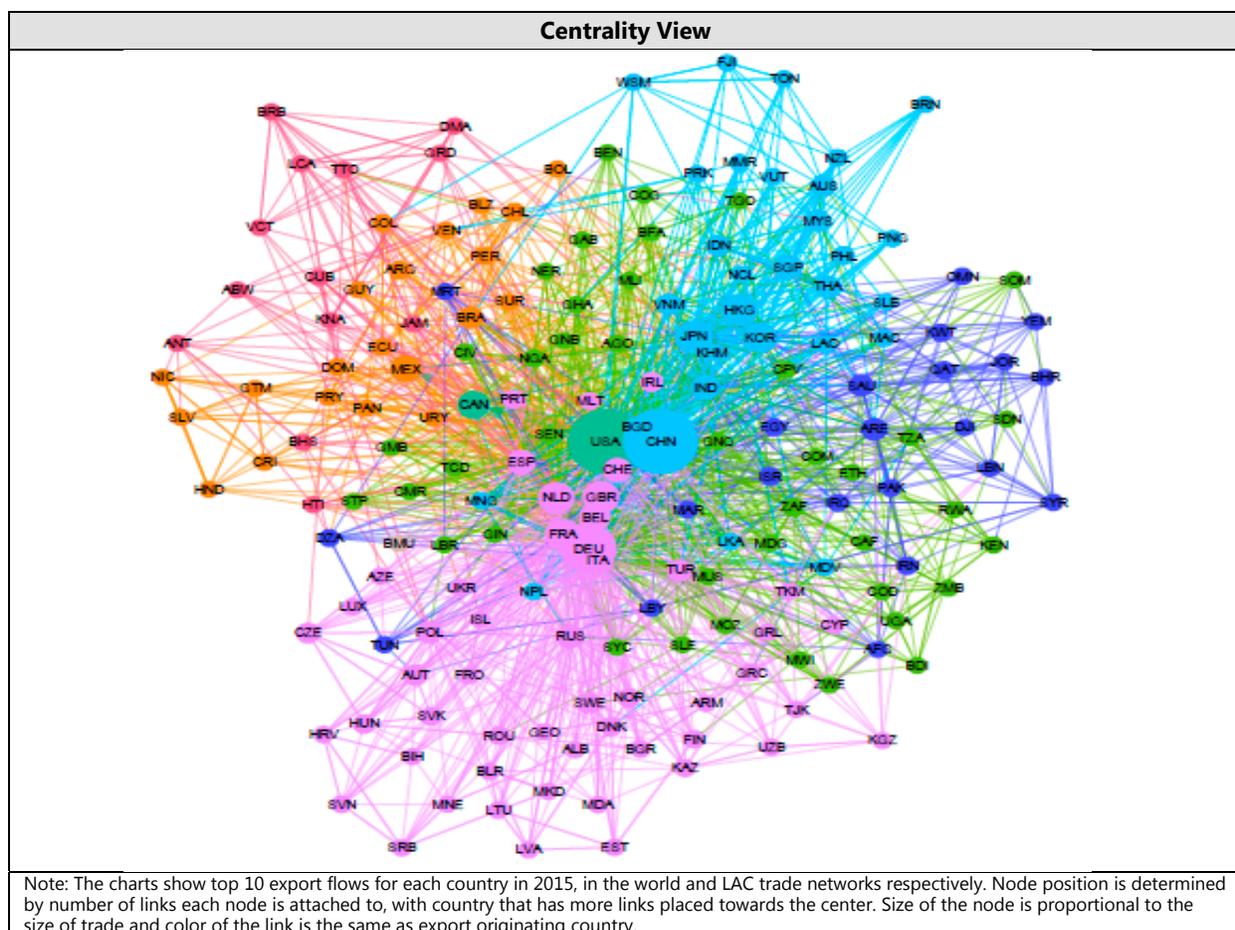
<sup>2</sup> In both charts in Figure 2, the countries that receive most of the top 5-10 trade flows are generally the larger ones economically or in terms of trade, and hence the most integrated in the weighted trade network as we will see later.

<sup>3</sup> The DOTS database contains annual, quarterly, and monthly trade data for approximately 184 countries, the world and major areas. Monthly and quarterly series are available starting 1960 and annual series are available starting 1947. It presents current figure on the value of merchandise exports and imports disaggregated according to a country's primary trading partners. Imports is reported on the basis of Cost, Insurance and Freight (CIF), while exports are reported on a Free on Board (FOB) basis. Standard macroeconomic data series, such as GDP, come from the World Economic Outlook (WEO) database.

link between two countries. The second is a weighted network, where entries reflect the size of the trade flows from exporters (rows) to importers (columns). For each of these networks, we focus on a few key measures, which are defined in more detail in Annex I:

- *Degree* is the number of trade links (partners) relative to total number of possible links in the binary network, with in-degree reflecting the number of import partners and out-degree the number of export partners;
- *Strength*: the intensity of that connection in a weighted network, i.e. sum of all bilateral trade flows of a country in the network, frequently scaled by the sum of all trade flows in the network;
- *Eigenvector centrality*: connectivity to many or to important links, a measure that has both weighted and unweighted counterparts;
- *Closeness centrality*: the average geodesic distance to other nodes (countries) in the network; and
- *Betweenness centrality*: the number of shortest paths connecting all nodes (countries) in the network to all other nodes that pass through the node of interest; high-betweenness is akin to being a network broker.



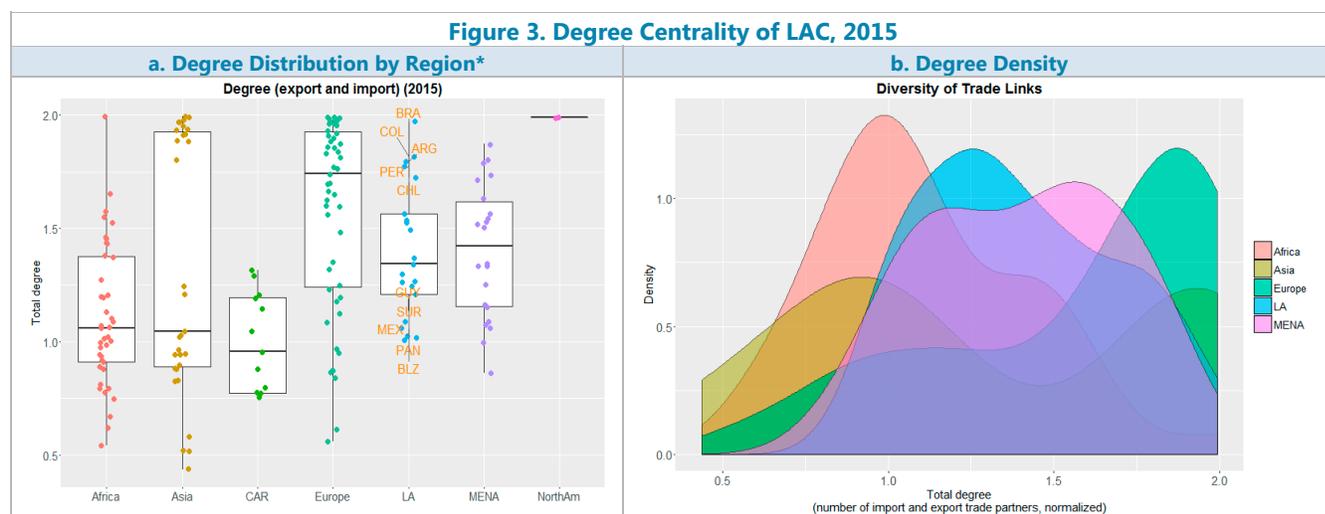


## Integration on the Extensive Margin (Degree)

**8. The Latin American region is well integrated in the WTN in terms of the number of its trade links (i.e. market diversification, or degree).** The LA region places somewhat above the world average in terms of market diversification, having trade links with about 70 percent of all countries in the world as of 2015, lagging behind only Northern America, Europe and MENA regions (Figure 3). This suggests the bulk of the fixed costs of penetrating new markets have already been incurred by many exporters in the region. Although the average degree in the LA region is higher than that of Asia, this reflects a more unimodal distribution of trade links across countries compared to a strongly bimodal distribution in Asia:

- Five large countries in LA are highly integrated into the WTN, with very well-diversified trade links (Brazil, Colombia, Argentina, Peru, and Chile). These countries have trade links on average covering about 91 percent of all potential trading partners, which is above or close to the 75th percentile of the global degree distribution. By contrast, the top 13 most integrated countries in Asia (of which 8 are emerging markets) have trading relations with 96 percent of their potential partners — a higher connectivity than the top LA countries. However, the regional average for Asia is lowered significantly by weak connectivity of its small remote islands and less developed countries, which give its degree density a bimodal distribution.

- Mexico is among the least integrated countries in an unweighted network as a result of the strong concentration of its trading relations with the U.S. market, having trade links with only half of its potential trade partners. Like Mexico, Panama, Belize, Guyana and Suriname are linked with only half of the countries.
- Larger economies tend to have more trade relations, and hence occupy more central role in the WTN (Figure 3d). Even accounting for the size of the economy Mexico, Panama and Venezuela stand out in the region as having lower diversification than one would expect for their size.<sup>4</sup> In subsequent sections, we will test formally the importance of country size as a determinant for trade integration.
- The Caribbean region has the weakest market diversification in terms of trade in goods, with less than half of all possible trade links realized. This reflects both the small size of their economies, a very strong trade integration within the Caribbean region itself and weaker links with the rest of the world, as well as the fact that data covers only trade in goods at a time when services account for the largest share of their GDPs.<sup>5</sup>



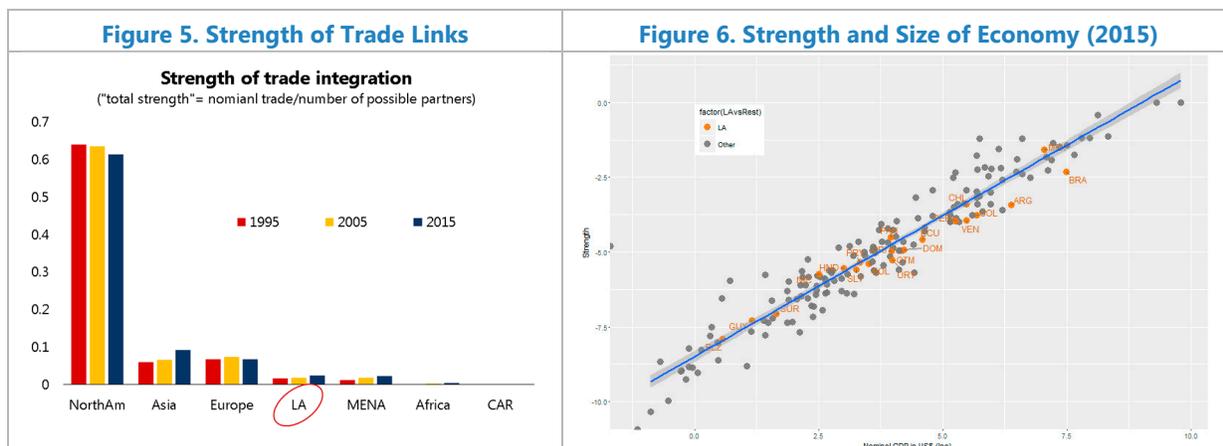
<sup>4</sup> For Panama, to a large extent this likely reflects the concentration of Panama’s trade in services whereas the bilateral trade data from DOTS used to assess the patterns of trading partners includes only trade in goods.

<sup>5</sup> There is no comprehensive bilateral trade in services data.

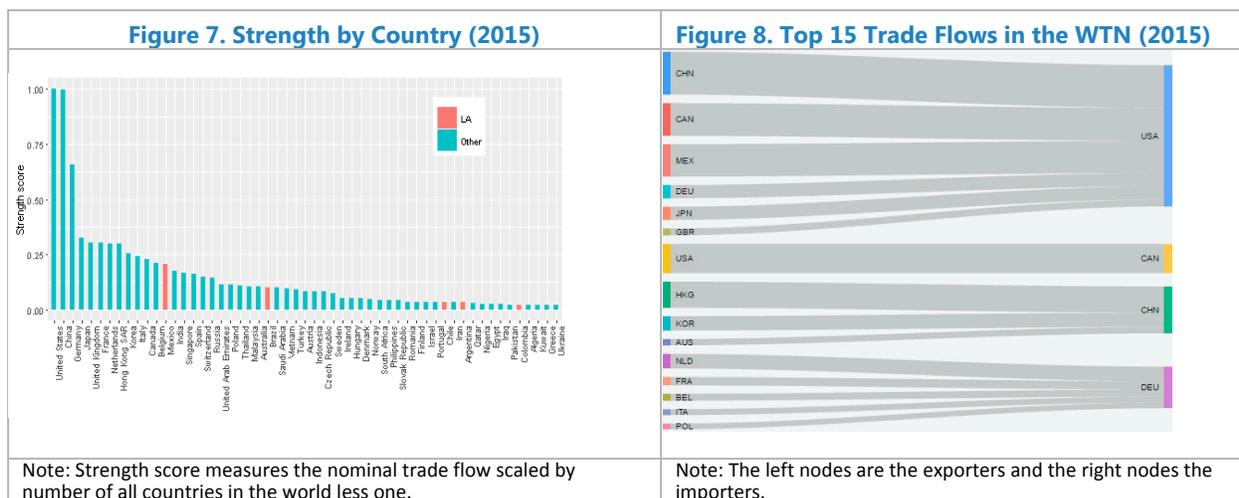


## Integration on the Intensive Margin (Strength)

**10. Weak trade integration largely reflects weak trade flows rather than an inability to penetrate diversified markets.** Under the basic measure of integration in a weighted network—namely, *strength* or sum of nominal trade flows at country level—the LA region lags behind the most integrated regions (North America, Asia, and Europe) in terms of the strength of its connections (Figure 5). The relatively small size of its economies explains most of the variation in the size of the flows, but in part this is also due to the weak trade flows relative to the economy in some large countries (especially in the case of Brazil, Argentina, Colombia and Venezuela, Figure 6).



**11. Despite the low average “strength” of trade integration of the region, Mexican trade flows stand out both in the region and in the world.** Mexico ranks 13th in the world in terms of its strength score in the WTN, in large part reflecting the size of its economy, after the U.S., Canada, China, Hong Kong, and largest European countries (Figure 7). In fact, the bilateral trade flow from Mexico to the US is the third largest in the world in 2015, following the bilateral exports flows from China and Canada to the U.S., with the export flow from Brazil to China ranking 75th in the world (Figure 8).

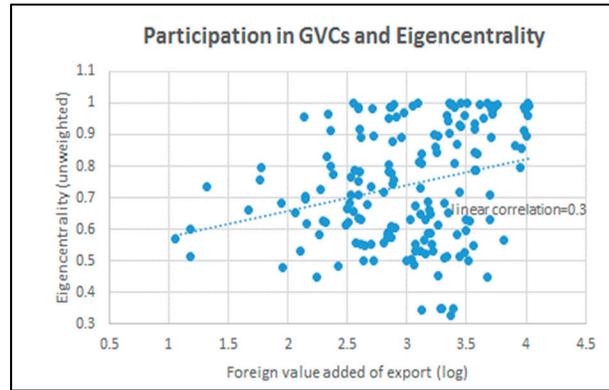


Note: Strength score measures the nominal trade flow scaled by number of all countries in the world less one.

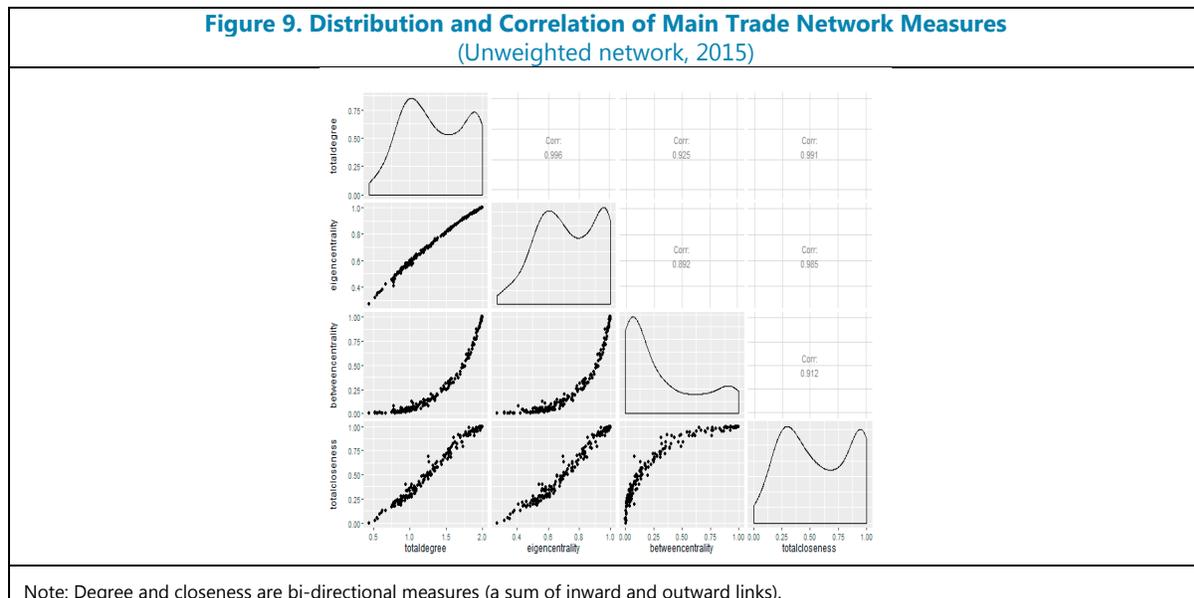
Note: The left nodes are the exporters and the right nodes the importers.

### Other Centrality Measures

**12. While degree and strength centrality measure direct connectivity to the trade network, other centrality measures reflect additional aspects of relevance in the network.** Eigenvector, betweenness or closeness centrality — which measure the importance of network nodes in terms of connectivity to important players, brokering between players, and closeness to connected players, respectively—may be relevant in the case of trade networks as measure of integration in global value chains, of the importance of countries as amplifiers of external shocks given their position in the network, or of the vulnerability of countries to spillovers from such shocks. For instance, eigencentrality in particular is positively correlated with measures related to country participation in global value chains (figure).

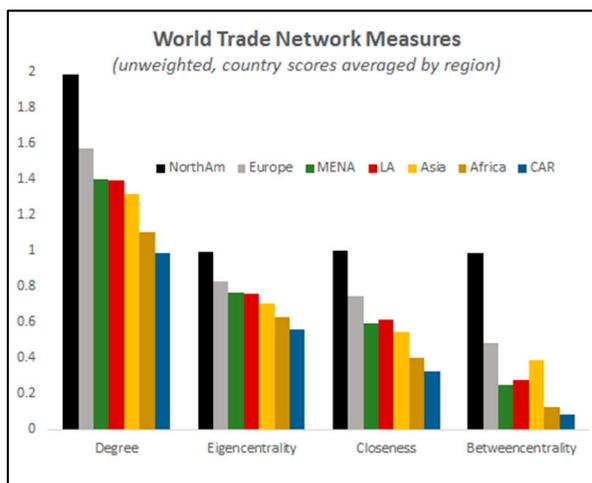


**13. Centrality measures are strongly correlated with degree and strength** (Figure 9). Most of the measures (closeness, eigencentrality) have a strong linear correlation among themselves and with degree centrality, driven by the high density of the WTNs compared to other social or technological networks. In particular, the average density of the WTN was 0.56 in 2015, suggesting more than half of the potential connections have been realized. Betweenness, on the other hand, has an exponential relationship with the remaining measures, suggesting a country needs to accumulate a certain threshold of bilateral connections before becoming a network broker. Figure 9 reports the correlations in the unweighted networks, whereas the correlations of the weighted measures with strength centrality is similarly strong in the weighted networks, but not reported here.



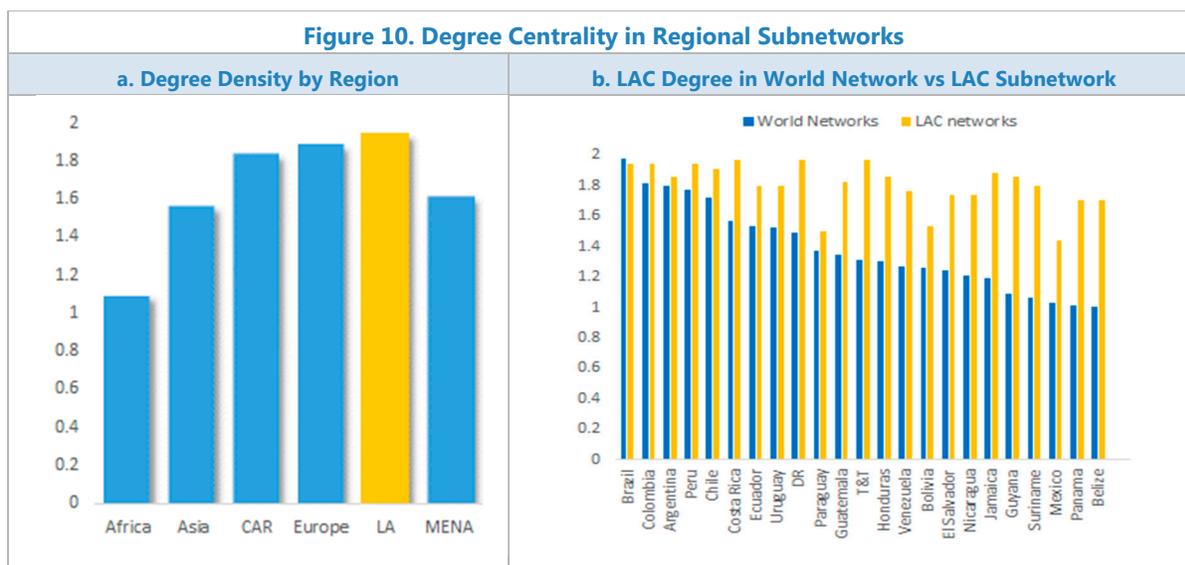
**14. The high correlation of network measures drives the consistent relative rankings of the regions under these measures.**

In unweighted networks, where the size of the flows is not taken into account, regional integration into the WTN is similar to that of degree. Based on simple averages, the North American region is by far the most connected, followed by Europe in second place, Middle East and Latin America as close thirds and finally followed by Asia, Africa and the Caribbean region. The regional rankings of betweenness centrality breaks this pattern, with the high connectivity of many Asian countries pulling the region ahead of Latin America in terms of this broker-centrality measure. Because of the high correlation of the measures in the WTN, the paper will focus primarily on degree and strength in discussing integration.

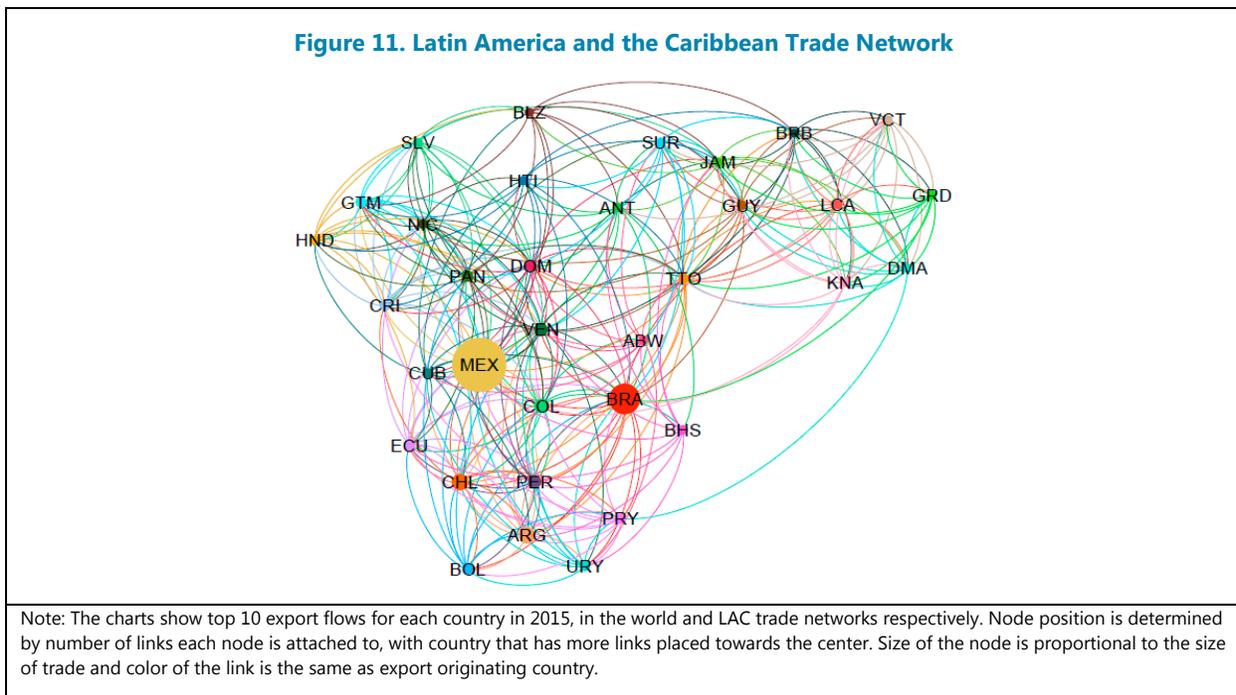
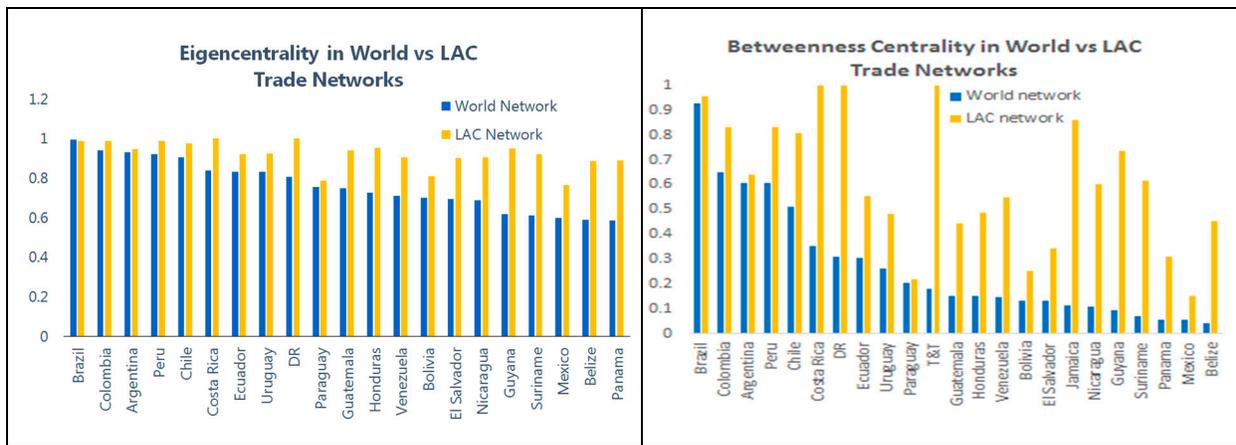


**Integration Within Latin America**

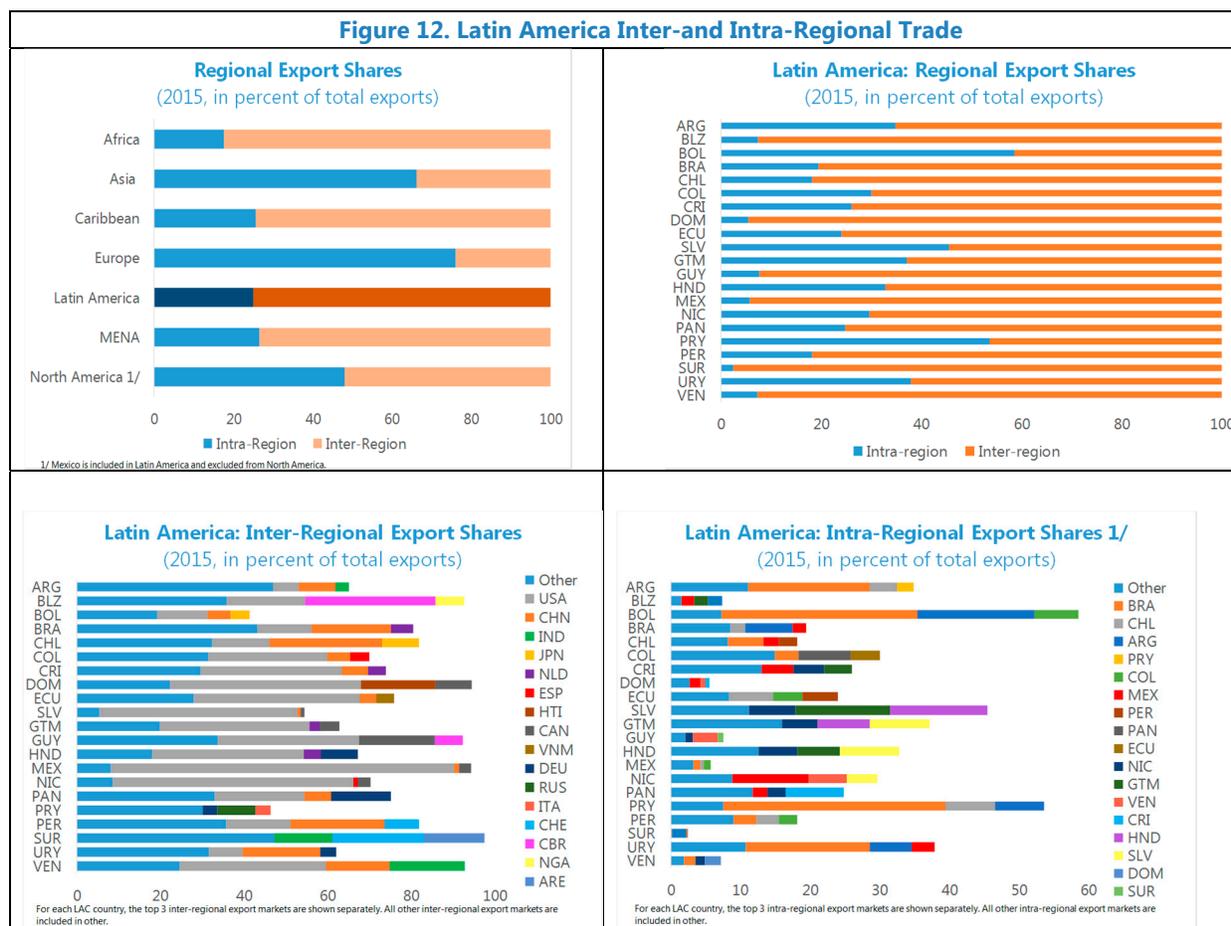
**15. Viewed independently from the rest of the world, the Latin America trade network is the densest regional network (Figure 10a).** It has almost perfect connectivity among countries, with 97 percent of the export and import links realized, in part because it has the smallest number of countries (North America excluded). The large countries, which are most integrated in the WTN, have only marginally higher degree in the LAC networks (Figure 10b). One exception is Brazil, which has established a higher share of potential trade links in the world than in the region, although the difference is marginal. Smaller countries in the region are much better integrated within the regional network, and several are overtaking the largest countries as the most integrated (Costa Rica, Dominican Republic, Trinidad and Tobago).



**16. The larger countries in Latin America do not play important regional roles as hubs.** As in the case of degree centrality, the largest countries in LAC maintain their centrality in the regional networks under the other network measures (such as eigenvector, betweenness and closeness centrality). However, Brazil's *eigencentality* score is higher in the WTN than in the regional one given its weak regional connectivity to important players (it is mostly a regional hub for Mercosur countries, as we discuss below); for Brazil and Argentina *betweenness* centrality in the regional networks is also only marginally higher than in the world network, again pointing to a weak regional role; while Mexico remains weakly connected in the regional (binary) network as well. On the other hand, smaller countries again take on a more central in the regional networks, especially in the case of betweenness centrality. The lack of strong regional hubs is apparent in the regional network chart in Figure 11, where no country is clearly centered in the network and there is apparent clustering along regional or trade agreement lines.



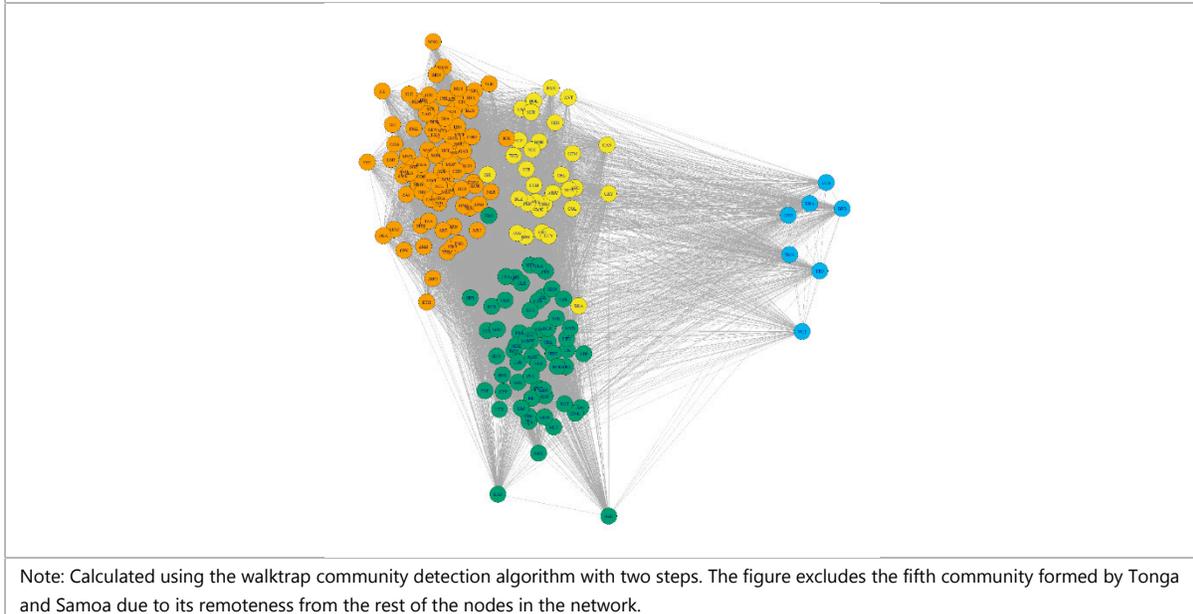
**17. LAC trade is more concentrated outside the region compared to the rest of the world (Figure 12).** With only about a 15 percent of total exports destined to regional markets, LAC lags behind developed economies in Asia and Europe, where regional destinations account for well over 50 percent of exports. This is in part the product of the high concentration of the region’s trade in commodities given its natural resource endowments and the strong trade links between Mexico and the U.S., which explains the high trade integration of the region with US and China. Among LAC countries, Bolivia, Paraguay and Uruguay stand out as more regionally integrated given their concentration of exports to Brazil as part of the Mercosur free trade agreement. Central America is another region that shows a higher degree of intra-regional integration. Moreover, the regional concentration of trade is less pronounced than concentration of outside trade: while the Brazilian market is clearly important for some economies, its role as a hub is more pronounced for its immediate neighbors and Mercosur partners (Argentina, Paraguay, Uruguay, and Bolivia as an associate member). It still features as one of the top three export markets in several countries in the region (Chile, Colombia, Peru, Venezuela), but in a much less important role. At the same time, Mexico takes over the hub role more clearly for the Central American countries.



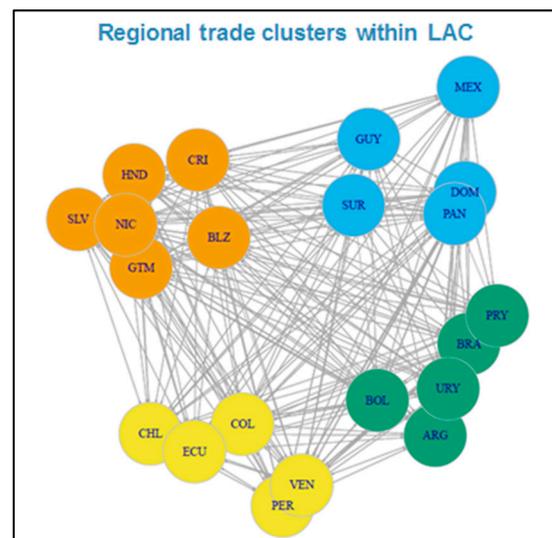
**18. The trade patterns above are also reflected in the clustering properties of the WTN.** Within the WTN, five distinct trade “communities” or clusters can be identified (Figure 13). One cluster is formed by North and Latin America (including Cuba, Jamaica and Israel), reflecting the role

of the US as a clear hub for the LA regional trade; a second cluster is formed by Europe and North Africa; and yet another by Middle East, Asia and Sub-Saharan Africa. The Caribbean countries—largely those in the ECCU (St. Lucia, Grenada, Dominica, St. Kitts and St. Vincent), Barbados and Trinidad and Tobago, all members of the CARICOM trading bloc—form a separate cluster quite distant in terms of strength of trade links from the rest of the world, given close trading in terms of goods and services. Two remote islands in Asia that are weakly connected to the rest of the world (Samoa and Tonga) form a separate group altogether.

**Figure 13. World Trade Network: Trade Communities (2015)**



**19. Similarly, the trade patterns discussed above are consistent with the clustering of regional trade around trade agreements and neighboring countries.** Four clusters can be identified within the LA trade network: (i) the Mercosur cluster (including associate member Bolivia); (ii) Mexico serves as a hub for few Central American and Caribbean countries (Dominican Republic, Panama, Suriname and Guyana); (iii) smaller Central America and Caribbean countries form the third cluster; with (iv) the fourth one broadly including the members of the Andean Community and Pacific Alliance (other than Bolivia). There is no clear trading hub comparable to China in Asia or Germany in Europe where these countries form the center of a regional value chain: importing (intermediate goods) from within the region and exporting to large markets (IMF 2015). The region has also yet to reap the advantages of Mexico's strong relationship with the U.S. market to develop Mexico into a regional hub.



## C. Integration in Actual versus Benchmark Trade Networks

**20. In this section, we compare the density of the world and Latin American trade networks with those predicted by benchmark trade networks.** As benchmarks, we estimate two models of trade network formation: one for the binary network (where the export-import matrix has ones if there is a bilateral trade link and zero otherwise) and one for the weighted network (where the export-import matrix reflects the actual nominal flows). Gravity models are traditionally used to estimate weighted models, while we apply gravity variables to also simulate a binary network formation. The empirical models provide the mechanisms for establishing the trade links and determining the strength of these links in the network on the basis of a few parameters, such as size of the economy, trade costs, existence or not of a trade agreements and other gravity variables.

### Binary (Unweighted) Networks: Actual vs. Benchmark

**21. We first generate a benchmark binary trade network.** We estimate a LOGIT model where the outcome variable is 1 if there is an export link from country *i* to *j*, and where the explanatory variables are the traditional gravity variables, such as size of the economies and trade costs:

$$\text{LOGIT}(\text{EXP}_{ij}) = \alpha_1 \ln \text{GDP}_i + \alpha_2 \ln \text{GDP}_j + \beta \ln \text{TRADECOST}_{ij} + \varepsilon_{ij} \quad (1)$$

where trade costs are measured by log level of distance (weighted by population) between countries *i* and *j*, and by dummies for contiguity, common language, colonial relationship, common colonizer post 1945, being landlocked and for existence of regional trade agreement in force.<sup>6</sup> To transform the model-estimated probabilities of country *i* exporting to country *j* into a binary variable of the existence or not of a trade link, we set a cut-off probability above which we would predict that an export link is formed and below which no link is formed. This cut-off probability is chosen to ensure that the density of the simulated world network is the same as the density of the actual world network for each particular year. Thus, the probability cut-off averages about 46 percent in the 1980s, increasing gradually to 52 percent by 2010-15.

Regression results: LOGIT with time fixed effects				
Explained variable: export link				
	Coef.	Std. Err.	z	P>z
Log GDP	0.723	0.0018	402.15	0.000
Log GDP of partner	0.598	0.0016	369.97	0.000
Distance	-0.829	0.0049	-169.66	0.000
Contiguity	0.148	0.0357	4.15	0.000
Common language	0.807	0.0093	86.45	0.000
Colony	2.177	0.0840	25.92	0.000
Commonly colonizer	0.283	0.0100	28.26	0.000
Landlocked	-0.336	0.0075	-44.83	0.000
Trade agreement	1.394	0.0173	80.62	0.000

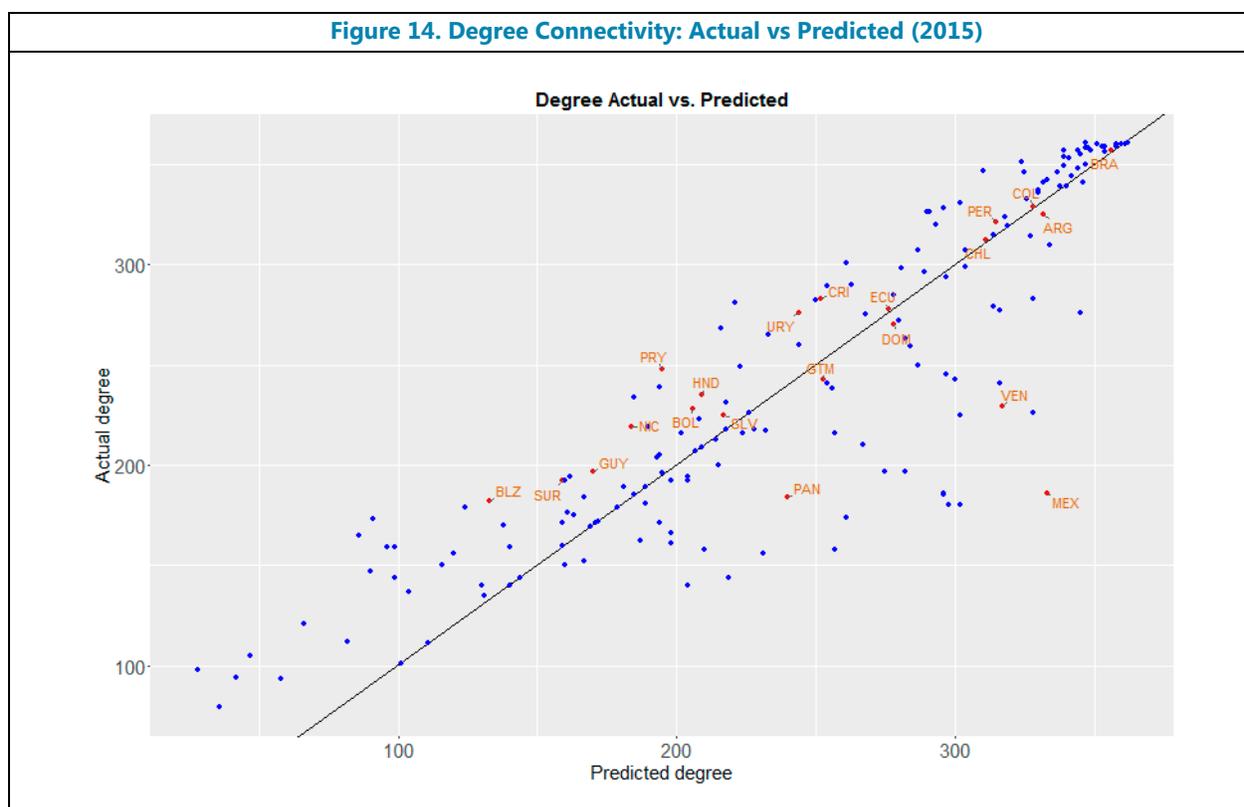
Note: year fixed effects not reported.

**22. The results suggest that all gravity variables are highly significant in affecting the likelihood of countries trading with each other.** As we have seen earlier in the simple scatter of degree and country size, the incentives to form bilateral trade links are closely related to the size of

<sup>6</sup> The GDP data series are obtained from the World Economic Outlook (WEO) database, while geographical and demographical variables (such as distance, language and colonial relationship) are obtained from the CEPII database.

the economy: an increase in the own or partner's GDP by 1 percent increases the odds ratio of having a trade link by 0.6-0.7 percent. As expected, distance or being landlocked reduced the probability of establishing a trading relation, while the strongest positive effects on trade links come from having had a colonial relationship. The coefficients and their significance are robust to whether the estimation is done with or without fixed time effects.

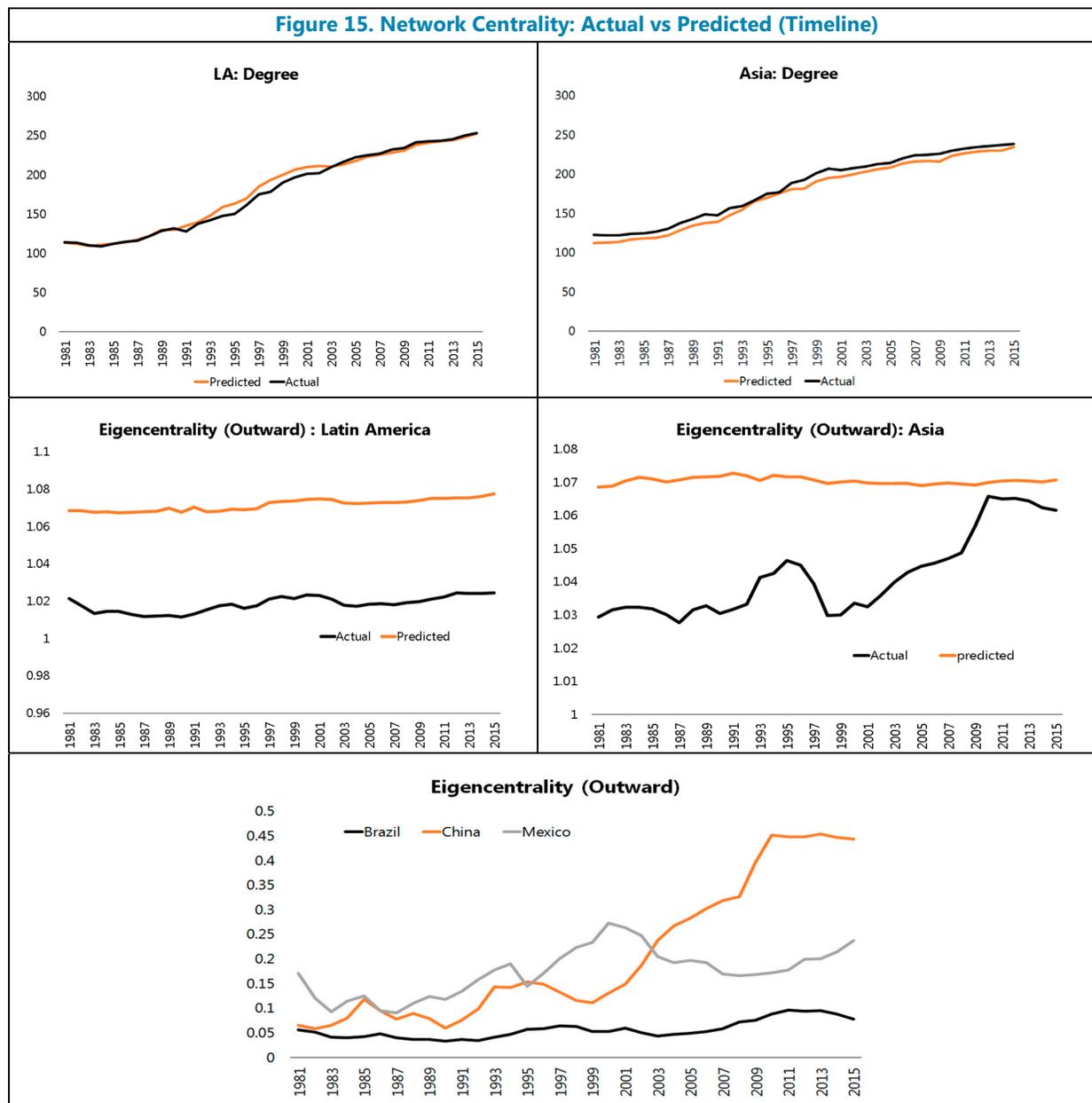
**23. How well does this benchmark model predict the topology of the actual trade networks?** Since the models by construction matches the degree of the entire network, we focus on how well it replicates individual country connectivity. We construct the usual network statistics from the simulated data, which we calculated earlier for the actual network. We find that the simulated data is able to match relatively well the cross-country and the time-series structure of the data. Figure 14 shows the results for the simulated vs actual degree (with the remaining measures broadly similar due to their high correlation). Mexico, Venezuela and Panama in particular stand out as being significantly less diversified than predicted, whereas many smaller countries are better connected relative to the what is predicted by the gravity variables (especially Belize, Suriname, Nicaragua and Paraguay). The high integration of the five countries with the largest degree centrality in the region can be fully explained with the logit-gravity model.



**24. In contrast to LAC, Asian economies were able to improve their centrality when comparing to the benchmark network.** The overall dynamics of trade integration is relatively well matched by the benchmark model (Figure 15). The evolution of degree is particularly well explained by the dynamic elements of the gravity model (economic growth) and the overall density of the

world networks. On the other hand, actual out-eigencentrality (or connectivity to important exporters) for the Latin American region consistently remains below the model-predicted out-eigencentrality. While a similar gap can be observed for Asian economies up until the late-1990s, this region appears to have caught up to predicted values over the past ten years as a result of the stronger integration into the global value chains. The LAC region’s participation in GVCs remains low and has also grown much slower than most regions.

**Figure 15. Network Centrality: Actual vs Predicted (Timeline)**



**Weighted Networks: Actual vs. Predicted**

**25. After comparing the binary WTN to its benchmark, we turn to creating a benchmark for the weighted WTN.** For the weighted network, we construct its benchmark on the basis of the trade flow predictions from non-linear specification of the gravity model with Poisson pseudo-maximum likelihood (PPML):

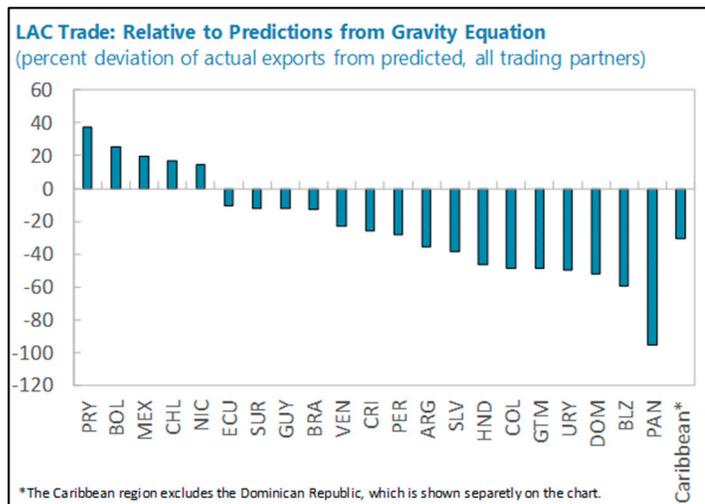
$$EXP_{ij} = \exp(\alpha_1 \ln GDP_i + \alpha_2 \ln GDP_j + \beta \ln TRADECOST_{ij}) + \varepsilon_{ij} \quad (2)$$

where the variables are the same as in regression (1) above.<sup>7</sup> The regression coefficients are highly significant and of the expected sign, with the exception of the colonial relationship (which has a negative correlation with export flows). On the basis of the predicted trade flows, we construct the weighted adjacency matrix and calculate the weighted network measures (including strength and weighted eigencentality).

Gravity regression results (PPML)	
explained variable:	exports
Ln GDP Exporter	0.810***
Ln GDP Partner	0.839***
Ln Weighted Distance	-0.629***
Contiguity	0.612***
Common language	0.479***
Colonial relationship	-0.125***
Common colonizer	0.920***
Landlocked	-0.431***
Regional trade agreement	0.183***
Observations	673644
* $p < 0.05$ , ** $p < 0.01$ , *** $p < 0.001$	

**26. Comparing the benchmark network measures to the actual data suggests that most LA countries are more weakly integrated into the WTN than predicted by the gravity model (Figure 16).**

To better gauge the significance of the deviations of strength centrality from its predicted levels—given that the model errors appear to be proportional to country size—we scale the strength gap by its predicted value (figure).<sup>8</sup> Adjusting trade flow deviations by the size of the flow makes it more clear that trade underperformance in the large countries like Brazil is in fact relatively small (only around 6 percent in the case of Brazil), while smaller countries like Panama and Belize show much larger underperformance in percentage terms. Only few countries in the region show higher-than-predicted strength (Paraguay, Bolivia, Mexico, Chile and

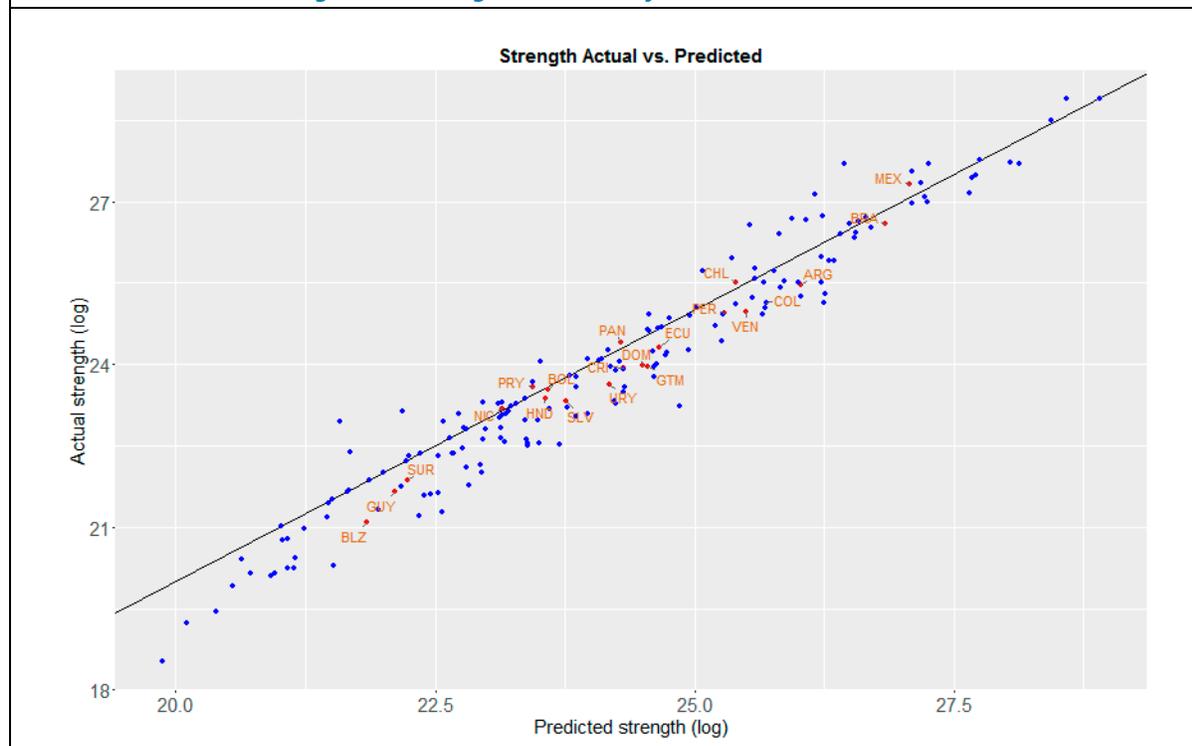


<sup>7</sup> The PPML specifications has a number of advantages over OLS estimates, including (i) the possibility of keeping the zero observations, since the estimation is on the level of exports and not on the logs; (ii) the error variance of bigger countries is bigger, so higher observed trade flows are also assumed to be more uncertain and a smaller weight is put on minimizing the residuals of big countries when estimating the coefficients; and (iii) if the error term in the original non-linear model is heteroskedastic, then the error term in the log-linearized model will be correlated with the explanatory variables, and OLS will be inconsistent.

<sup>8</sup> This is equivalent to scaling bilateral export gap by predicted exports, when strength is not scaled by total flows in the network to begin with.

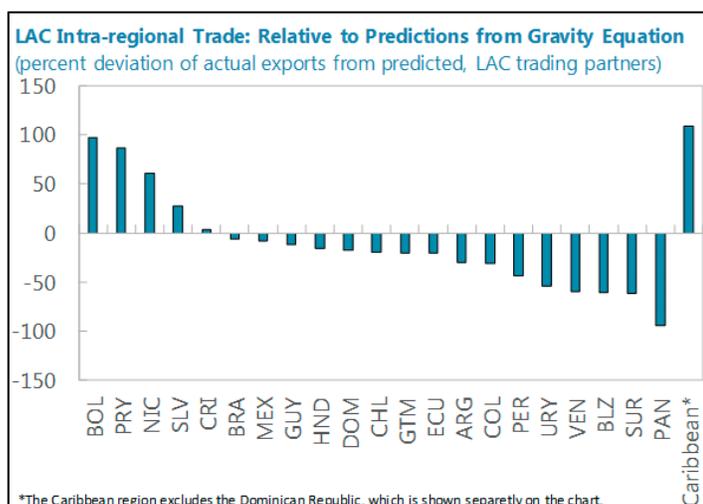
Nicaragua). Relative to the size of the trade flows, Paraguay and Bolivia appear to over-trade the most, while Mexico over-trades at broadly similar levels as Chile. The qualitative results for other weighted network measures are in line with the ones for strength, and are not reported here.

**Figure 16. Strength Connectivity: Actual vs Predicted (2015)**



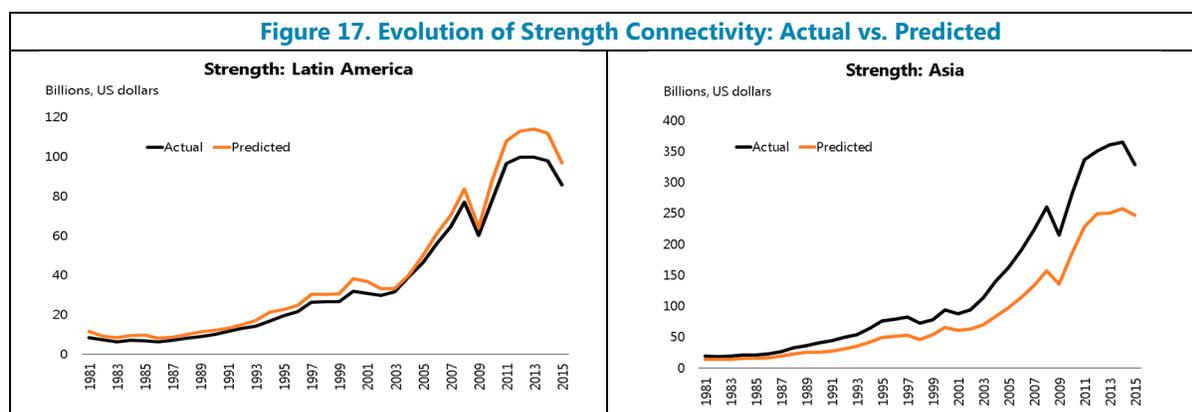
**27. The weak regional role of large LA countries becomes apparent when we compare actual strength with the predictions of the benchmark for the LA regional subnetwork.**

The figure herein shows the percent strength gaps calculated for the regional subnetwork, i.e. it compares the sum of actual exports to LAC countries to the sum of predicted exports to LAC countries. As was the case for the world network, most countries in LA appear to under-trade regionally as well. Both Chile and Mexico, who have been over-trading in the context of the world network, are estimated to under-trade with regional partners. This reflects the clear extra-regional integration of both countries, and in the case of Mexico its connectivity to the U.S. On the other hand, El



Salvador and Costa Rica under-trade globally but have strong regional ties. Bolivia, Paraguay and Nicaragua are estimated to overtrade both in the work and regional networks.

**28. It is worth noting that the underperformance in the LAC weighted strength relative to the model is a relatively recent phenomenon, with the actual data matching the benchmark predictions very closely until 2010 (Figure 17).** In other words, the volume of trade flows has not kept up with the predictions implied by the evolution of the LAC and partner economies and/or has not reaped the full benefits of the trade agreements. In contrast, Asia has consistently over-performed against the predicted trade flows.



## D. Conclusions

**29. Latin America has made important progress in integrating into the WTN, but there is substantial room for further integration.** It is particularly well connected in terms of market diversification, but many countries are still under-connected due to the concentration of their exports either geographically (Mexico) or in terms of composition (Venezuela, Panama). This, along with weak participation in global value chains, prevents the region from reaching a critical threshold of connectivity that would allow it to play a more central role in the world networks.

**30. LAC's integration in terms of the intensity of the trade flows is somewhat weaker.** The strength of the trade links has generally been commensurate with the evolution of the regional economies, but appear to have slowed below these levels over the past few years. Mexico's integration in the U.S. supply chains have boosted the strength of its connectivity into the world networks, but other larger countries have lagged behind, reducing the overall centrality of the region in the world network.

**31. The density of the LAC trade subnetwork is high due to the small number of countries in the region, but the strength of these connections is weak.** This reflects the extra-regional concentration of their trade, with the US playing the role of the region's trade hub. The largest countries in the region (Mexico, Brazil) are not central to the LAC network, and play the role of only local hubs to their immediate neighbors or trade agreement partners. There is significant scope for larger countries to position themselves for a more central role in the regional subnetwork, but the paper does not examine the factors that could facilitate such integration.

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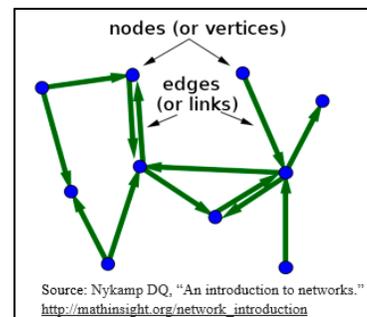
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## Annex I. An Overview of Network Measures

This annex provides definitions and formulas for various network analysis measures, drawn from Newman (2010).

A *network* is a structure that made up of a set of objects (called nodes or vertices) that are connected together. A node or vertex is the fundamental unit of which network are formed, and the connections between the nodes are called edges or links. A weighted or valued network can be represented by giving the edge values equal to the weights of the corresponding connections, and a directed graph is a network in which each edge has a direction, pointing from one vertex to another.



Annex Table 1. Network Measures		
Measure	Definition	Formula
Degree	The degree of a node is the number of connections it has to other nodes	$k_i = \sum_{j=1}^n A_{ij}$ where $A_{ij} = 1$ if there is a connection between $j$ and $i$ .
Strength	The sum of weights attached to ties belonging to a node (e.g. value of total trade).	$s_i = \sum_{j=1}^N A_{ij}w_{ij}$ where $A_{ij} = 1$ if there is a connection between $j$ and $i$ and $w_{ij}$ denotes the weight of such connection, in our cases it is the value of the trade flows.
Eigenvector Centrality	Eigenvector centrality gives each vertex a score proportional to the sum of the scores of its neighbors. This is based on the concept that connections to high-scoring nodes contribute more to the score of the node in question than equal connections to low-scoring nodes. <i>Inward eigencentrality</i> considers only vertices that points out to vertex $v$ and <i>outward eigencentrality</i> considers those that vertex $v$ points to. <i>Weighted eigencentrality</i> assigns weights to each connection (links) considered in calculation.	$x_v = \frac{1}{\lambda} \sum_{t \in M(v)} A_{ij}x_j = \frac{1}{\lambda} \sum_{t \in G} a_{vt}x_t$ Where $x_v$ is the relative centrality score of vertex $v$ . For a given graph $G:=(V,E)$ with $ V $ number of vertices, $A = (a_{v,t})$ is the adjacency matrix, i.e. $a_{v,t}=1$ if vertex $v$ is linked to vertex $t$ , and $a_{v,t}=0$ otherwise. $M(v)$ is a set of neighbors of $v$ and $\lambda$ is a constant.
Closeness Centrality	The closeness centrality is calculated as the sum of the length of the shortest paths between the vertex and all other vertices in the graph. Thus the more central a node is, the closer it is to all other nodes.	$C(x) = \frac{n}{\sum_y d(y,x)}$ Where $d(y,x)$ is the distance (length of the shortest path) between vertex $x$ and $y$ . $n$ is the total number of shortest paths between the vertices and all other vertices.

<b>Annex Table 1. Network Measures (Concluded)</b>		
Betweenness Centrality	Betweenness centrality is a measure of centrality based on shortest paths. For every pair of vertices in a graph, there exists a shortest path between the vertices such that either the number of edges that the path passes through (for undirected graphs) or the sum of the weights of the edges (for directed graphs) is minimized. The betweenness centrality for each vertex is the number of these shortest paths that pass through the vertex.	$C_B(v) = \sum_{s \neq v \neq t \in V} \frac{\sigma_{st}(v)}{\sigma_{st}}$ <p>Where <math>\sigma_{st}</math> is the total number of shortest paths from node s to node t and <math>\sigma_{st}(v)</math> is the number of those paths that pass through v.</p> <p>The betweenness of a vertex v in a graph G:=(V,E) with V vertices is computed as follows:1. For each pair of vertices (s,t), compute the shortest paths between them. 2. For each pair of vertices (s,t), determine the fraction of shortest paths that pass through the vertex in question (here, vertex v). 3. Sum this fraction over all pairs of vertices (s,t).</p>
Authority Centrality	The authority centrality of a vertex is defined to be proportional to the sum of the hub centralities of the vertices that point to it.	$x_i = \alpha \sum_j A_{ij} y_j$ <p>Where <math>x_i</math> is the authority centrality and <math>y_j</math> is the hub centrality, and <math>A_{ij} = 1</math> if vertices j points to vertices i.</p>
Hub Centrality	The hub centrality of a vertex is proportional to the sum of the authority centralities of the vertices it points to.	$y_i = \beta \sum_j A_{ji} x_j$ <p>Where <math>x_i</math> is the authority centrality and <math>y_j</math> is the hub centrality, and <math>A_{ji} = 1</math> if vertices i points to vertices j.</p>