Emerging countries and trade regionalization. A network analysis

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1. Introduction

The impressive growth of trade flows from emerging countries and the proliferation of bilateral and regional preferential trade agreements are among the main trends that characterized the world economy in the past decade, and that drew the attention of policy-makers on the deep effects that they have on the organization of international markets. The increasing trade shares of Brazil, Russia, India and China (the so-called BRICs) have been largely documented and discussed, but together with this small group of large economies, many more mid-size emerging countries are rapidly expanding their exports and their imports. As discussed by Hanson (2012), since the early 1990s, low- and middle-income economies more than doubled their total share of world exports. As far as regionalization is concerned, two opposite trends are observed: on the one hand, there seems to be a trend of increasing regionalization in trade. On the other hand, as transportation and communication costs decreased, the average number of trading partners of each country has been increasing over time, and more firms trade at long distance, suggesting that regionalization should be declining, as shown also by the increase in the number of preferential trade agreements (PTAs) being signed between far away countries. Overall, the number of existing trade agreements between both geographically close and far away countries has increased very rapidly since the 1990s, and in 2011 nearly 300 such agreements were in place. The amount of international trade covered by these agreements seems to increase as well: according to the World Trade Organization (WTO, 2011), the value of trade between members of PTAs has grown faster than the world average in the past decades, increasing the share of PTA trade to world trade to 35% in 2008. In recent years, emerging countries have become very active in signing PTAs and nowadays the vast majority of PTAs in place is between developing or emerging countries (WTO, 2011).

In this paper, we put together these two trends to better understand the characteristics of the process of internationalization which is involving so many emerging countries. In particular, by considering the extent of regionalization in trade or the preferentiality of regional trade, as well as the structure of some existing trade agreements in terms of influence of individual countries on intra-regional trade flows, we address the following questions: is internationalization of emerging countries starting at a regional level and eventually evolving to make them global players? Is the growing export strength of many low- or mid-income and size economies due to their linkages to some increasingly important traders in the world market, or is it an autonomous development of their economies?

Measuring trade regionalization and detecting leadership patterns in regional trade networks may be done in different ways, including the use of gravity models, intensity indices or network analysis tools. In this paper we start from a particular specification of bilateral trade intensity indices which allows measuring revealed trade preferences, overcoming several statistical shortcomings of traditional indicators (Section 2). We then apply the tools of network analysis, in order to take into account whether local trade structures and preferential agreements affect the overall system of international trade (Section 3). In both sections we study the role of BRICs in the global and regional trade networks in three years: 1995, 2008 and 2011. The four regions considered here connected to each BRIC country are the Southern Common Market (Mercosur),[1] the

[1] The Mercosur was established in 1991 and until 2011 included Argentina, Brazil, Paraguay and Uruguay. The recent accessions of Venezuela and Bolivia have not been considered in this paper.

Commonwealth of Independent States (CIS),[2] the South Asian Free Trade Area (SAFTA)[3] and a regional grouping including China and member countries of the Association of South East Asia Nations (ASEAN).[4] The data used in the paper are drawn from the Direction of Trade Statistics (DOTS) of the International Monetary Fund (IMF) and refer to the value of imports in current US dollars.

2. Bilateral trade intensity indices and the measurement of trade regionalization and leadership

The dominant approach to the measurement of trade intensity between two countries is based on a comparison between actual bilateral trade flows and their potential level, estimated through a gravity model as a function of the economic size of the two countries and the relative importance of bilateral trade barriers, including distance, protectionist policies, and other factors segmenting international markets. Gravity models have also been widely applied to study the effects of preferential trade agreements and other proximity factors, such as the use of a common language, migration flows, international production fragmentation, or past colonial ties, which can explain the emergence of privileged routes in the world trade network. However, model specification and econometric methods are still very controversial and the estimates obtained vary widely across different studies (Adams, Dee, Gali, & McGuire, 2003; Anderson, 2011; Cardamone, 2007; Fontagné & Zignago, 2007; Mordonu, Rayp, Herz, & Wagner, 2011).

In most specifications of the gravity model, the dependent variable is the value of bilateral trade at current or constant prices. An alternative and simpler approach is based on the idea that, before making any econometric estimate, the intensity of trade can be measured by comparing the actual value of trade to a properly defined benchmark. This implies that one or more of the variables used as regressors in gravity models is included in the intensity benchmark, so that the subsequent econometric estimates can focus on a more limited set of exogenous variables.[5]

Trade intensity indices are based on a comparison between actual bilateral trade flows and the hypothetical value they would reach in a situation of *geographic neutrality*, namely if the reciprocal importance of each country were equal to its weight in world trade (Kunimoto, 1977). In other words, given the *trade* size of the two countries, which depends on both their economic size and their degree of international openness, bilateral trade intensity indices aim at capturing the

[2] The idea to create a CIS Free Trade Area (CISFTA) was agreed in 1994, but its implementation has been very slow and with different levels of participation by member countries. In this paper we have considered the entire CIS membership, regardless of its changes over time, which includes Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, Kyrgyzstan, Moldova, Russia, Tajikistan, Turkmenistan, Ukraine and Uzbekistan.

[3] The SAFTA Agreement was concluded in 2004 among the member states of the South Asian Association for Regional Cooperation (SAARC), including Afghanistan, Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan and Sri Lanka. Bhutan has not been included in our analysis for lack of data. The accession of Afghanistan in 2011 has not been considered.

[4] The ASEAN was established in 1967, and the ASEAN Free Trade Area (AFTA) was created in 1992. Its current member states are Brunei, Cambodia, Indonesia, Laos, Malaysia, Myanmar, the Philippines, Singapore, Thailand and Vietnam. An ASEAN-China Free Trade Area (ACFTA) was established in 2010, but bilateral preferential trade agreements had already been concluded in previous years. See: http://www.asean.org/news/item/asean-china-dialogue-relations.

[5] The relationship between trade intensity indices and gravity models of international trade is analyzed in Leamer and Stern (1970), Drysdale and Garnaut (1982) and Frankel (1997). Gaulier (2003) shows how trade intensity indices can be related to the gravity model proposed by Deardorff (1998). Trade intensity indices are used in the context of gravity models by Gaulier, Jean, and Ünal-Kesenci (2004) and by Zhang and van Witteloostuijn (2004).

degree of reciprocal *preference* between two trading partners, which can be the result of geographic nearness and/or other proximity factors. Referring to a geographic neutrality threshold implies that proximity is implicitly defined in relative terms, that is as the ratio between bilateral distance and the average distance from the other countries.

Analogous indicators, called bilateral trade propensity indices, can be obtained starting from an alternative specification of the geographic neutrality threshold, in terms of GDP rather than of total trade.[6] In other words, geographic neutrality can be defined as a situation in which the reciprocal importance of each country in bilateral trade is equal to its weight in world GDP. This benchmark looks more consistent with the logic of gravity models,[7] but is implicitly based on the arbitrary assumption that the trade-to-GDP ratio is constant across countries. On the contrary, it is easy to show that this traditional measure of trade openness is not at all constant, and among other factors affecting it, it is negatively related to country size for a variety of reasons, including the simple fact that, by definition, large countries face a lower ratio between the size of foreign and domestic markets.[8]

The variance of bilateral intensity indices around their neutrality benchmark may be seen as a measure of the combined effect of relative distances and other factors hindering (or facilitating) bilateral trade. An abstract world in which the variance of intensity indices is zero may be taken as a benchmark of full globalization: a ‘frictionless’ world in which distance and other barriers or proximity factors do not affect the geography of trade.[9]

Intensity indices have also been used to measure trade regionalization, that is the tendency of countries belonging to the same region to trade relatively more between each other (intra-regional trade) than with the rest of the world (inter-regional trade).[10]

Following a similar logic, trade intensity indices can be adapted to the task of detecting possible hierarchical structures in the geography of international trade, such as core-periphery or hub-and-spoke patterns. A typical hub in a region plays a dominant role in the trade of its regional partners, but exhibits a more intense orientation toward the rest of the world.

In the next sub-section we will discuss the analytical structure of trade intensity indices and show how they can be used to describe the patterns of bilateral trade, with particular reference to their ability to reveal possible hierarchical networks. Section 2.2 will apply these indices to study the role of BRICs in their regions.

2.1. Revealed trade preference indices

As shown by gravity models, the variable size of a country’s possible partners is the most important determinant of the geographic distribution of its bilateral trade flows. So, bilateral trade shares of different partners are strongly (and trivially) correlated with their total trade size. Trade

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[6] These indices are discussed by Anderson and Norheim (1993) and Frankel (1997).

[7] Applying the Kunimoto (1977) framework to intra-regional trade propensity indices (Iapadre, 2006) shows their strong relationship with the logic of gravity models.

[8] Indicators based on a mixture of trade and GDP data raise additional problems, related to the fact that trade flows are measured in terms of gross output (including the value of intermediate goods), whereas GDP is expressed in terms of value added. Moreover, since GDP includes the services sector, bilateral trade in goods and services should be used in the numerator of the indices, but this is often precluded by data availability problems.

[9] A less demanding benchmark could be obtained through distance-adjusted intensity indices, following the logical framework of the gravity model of international trade. See De Lombaerde and Iapadre (2008).

[10] See Iapadre and Plummer (2011).

intensity indices are aimed at correcting for this problem by giving a size-independent measure of the strength of bilateral trade linkages.

In its simplest and most widely used form, which is a geographic equivalent of the well-known Balassa (1965) index of revealed comparative advantages, a bilateral trade intensity index (I_{ij}) is equal to the ratio between a partner country's share of the reporting country's total trade (S_{ij}) and its share of world trade (W_j):

$$I_{ij} = S_{ij}/W_j = (T_{ij}/T_{iw})/(T_{wj}/T_{ww}) \quad (1)$$

where T_{ij}: trade (exports plus imports) between reporting country i and partner country j; T_{iw}: trade between reporting country i and the world; T_{wj}: world trade with country j; T_{ww}: total world trade.

So, bilateral intensity indices are equal to one if the geographic distribution of a country's trade flows is proportional to the trade size of its partners (*geographic neutrality*).

Bilateral trade intensity indices are affected by at least three problems, which limit their usefulness: their range is not homogeneous across partner countries (*range variability*) and is asymmetric around the geographic neutrality threshold of one (*range asymmetry*), and their changes over time can be difficult to interpret (*dynamic ambiguity*).[11]

Range variability is shown by the fact that $0 \leq I_{ij} \leq (1/W_j)$. In other words, the maximum value of the index, which is reached when country j is the only partner of country i, is a decreasing function of the partner country's total trade, so that indices computed for different countries and/or periods are not perfectly comparable among each other.

The problem of range variability has been addressed, among others, by Anderson and Norheim (1993). A possible solution is offered by a 'homogeneous' bilateral trade intensity index (HI_{ij}), given by the ratio between a partner country's share of the reporting country's total trade (S_{ij}) and its weight in total trade of the *rest* of the world (V_{ij}):

$$HI_{ij} = S_{ij}/V_{ij} = (T_{ij}/T_{iw})/(T_{oj}/T_{ow}) \quad (2)$$

where T_{oj}: trade between the rest of the world (excluding country i) and country j; T_{ow}: trade between the rest of the world and the world.

The range of HI_{ij} goes from zero (no bilateral trade) to infinity (only bilateral trade) with a geographic neutrality threshold of one, when the importance of country j for country i is equal to its weight in world trade. Unlike the traditional Balassa index, HI_{ij} is homogeneous in the sense that its maximum value does not depend on the size of the partner country.

However, both indices are asymmetric around their geographic neutrality threshold. The range below the threshold value of one is much smaller than above, which may give rise to biased assessments of the index changes, and create problems in econometric estimates involving the index.

Another problem of HI_{ij} is that, under certain conditions,[12] its changes over time can have the same sign as the changes of the complementary 'extra-bilateral' trade intensity index HE_{ij}, which measures the intensity of trade relations between country i and all the other countries except country j:

$$HE_{ij} = (1 - S_{ij})/(1 - V_{ij}) \quad (3)$$

[11] These problems have been analyzed by Iapadre (2006) with particular reference to intra-regional trade intensity indices.

[12] See Iapadre (2006: 70–71).

When this problem occurs, interpreting the indices becomes difficult and confusing, because they convey the ambiguous information that trade intensity is increasing (or decreasing) simultaneously with country *j* and with the rest of the world, which would be an oxymoron.

A possible joint solution for the range asymmetry and dynamic ambiguity problems is to consider the ratio between the difference and the sum of HI_{ij} and HE_{ij} as an indicator of *relative* bilateral trade intensity. In Iapadre and Tironi (2009) this ratio has been defined as the bilateral *revealed trade preference index* (RTP_{ij}):

$$RTP_{ij} = (HI_{ij} - HE_{ij})/(HI_{ij} + HE_{ij}) \tag{4}$$

This index ranges from minus one (no bilateral trade) to one (only bilateral trade) and is equal to zero in the case of geographic neutrality.

An additional property of the bilateral *RTP* index is that, unlike trade intensity indices, it is perfectly symmetric across partner countries, in the sense that:

$$RTP_{ij} = RTP_{ji} \tag{5}$$

independently of country size.

RTP indices can also be used to map the intensity of trade within a region *r*. For each of its member countries, intra-regional revealed trade preferences can be computed simply by applying the above formulas to the country's trade with the rest of the region, treated as a single partner.

$$RTP_{ir} = RTP_i = (HI_{ir} - HE_{ir})/(HI_{ir} + HE_{ir}) \tag{6}$$

It can be shown that HI_{ir} is the weighted average of the corresponding bilateral indices between country *i* and its regional partners, with weights given by the relative trade size of country *i*'s partners for the rest of the world ($V_{ij}/\Sigma_{j \neq i} V_{ij}$).

An intra-regional RTP index (RTP_{rr}) can be computed also for the region as a whole, and is equivalent to the 'regional trade introversion' index proposed by Iapadre (2006). It measures in relative terms to what extent a region's member countries tend to trade among each other more intensively than with third countries. This is often the result not so much of a high degree of regional integration as of structural problems limiting the region's members' ability to participate in the international trade network.

For any given level of regional introversion, bilateral trade flows among member countries and with the rest of the world may exhibit different patterns, reflecting several factors, such as differences in country size, degree of openness and relative distance. Possible hierarchical structures within the regional trade network may also influence the level of bilateral trade. For example, in a 'hub-and-spoke' network, the importance of the 'hub' country for the rest of the region (the spokes) is greater than the importance of the spokes for the hub, which tends to be more oriented toward the rest of the world.

However, these leadership structures cannot be captured if the RTP indices are computed on the value of bilateral trade (exports plus imports). In this case, RTP indices, unlike trade intensity indices, preserve the bilateral symmetry property of trade values, so that the importance of the hub for the spokes is by definition equal to the importance of the spokes for the hub.

Conversely, bilateral symmetry does not emerge if the matrix refers only to exports or imports. If we define revealed import and export preference indices as:

$$RMP_{ij} = (HMI_{ij} - HME_{ij})/(HMI_{ij} + HME_{ij}) \tag{7}$$

$$RXP_{ij} = (HXI_{ij} - HXE_{ij})/(HXI_{ij} + HXE_{ij}) \tag{8}$$

Table 1
MERCOSUR.

	Intra-regional import preference			Intra-regional export preference			Revealed trade leadership		
	1995	2008	2011	1995	2008	2011	1995	2008	2011
Argentina	0.905	0.935	0.916	0.945	0.900	0.903	0.020	−0.017	−0.007
Brazil	0.837	0.666	0.646	0.788	0.753	0.719	−0.025	0.044	0.037
Paraguay	0.958	0.949	0.945	0.804	0.978	0.934	−0.077	0.015	−0.005
Uruguay	0.965	0.948	0.939	0.964	0.903	0.909	0.000	−0.023	−0.015
Regional trade introversion	0.891	0.845	0.823	0.891	0.845	0.823			

where HMI_{ij}, HME_{ij}, HXI_{ij} and HXE_{ij} are the homogeneous import and export intensity indices built applying formulas (2) and (3) to import and export data, it is generally true that:

$$(RMP_{ij} \equiv RXP_{ji}) \neq (RMP_{ji} \equiv RXP_{ij})$$

So, a country's intra-regional RMP is normally different from its intra-regional RXP. This is not the trivial result of bilateral trade imbalances, as the asymmetry would emerge even if the country's imports from the region were equal to its intra-regional exports. The gap between RMP_{ir} and RXP_{ir} reflects the different relative importance of each partner in imports and exports, taking the intensity of trade with the rest of the world into account.

So, if $RMP_{ir} < RXP_{ir}$, region r's relative importance as a source of imports for country i is smaller than its importance as a destination market for its exports. This gap can be used to identify hubs in a regional trade network, as define above, and measure the strength of their leadership.In particular, a *revealed trade leadership* index (RTL_{ir}) may be defined as:

$$RTL_{ir} = (RXP_{ir} - RMP_{ir})/2 \tag{9}$$

According to this descriptive framework, trade leadership can take any of two opposite forms:

(1) *Local suppliers* ($RTL_{ir} > 0$), whose intra-regional preference is higher for exports than for imports. In other words, their importance as a source of imports for the rest of the region is greater than their dependence on intra-regional imports. This can be the result of the leader country attracting foreign direct investment and related imports of intermediate goods, which are used to produce final goods for the entire regional market;

(2) *Export hubs* ($RTL_{ir} < 0$), whose intra-regional preference is higher for imports than for exports. In other words, their importance as destination markets for the rest of the region is greater than their reliance on intra-regional exports. In some cases, this can be the result of regional production networks, in which final products made of inputs produces in different spokes are exported by the hub country to the rest of the world.

2.2. *Trade leadership patterns in emerging regions*

The indicators described in the previous section have been applied to the study of regional trade networks in the four regions of BRICs. The results are shown in Tables 1–4.

The level of regional trade introversion is quite different across the four regions, and lower in South and East Asia than in the other two regions. There is however a common and pronounced downward trend of regional introversion, which can be seen as a sign of the increasingly

Table 2
CIS.

	Intra-regional import preference			Intra-regional export preference			Revealed trade leadership		
	1995	2008	2011	1995	2008	2011	1995	2008	2011
Republic of Armenia	0.992	0.812	0.829	0.997	0.895	0.848	0.003	0.042	0.009
Republic of Azerbaijan	0.986	0.834	0.801	0.994	0.343	0.549	0.004	−0.246	−0.126
Belarus	0.997	0.957	0.951	0.997	0.955	0.951	0.000	−0.001	0.000
Georgia	0.989	0.828	0.805	0.996	0.715	0.786	0.004	−0.056	−0.009
Kazakhstan	0.997	0.905	0.592	0.998	0.817	0.669	0.000	−0.044	0.039
Kyrgyz Republic	0.997	0.927	0.796	0.995	0.977	0.977	−0.001	0.025	0.091
Moldova	0.996	0.853	0.850	0.997	0.924	0.883	0.000	0.035	0.016
Russian Federation	0.984	0.580	0.518	0.979	0.712	0.696	−0.003	0.066	0.089
Tajikistan	0.995	0.935	0.838	0.996	0.873	0.762	0.001	−0.031	−0.038
Turkmenistan	0.994	0.832	0.787	0.998	0.957	0.714	0.002	0.063	−0.036
Ukraine	0.992	0.878	0.909	0.996	0.890	0.906	0.002	0.006	−0.002
Uzbekistan	0.993	0.911	0.885	0.995	0.952	0.946	0.001	0.020	0.031
Regional trade introversion	0.992	0.827	0.796	0.992	0.827	0.796			

Table 3
SAFTA.

	Intra-regional import preference			Intra-regional export preference			Revealed trade leadership		
	1995	2008	2011	1995	2008	2011	1995	2008	2011
Bangladesh	0.911	0.844	0.800	0.500	0.072	−0.024	−0.206	−0.386	−0.412
India	−0.314	−0.499	−0.634	0.638	0.372	0.197	0.476	0.436	0.415
Maldives	0.875	0.794	0.764	0.925	0.705	0.746	0.025	−0.045	−0.009
Nepal	0.907	0.979	0.971	0.798	0.977	0.963	−0.054	−0.001	−0.004
Pakistan	0.183	0.484	0.332	0.430	0.245	0.239	0.124	−0.119	−0.046
Sri Lanka	0.864	0.891	0.877	0.464	0.522	0.497	−0.200	−0.184	−0.190
Regional trade introversion	0.603	0.381	0.219	0.603	0.381	0.219			

Table 4
ASEAN + CHINA.

	Intra-regional import preference			Intra-regional export preference			Revealed trade leadership		
	1995	2008	2011	1995	2008	2011	1995	2008	2011
Brunei Darussalam	0.814	0.837	0.676	0.409	0.426	0.046	−0.202	−0.205	−0.315
Cambodia	0.942	0.766	0.874	0.889	−0.115	−0.037	−0.026	−0.441	−0.455
P.R. China: Mainland	−0.189	−0.271	−0.310	−0.372	−0.359	−0.430	−0.092	−0.044	−0.060
Indonesia	0.322	0.601	0.556	0.036	0.480	0.462	−0.143	−0.061	−0.047
Lao People’s Democratic Republic	0.853	0.940	0.919	0.803	0.908	0.912	−0.025	−0.016	−0.003
Malaysia	0.356	0.509	0.518	0.657	0.631	0.613	0.151	0.061	0.048
Myanmar	0.915	0.918	0.890	0.778	0.871	0.817	−0.069	−0.023	−0.036
Philippines	0.116	0.433	0.390	0.154	0.659	0.568	0.019	0.113	0.089
Singapore	0.504	0.460	0.357	0.571	0.621	0.552	0.033	0.081	0.097
Thailand	0.168	0.338	0.308	0.467	0.552	0.537	0.149	0.107	0.115
Vietnam	0.607	0.607	0.553	0.416	0.298	0.277	−0.096	−0.154	−0.138
Regional trade introversion	0.321	0.215	0.120	0.321	0.215	0.120			

global character of international economic integration. In other words, although trade introversion remains very high, particularly in some developing regions, its widespread decline seems to suggest that the trade-hindering effects of distance and border barriers have gradually weakened. In addition, it could be reminded that the multiplication of regional and bilateral trade agreements has eroded their preference margins with respect to the multilateral regime, reducing the scope for trade diversion effects.

In our group of regions, Mercosur shows the least pronounced fall in trade introversion (Table 1). Intra-regional trade preferences have declined in Brazil, particularly on the import side, but less so in the other member countries, where they remain at relatively high levels. Argentina, which was a *local supplier* in 1995, has turned into an *export hub* due to opposite changes in its import and export intra-regional preferences. The leading role of Brazil as a *local supplier* emerged only in 2008 and has weakened during the global crisis.

The CIS region was characterized in 1995 by extremely high rates of intra-regional trade preferences, very close to the maximum possible level of trade introversion (Table 2). Constrained by the problems created by the transition to the market system, CIS countries tended initially to trade almost exclusively between each other, following the patterns of their previous regimes. The opening to extra-regional trade has been very rapid in the following decade, and regional trade introversion has continued to fall during the global crisis. Russia has rapidly assumed the lead of this process, playing the role of a dominant *local supplier*. However, other smaller countries, such as Azerbaijan and the Kyrgyz Republic, show relatively high RLP indices, even if their tiny size still translates into higher levels of intra-regional preferences.

In the case of SAFTA (Table 3) regional trade introversion has fallen drastically between 1995 and 2011. The dominant role of India as *local supplier* has never been challenged, even if its RLP index has slightly dropped. It is interesting to note that India's intra-regional import propensity is markedly and increasingly negative, showing that the importance of SAFTA partners as import suppliers is much lower for India than for the rest of the world. This peculiar result is mostly driven by the very low level of bilateral trade intensity with Pakistan.

The case of the ASEAN-China region is even more striking. China's linkages with ASEAN countries appear relatively weak, as both indices of intra-regional trade preferences are strongly negative. Since the preference index is higher on the import than on the export side, China can be seen as an *export hub* of the region, which would be consistent with the wide-spread idea that trade regionalization in East Asia is mostly a market-driven process, connected with international production fragmentation. However, other countries, including Indonesia and Vietnam, play a similar role in the region, whereas Malaysia, Philippines, Singapore and Thailand show the preference pattern of *local suppliers*. Overall the trade introversion of the region, which was already low in 1995, has fallen to 0.12 in 2011, close to the threshold of geographic neutrality. Few regions in the world show such a short distance from the benchmark of global integration.

3. Network centrality as a measure of asymmetry in integration

A different approach to measuring economic integration of countries through trade uses the tools of network analysis. Representing international trade flows between countries as a network of nodes (the countries) and links (the trade flows between each country pair) allows to give emphasis to the structure of the relationships between the countries (De Benedictis & Tajoli, 2011). This is exactly the purpose of network analysis, which in fact places emphasis on the relationship between vertices in the graph and on the structure of the system itself. The application of network analysis to international trade relations can, therefore, complement other empirical analyses of trade. In particular, network analysis allows on the one hand to take into account whether local trade structures affect the overall system of international trade (Piccardi & Tajoli, 2012), and on the other hand, to look at the structure within the local networks, to highlight their asymmetries and to understand if they are built around a country acting like a hub of the system, or they represent a system of countries with similar role and importance.

Centrality measures are often used in order to understand whether connectivity in the network is evenly distributed. This assessment can be made for individual network nodes through a variety of centrality measures which have been developed, or for the network (or sub-network) as a whole through the centralization indices. In network analysis, the centrality of a node is directly related to its connectivity to the rest of the system, and it is interpreted as a measure of its importance in the network structure. In general, if for any reason a central node is disconnected from the network, the whole network structure would be affected, and if a shock hits a central node, the transmission of the shock will be fast and widespread. In an international trade network, centrality measures based on the number of trade links of a given country and their strength indicate how well connected a country is to the rest of the system, and to what extent the position of the country shapes the network. The measures of centrality that we use in this work try to assess how influential a country is for the international trade system as a whole, and for a specific region. Within a given region, the region's structure and level of cohesion depend crucially on the central country.

3.1. Measures of centrality and centralization

The simplest measure of centrality of a node is the *degree centrality*, measuring the number of its neighbors, or direct links of a node (for a formal definition of all the centrality measures used see the Appendix). This measure is often standardized taking the node's degree divided by the maximum possible degree. This index can also be applied to weighted networks, where existing links between nodes are not equivalent, but they are weighted according to their strength. In the world trade network, the natural weight given to countries' links formed by trade flows is the value of trade carried by each link.

In a perfectly uniform network (or regular network), each node has exactly the same number of links, or if weighted, would have the same number of links with the same distribution of strength, so each node would have exactly the same normalized degree centrality, or in other words no node would be more central than others. For example, a directed complete network with N nodes (where every node is directly connected to every other node in both directions) is a regular network in which the degree of every node is $N-1$ and every node has the same standardized maximum centrality measure. Instead, in a so-called star network there are two groups of nodes: a core node linked to all nodes in the periphery, while nodes in the periphery are linked only to the core node, and not to each other. In a pure star, the degree of the unique core vertex is $N-1$, and the degree of the $N-1$ periphery vertices is 1, and the core node would have the maximum degree centrality, while the periphery nodes would have the minimum one.

The *degree centralization of a network* is defined relatively to the maximum attainable centralization, and it refers to the absolute differences between the centrality scores of the vertices and the maximum centrality score among them. So, the higher the variation in the degree of vertices the higher the centralization of a network: for example, the degree centralization of any regular network is 0, while a star has a degree centralization of 1. In this respect, centralization can measure the evenness of the distribution of links within the network.

Different measures of centrality capture different aspects of the importance or influence of a node, and there is no general consensus on whether one is more appropriate than others, also because each measure makes implicitly different assumptions about the kind of links between nodes, and stresses a specific role or effect of connectivity. A centrality measure often used to capture "influence" within a network is the *eigenvector centrality*, which measures the importance of a node in terms of its connections to other central nodes. The measure is the sum of the centralities of the neighbors' nodes (the nodes connected to the observed one), multiplied by a normalization parameter. This index is not straightforward in its interpretation, but as suggested by Borgatti (2005), it seems more appropriate to capture the type of "influence" associated to international trade flows than other centrality measures (such as closeness centrality or betweenness centrality).[13]

If the network is directed (i.e. links point in a specific direction from one node to another), as it is natural to consider the international trade network, distinguishing between import and export flows, we can compute a centrality measure that also takes into account whether a country is important in the network as an import destination (because it is pointed by many highly ranked countries, it has a high "authority" score, in network jargon), or whether it is a key exporter (as its trade flows are directed to many important destinations, it has a high "hub" score in the network). In what follows, we present different centrality measures for the BRICs, and we assess the results in terms of their role in the international trade system.

3.2. The role of emerging countries in regional trade networks

The first set of results is reported in Table 5, where centrality for each country is computed taking into account the whole world trade network structure, using a dataset of 188 countries. As mentioned, different measures of centrality capture different aspects of the role of countries in the system, and this is why more than one index is in the table. For each centrality measure, the first three countries ranked in terms of centrality are reported, together with the rank and index for the BRICs. All the indices are in relative terms, assigning a value of 100 to the most central country (or countries, if more countries occupy equivalent positions) in the network.

The first measure is degree centrality, which simply measures how well connected a country is to the rest of the system in terms of the number of existing links. Not surprisingly, large and advanced economies are very well connected and are ranked in the first positions. Interestingly, using this first indicator, which does not consider the weight of trade flows, European countries and Canada appear better placed than the USA, which in fact is a relatively less open economy. Already in 1995, the BRICs appear fairly well connected and central in the system, with the possible exception of Russia, whose index value is about half the one of the top country. All the BRICs catch-up considerably in terms of the number of their connections in the past decade and by 2008 they appear nearly as well connected as the top advanced countries. Their position and their indices do not change much with the recent global crisis.

A slightly different picture emerges from the second set of centrality measures in Table 5, where the economic weight of countries in terms of the amount traded plays a role, as trade links are weighted according to their value in current U.S. dollars. In this case, the USA are ranked first constantly throughout the observation period, followed by Germany in 1995 and 2008. It is indeed remarkable the change occurred to the position of China, not only in terms of ranking, but especially looking at the value of the index. China's centrality was about one quarter of the USA back in 1995, it increased to three quarters of its value by 2008, and the index is very close to

[13] For a definition and discussion of the implications of different centrality measures see Borgatti (2005).

Table 5
Overall centralities in the World Trade Network.

1995			2008			2011		
Rank	Country	Index	Rank	Country	Index	Rank	Country	Index
Total degree centrality								
1	Germany	100	1	Canada	100	1	Canada	100
2	UK	99.72	2	Germany	100	1	France	100
3	France	99.44	3	UK	100	1	Italy	100
3	Italy	99.44	6	India	99.45	1	Switzerland	100
15	China	93.06	7	China	99.17	1	UK	100
23	India	87.78	15	Brazil	98.34	6	China	99.72
24	Brazil	86.67	29	Russia	94.48	11	India	99.17
70	Russia	56.11				21	Brazil	97.79
						30	Russia	94.20
Total weight centrality								
1	USA	100	1	USA	100	1	USA	100
2	Germany	67.65	2	Germany	76.49	2	China	97.50
3	Japan	56.11	3	China	75.84	3	Germany	73.75
8	China	25.26	12	Russia	21.90	12	India	21.01
19	Russia	9.29	16	India	14.62	13	Russia	20.77
23	Brazil	7.46	19	Brazil	12.04	18	Brazil	14.32
30	India	4.90						
Eigenvector centrality								
1	USA	100	1	USA	100	1	USA	100
2	Canada	56.47	2	Canada	48.89	2	China	53.06
3	Japan	49.57	3	Germany	45.47	3	Canada	47.04
13	China	19.19	4	China	40.04	15	India	14.17
21	Brazil	8.53	16	Russia	11.81	16	Brazil	12.67
30	Russia	3.79	19	India	10.12	19	Russia	9.84
33	India	3.65	20	Brazil	10.11			
Authority centrality								
1	USA	100	1	USA	100	1	USA	100
2	Germany	29.90	2	Japan	26.38	2	Japan	31.59
3	Japan	27.44	3	Germany	26.30	3	Hong Kong	30.36
10	China	14.38	5	China	21.64	4	China	30.05
21	Brazil	4.97	16	Russia	8.82	13	India	11.60
31	Russia	2.39	18	India	7.34	17	Russia	8.63
32	India	2.38	21	Brazil	6.08	19	Brazil	8.39
Hub centrality								
1	Japan	100	1	China	100	1	China	100
2	Canada	90.81	2	Canada	65.40	2	Canada	50.82
3	USA	60.37	3	Germany	44.98	3	Mexico	41.51
5	China	49.24	14	Russia	14.19	13	Russia	13.64
22	Brazil	8.31	17	Brazil	9.96	16	India	10.03
23	Russia	7.27	20	India	8.73	17	Brazil	9.92
27	India	5.87						

the maximum one in 2011. Even if its centrality is still relatively low, the extent of the increase is similar for India, while it appears somewhat smaller (even if substantial also in this case) for Brazil and Russia.

As mentioned, a more interesting measure of the influence of a country on the world trade network is given by the last set of centrality indicators, measuring not only the number and amount of connections of a country, but also their “quality”, in terms of the importance of the nodes to which each country is connected. Looking at eigenvector centrality, again the USA are ranked first confirming that they are not only very well connected, but they are connected to all the relevant players in the global market. In 1995 and 2008 Canada ranks second, especially because of its strong ties with the USA, the most important node in the network. Also in this respect, the rise of the BRICs is impressive: China moves from being a relatively peripheral country in 1995, with an index equivalent to one fifth of the USA to being the second most central node of the world trading network in 2011, still far from the influence of the USA, but much closer than in the past. A significant improvement is recorded also for India and Brazil, but both countries appear still far from the Chinese position in the global scenario. Russia is the country in this group still farther away from the main global markets.

Eigenvector centrality can be “decomposed” considering the direction of the links, or the direction of the trade flow, to assess the centrality of a country as a market (if links from the main nodes point to it, i.e. it receives imports from the most important traders) rather than as a producer and exporter (if its links point to the main nodes, i.e. it exports to the most important markets of the network). In the first case, the country will have a high *authority* score, in the second it will have a high *hub* score. In terms of authority, i.e. the main import markets, the results are in line with expectations, and throughout the observation period, the USA rank first, followed at a distance by another large advanced economy. But the BRICs improved very much their position also in terms of being increasingly important global markets, and China is now ranked fourth in terms of authority, even if its index is still only one third of the USA. China is now also firmly the first hub (i.e. the most central exporter, not only the largest) in the world trade network. The other BRICs are ranked lower, even if also in this case they show higher positions now than in the mid-90s. The centrality of India and Brazil as exporters is very similar to the centrality they display as importers, while Russia, closely connected to the European markets as a major oil and gas exporter, has a significantly higher score as a hub rather than as authority.

Similarly to the assessment done at the global level, the centrality of the BRICs can be measured also within their trade regions. In line with what is usually done, and with the indices presented in the previous section, we considered as relevant region for each of the countries considered the countries that belong to the same preferential trade agreement, with the partial exception of China, assigned to the ASEAN region even if there was no formal agreement between China and the ASEAN group until 2010. Focusing on specific sub-regions of the network allows to not only to determine whether Brazil, Russia, China and India play a central role in the region, as we could expect, but also to what extent their influence in the region is asymmetric.

The results are presented in Tables 6–9. Brazil, as expected, plays a central role in Mercosur, but overall this does not appear like a very centralized region (the centralization index is just above 0.5, where 1 would indicate full centralization and 0 no centralization at all), as the relevance of Brazil is counterbalanced by Argentina, which in terms of weighted links is nearly as central as Brazil, and even more central in terms of “influence” (as measured by eigenvector centrality) since 2008. But the two countries play a quite different role in the area: Brazil is by far the most important exporter, while Argentina is a leading authority, as it is the main market for Brazil, but the converse is not true. In some industries, exports from Brazil to Argentina might not even be

Table 6
Centralities in Mercosur.

1995		2008		2011	
Total weight centrality					
Brazil	100	Brazil	100	Brazil	100
Argentina	90.05	Argentina	98.67	Argentina	93.35
Uruguay	18.67	Paraguay	18.90	Uruguay	17.53
Paraguay	15.16	Uruguay	16.58	Paraguay	15.93
Weight centralization	0.5871		0.5528		0.5773
Eigenvector centrality					
Brazil	100	Argentina	100	Argentina	100
Argentina	79.47	Brazil	89.90	Brazil	93.00
Uruguay	22.88	Uruguay	22.75	Paraguay	23.93
Paraguay	22.15	Paraguay	21.83	Uruguay	23.09
Eigenvector centralization	0.585		0.5517		0.5333
Authority centrality					
Brazil	100	Argentina	100	Argentina	100
Uruguay	10.20	Paraguay	14.49	Paraguay	16.02
Paraguay	9.18	Uruguay	11.24	Uruguay	11.98
Argentina	3.54	Brazil	6.52	Brazil	8.10
Authority centralization	0.9236		0.8925		0.8797
Hub centrality					
Argentina	100	Brazil	100	Brazil	100
Uruguay	13.19	Paraguay	10.38	Argentina	9.06
Paraguay	9.13	Argentina	7.37	Uruguay	3.61
Brazil	4.48	Uruguay	3.39	Paraguay	3.16
Hub centralization	0.9107		0.9295		0.9472

directed to Argentina as a final market: some important international production chains (like in the automobile sector) are shared between Brazil and Argentina, and the presence of such production arrangements can influence the observed outcome. The central role of Brazil as exporter does not show up yet in 1995, at the very early stages of Mercosur, but nowadays it seems that Mercosur is built around Brazil's export capacity (also in raw materials), but Brazil does not play such a relevant role as a market in the area.

More asymmetric is the situation in the CIS (Table 7), where Russia's centrality is challenged only to some extent by Ukraine and Belarus, as the overall centralization indices are close to 0.8, and some countries appear as truly peripheral. Here again, the centrality of Russia is linked essentially to its role as an exporter, while the indices as authority are much lower.

Somewhat less central in their respective regions is the role of India and China. Both countries have very strong ties with countries outside of the region, and this might be the reason for the result. India, being the largest economy of Southern Asia, is also the largest trader in terms of values and the most central exporter. But it has a very low authority scores, and the result is that its overall influence, as measured through eigenvector centrality is not very high. In the SAFTA region, we also observe a downward trend in centralization, as the other countries of the agreement are becoming less and less peripheral.

Also South-Eastern Asia trade is much less dominated by China that could be expected: the centralization indices are generally lower than the ones observed for the CIS. Still in 2008, China's influence as a trader in the area was lower than that of Singapore, that was the most connected

Table 7
Centralities in the CIS.

1995		2008		2011	
Total weight centrality					
Russia	100	Russia	100	Russia	100
Ukraine	62.02	Ukraine	56.37	Ukraine	66.80
Belarus	23.89	Belarus	39.50	Belarus	42.02
Kazakhstan	21.20	Kazakhstan	29.07	Kazakhstan	11.77
Uzbekistan	11.58	Uzbekistan	9.14	Uzbekistan	7.74
Turkmenistan	6.83	Turkmenistan	7.86	Azerbaijan	5.70
Moldova	4.75	Azerbaijan	3.72	Kyrgyz	3.44
Tajikistan	2.97	Kyrgyz	3.09	Turkmenistan	3.30
Azerbaijan	1.92	Moldova	2.65	Georgia	2.54
Kyrgyz	1.86	Georgia	2.34	Moldova	2.50
Armenia	1.77	Tajikistan	2.11	Tajikistan	1.79
Georgia	1.20	Armenia	1.59	Armenia	1.61
Weight centralization	0.8727		0.8569		0.8644
Eigenvector centrality					
Russia	100	Russia	100	Ukraine	100
Ukraine	97.33	Belarus	91.41	Russia	87.33
Belarus	44.83	Ukraine	87.55	Belarus	81.94
Kazakhstan	25.30	Kazakhstan	57.70	Uzbekistan	8.23
Uzbekistan	13.83	Uzbekistan	13.79	Azerbaijan	7.09
Moldova	6.40	Azerbaijan	7.37	Kazakhstan	6.30
Turkmenistan	6.33	Kyrgyz	6.65	Moldova	5.37
Tajikistan	2.24	Moldova	5.73	Kyrgyz	5.02
Armenia	1.83	Turkmenistan	5.24	Turkmenistan	4.99
Kyrgyz	1.74	Tajikistan	5.01	Georgia	3.86
Azerbaijan	1.61	Armenia	4.20	Armenia	3.56
Georgia	0.73	Georgia	4.03	Tajikistan	2.87
Eigenvector centralization	0.8162		0.7376		0.8031
Authority centrality					
Ukraine	100	Belarus	100	Ukraine	100
Belarus	41.62	Ukraine	86.62	Belarus	84.65
Kazakhstan	25.31	Kazakhstan	59.27	Uzbekistan	7.45
Russia	24.57	Russia	14.66	Russia	6.97
Uzbekistan	12.48	Uzbekistan	10.55	Azerbaijan	5.71
Moldova	4.29	Kyrgyz	6.50	Kyrgyz	4.41
Turkmenistan	2.41	Azerbaijan	6.10	Turkmenistan	3.86
Tajikistan	1.99	Tajikistan	4.64	Armenia	3.06
Armenia	1.88	Turkmenistan	4.09	Tajikistan	2.75
Kyrgyz	1.51	Armenia	3.78	Moldova	1.77
Azerbaijan	1.31	Moldova	3.31	Georgia	1.55
Georgia	0.69	Georgia	2.23	Kazakhstan	0.42
Authority centralization	0.8927		0.8166		0.8886
Hub centrality					
Russia	100	Russia	100	Russia	100
Ukraine	20.30	Ukraine	12.09	Belarus	9.33
Belarus	12.42	Turkmenistan	10.28	Ukraine	6.31
Kazakhstan	9.00	Belarus	8.68	Kazakhstan	4.36

Table 7 (*Continued*)

1995		2008		2011	
Turkmenistan	6.33	Kazakhstan	8.19	Azerbaijan	2.76
Uzbekistan	4.29	Uzbekistan	4.87	Uzbekistan	1.55
Moldova	2.50	Moldova	0.73	Turkmenistan	1.50
Azerbaijan	0.78	Azerbaijan	0.62	Moldova	0.45
Tajikistan	0.78	Kyrgyz	0.44	Georgia	0.36
Kyrgyz	0.55	Georgia	0.41	Kyrgyz	0.12
Armenia	0.27	Armenia	0.12	Tajikistan	0.08
Georgia	0.25	Tajikistan	0.12	Armenia	0.07
Hub centralization	0.9477		0.9577		0.9755

Table 8
Centralities in SAFTA.

1995		2008		2011	
Total weight centrality					
India	100	India	100	India	100
Bangladesh	68.12	Bangladesh	35.33	Bangladesh	38.83
Sri Lanka	35.19	Sri Lanka	29.83	Sri Lanka	34.40
Pakistan	21.18	Pakistan	24.41	Nepal	21.51
Nepal	8.80	Nepal	22.91	Pakistan	20.89
Maldives	3.43	Maldives	1.66	Maldives	1.46
Weight centralization	0.7266		0.7717		0.7658
Eigenvector centrality					
Bangladesh	100	Bangladesh	100	Bangladesh	100
Sri Lanka	47.51	Sri Lanka	78.03	Sri Lanka	84.97
India	31.39	Pakistan	56.90	Nepal	54.93
Pakistan	23.94	Nepal	55.40	India	54.37
Nepal	13.90	India	53.11	Pakistan	39.17
Maldives	4.90	Maldives	5.17	Maldives	4.28
Eigenvector centralization	0.7567		0.5028		0.5246
Authority centrality					
Bangladesh	100	Bangladesh	100	Bangladesh	100
Sri Lanka	47.02	Sri Lanka	81.10	Sri Lanka	88.61
Nepal	11.69	Nepal	61.47	Nepal	59.92
Pakistan	8.04	Pakistan	55.71	Pakistan	37.40
Maldives	3.09	Maldives	3.45	Maldives	2.67
India	0.59	India	0.88	India	0.83
Authority centralization	0.8591		0.5948		0.6211
Hub centrality					
India	100	India	100	India	100
Pakistan	13.17	Pakistan	5.56	Pakistan	8.94
Sri Lanka	1.26	Nepal	1.16	Bangladesh	0.62
Maldives	0.65	Sri Lanka	0.81	Sri Lanka	0.60
Bangladesh	0.60	Bangladesh	0.76	Nepal	0.30
Nepal	0.37	Maldives	0.18	Maldives	0.17
Hub centralization	0.9679		0.9831		0.9787

Table 9
Centralities in ASEAN and China.

1995		2008		2011	
Total weight centrality					
Singapore	100	China	100	China	100
Malaysia	78.15	Singapore	83.81	Singapore	61.74
Thailand	42.25	Malaysia	66.55	Malaysia	59.38
China	37.50	Thailand	49.70	Thailand	45.17
Indonesia	22.25	Indonesia	45.45	Indonesia	43.27
Philippines	11.01	Philippines	21.64	Vietnam	19.89
Vietnam	7.09	Vietnam	21.38	Philippines	14.34
Myanmar	4.00	Myanmar	4.39	Myanmar	4.69
Brunei	3.74	Brunei	2.07	Cambodia	3.06
Cambodia	2.68	Laos	1.52	Laos	1.79
Laos	0.93	Cambodia	1.35	Brunei	1.59
Weight centralization	0.7904		0.7021		0.7451
Eigenvector centrality					
Singapore	100	Singapore	100	China	100
Malaysia	66.75	China	92.16	Singapore	77.83
Thailand	42.73	Malaysia	62.71	Indonesia	57.94
China	35.58	Indonesia	61.43	Malaysia	56.69
Indonesia	28.87	Thailand	49.58	Thailand	48.96
Philippines	13.28	Vietnam	39.96	Vietnam	36.08
Vietnam	11.11	Philippines	20.76	Philippines	14.62
Brunei	7.48	Myanmar	6.19	Myanmar	8.40
Myanmar	6.55	Cambodia	2.50	Cambodia	6.00
Cambodia	4.76	Brunei	2.05	Brunei	2.63
Laos	0.86	Laos	1.82	Laos	2.13
Eigenvector centralization	0.7820		0.6608		0.6887
Authority centrality					
Singapore	100	Singapore	100	China	100
Thailand	19.48	China	85.60	Singapore	66.76
Indonesia	15.77	Indonesia	45.33	Indonesia	38.43
China	14.13	Malaysia	43.08	Malaysia	34.01
Malaysia	11.20	Thailand	41.15	Thailand	33.17
Philippines	4.99	Vietnam	29.98	Vietnam	22.68
Vietnam	2.78	Philippines	15.03	Philippines	10.13
Brunei	2.61	Myanmar	4.71	Myanmar	5.44
Myanmar	2.29	Cambodia	1.89	Cambodia	3.82
Cambodia	1.36	Laos	1.66	Laos	1.77
Laos	0.47	Brunei	1.50	Brunei	1.77
Authority centralization	0.9249		0.7301		0.7820
Hub centrality					
Malaysia	100	Malaysia	100	Malaysia	100
Thailand	34.08	China	84.36	China	62.20
China	23.93	Thailand	56.00	Thailand	58.10
Singapore	14.02	Singapore	55.13	Indonesia	52.70
Philippines	6.38	Indonesia	48.13	Singapore	51.94
Indonesia	2.90	Philippines	31.95	Philippines	24.71
Vietnam	2.65	Vietnam	11.10	Vietnam	15.55

Table 9 (*Continued*)

1995		2008		2011	
Brunei	1.36	Myanmar	2.86	Myanmar	3.10
Myanmar	1.27	Brunei	1.94	Laos	1.32
Cambodia	0.37	Laos	0.62	Brunei	1.22
Laos	0.13	Cambodia	0.34	Cambodia	0.51
Hub centralization	0.9129		0.7076		0.7287

country of ASEAN. And even in 2011, the main hub of the region is Malaysia, with China being in terms of exports relatively less influential in the area than in 2008. Interestingly, the score of China in terms of hub centrality is higher when measured at the world level than at the regional level. The strong trade ties with the USA can explain this result, but it is possible that the lack of a full-fledged trade agreement between China and ASEAN until 2010 was also partly responsible.

A comparison of the centralities of the analyzed countries in 2011 at the global and regional level is presented in Fig. 1. In this representation, the eigenvector centralization index computed at the global level for the world trade network is re-normalized to be equal to 100 for the country with the highest global score in each of the regions, and the indices of the other countries in the region are re-scaled accordingly. In each respective region, Brazil, Russia, India and China have the highest global centrality index, and therefore their global index takes the value 100 in Fig. 1. But in most cases, these countries are not ranked with the highest score if centralization is computed at the regional level. This is particularly evident in the case of India, which in relative terms appears to be more central for global trade than for the Southern Asian region. China ranks at the top both at the global and regional level in terms of overall eigenvector centrality, but only in 2011. As mentioned, still in 2008 China was regionally ranked lower than Singapore, which as

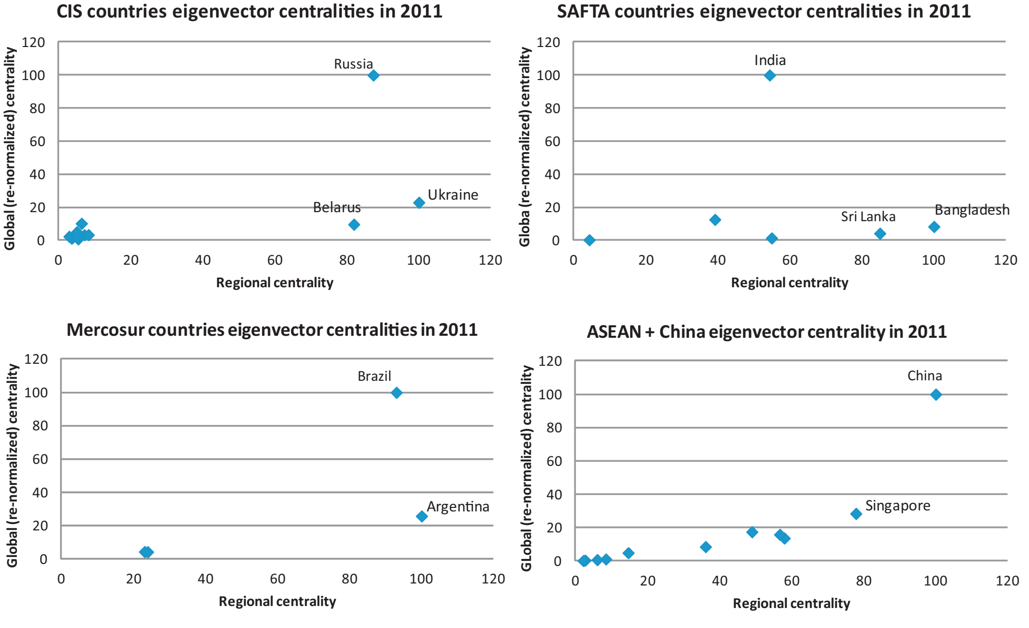

Fig. 1. Global and regional centralities.

Fig. 1 shows displays a relatively low centrality at the global level, but whose centrality is very close to China's in East Asia.

4. Conclusions

The role of emerging countries in the international trade network has grown spectacularly in the last few decades, not only in terms of trade values and market shares, but also in terms of number of trading partners and leadership role. These changes have occurred in a context characterized by two interconnected and partially competing processes: on one hand, an increase in international economic integration, driven by trade liberalization policies and international production fragmentation; on the other, a rising number of bilateral and regional preferential trade agreements, potentially leading to higher degree of trade regionalization.

We have tried to better understand the linkages among these processes, by analyzing in different ways the role played by the BRICs in the world trade network, as well as in their regions. Our results are strongly affected by the choice of statistical instruments, and further research would be needed to better clarify the linkages among different techniques, but some interesting conclusions may be drawn at this stage.

The first result concerns the scenario. The degree of trade regionalization, as measured by regional introversion indices, has fallen substantially between 1995 and 2011 in all the four regions covered by our analysis, showing that the forces driving toward global integration have been so far stronger than the trade-diverting effects of regional integration. This is particularly evident in the case of Asia, but also CIS and, to a lesser extent, Mercosur have shown a clear trend toward a lower degree of regional trade introversion.

The regional role played by each of the BRICs is different. Whereas China tends to play a role of export hub in South-East Asia, importing intermediate goods from the rest of the region and exporting final goods to the rest of the world, the regional role of Brazil, India and Russia appears to be that of dominant local suppliers, with a strong export role in partner countries fed by imports coming predominantly from the rest of the world. The evidence produced by the set of indices used in this work, especially with respect to the existing differences in terms of export and import flows at the regional and global level allows to conclude that the larger country in each region in terms of economic size and sheer trade volumes is not always also the main attractor of the region's trade flows, or the center of the regional trade structure.

But the results also show that the BRICs are the most globalized countries in terms of connectivity to the world trading system in each of their respective regions. Given the advantage of this position, they could play the important role of linking smaller nearby countries to the large international markets. Regional PTAs with a low level of introversion are in line with this role of global hubs played by one or more of the included countries. Insofar as PTAs give rise to these outward-looking structures, connected to the global trading system, rather than isolating group of countries within a given geographical area, they can be useful policy instruments for development. The main risk of such asymmetric trade organizations is the dependence of the smaller countries on a very strong center, but at the same time this link can also be their best chance to grow as exporters.

Appendix A.

A.1. Network definition and notation

A network is represented by a graph with N nodes and L links. An *unweighted* network is completely described by an $N \times N$ adjacency matrix $A = [a_{ij}]$ where

$$\begin{cases} a_{ij} = 1 & \text{if the link } i \rightarrow j \text{ exists} \\ a_{ij} = 0 & \text{otherwise} \end{cases}$$

A is *asymmetrical* if the network is *directed*. A weighted network is described by a $N \times N$ weight matrix $W = [w_{ij}]$ where

$$\begin{cases} w_{ij} > 0 & \text{if the link } i \rightarrow j \text{ exists} \\ w_{ij} = 0 & \text{otherwise} \end{cases}$$

A.2. ***Centrality measures***

A.2.1. Total degree centrality

The degree (or connectivity) k_i of a node i is the number of links incident with the node, and is defined in terms of the adjacency matrix A

$$k_i = \sum_{j \in N} a_{ij}$$

If the graph is directed, the degree of the node has two components: the number of outgoing link $k_i^{out} = \sum_j a_{ij}$ (referred to as the out-degree of the node), and the number of ingoing links $k_i^{in} = \sum_j a_{ji}$ (referred to as the in-degree of the node). The total degree is then defined as $k_i = k_i^{out} + k_i^{in}$.

Finally we define total degree centrality of a node as the sum of the relative in-degree centrality and out-degree centrality scores.

A.2.2. Total strength centrality

Generalizing the above measure of degree centrality to the case of a weighted network and integrating the information about the number and weights of the link incident in a node, the strength s_i is defined as

$$s_i = \sum_{j \in N} w_{ij}$$

If the graph is directed, the degree of the node has two components: the sum of weights of outgoing link $s_i^{out} = \sum_j w_{ij}$ (referred to as the out-strength of the node), and the sum of weights of ingoing links $s_i^{in} = \sum_j w_{ji}$ (referred to as the in-strength of the node). The total strength is then defined as $s_i = s_i^{out} + s_i^{in}$.

We then define total strength centrality of a node as the sum of the relative in-strength centrality and out-strength scores.

A.2.3. Eigenvector centrality

If we define γ_i as the centrality (or 'importance') of a node i and assert that this depends somehow on γ_j if j is a neighbor of i and that this importance is transmitted through the network structure (defined for example by the adjacency matrix A), then we are hypothesizing a proportional relation of this type

$$\gamma_i \propto \sum_j a_{ij}\gamma_j$$

If we consider the simplest case of a linear combination to model this relation we can obtain this equation

$$\gamma_i = \alpha \sum_j a_{ij}\gamma_j$$

Letting $\gamma = [\gamma_1, \gamma_2, \ldots, \gamma_N]$ ' and $\lambda = 1/\alpha$ we can reformulate the above equation to obtain the following eigenvector equation

$$A\gamma = \lambda\gamma$$

If the network is connected (A is irreducible) the centrality scores γ_i are given by the only solution with $\lambda > 0$ and $\gamma_i > 0$ for each node i (Frobenius–Perron theorem).

A.2.4. Hub and authority centrality

These indicators of centrality generalize eigenvalue centrality to allow nodes to have two attributes:

- "authority": for example how much knowledge, information, etc. held by a node;
- "hubness": for example how well a node 'knows' where to find knowledge information.

With the same recursive logic applied to obtain the eigenvector centrality scores, we now define two linear equations correlating the two indicators of centrality. Supposing that authority centrality score of the node i (x_i) is related to hub centrality score of j (y_j) if the latter is a direct neighbor of i we define authority centrality score as

$$x_i = \alpha \sum_j a_{ji} y_j$$

then, the hub centrality score of the node i (y_i) is related to authority centrality score of j (x_j) if the latter is a direct neighbor of i. We define hub centrality score as

$$y_i = \beta \sum_j a_{ij} x_j$$

The underlying idea is that good authorities point to good hubs and vice versa. If the network is connected (A is irreducible) the centrality scores x_i and y_i are given by the only solution with $1/\alpha > 0$ and $1/\beta > 0$ and $x_i > 0$ and $y_i > 0$ for each node i (Frobenius–Perron theorem).

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