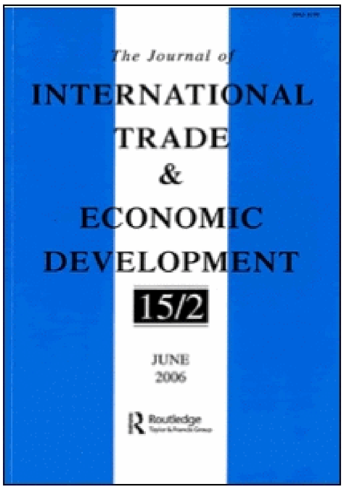

The Journal of International Trade & Economic Development
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713722379

Using complex networks analysis to assess the evolution of international economic integration: The cases of East Asia and Latin America

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Online publication date: 11 June 2010

To cite this Article Reyes, Javier , Schiavo, Stefano and Fagiolo, Giorgio(2010) 'Using complex networks analysis to assess the evolution of international economic integration: The cases of East Asia and Latin America', The Journal of International Trade & Economic Development, 19: 2, 215 — 239

To link to this Article: DOI: 10.1080/09638190802521278
URL: http://dx.doi.org/10.1080/09638190802521278

The Journal of International Trade & Economic Development
Vol. 19, No. 2, June 2010, 215–239

Using complex networks analysis to assess the evolution of international economic integration: The cases of East Asia and Latin America

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(*Received 29 April 2008; final version received 1 October 2008*)

This paper exploits recently-developed indicators based on network analysis to investigate the pattern of international integration followed by East Asian countries and compares it with the Latin American performance. Standard trade openness indicators fall short of portraying the peculiarity of the Asian experience, and of explaining why other emerging markets with similar characteristics have been less successful over the last 25 years. The analysis offers an alternative perspective on the issue regarding international economic integration by taking into account the whole structure of international trade relationships and by determining both the position of countries in the world trade network, and its evolution over time. We find that East Asian countries are more integrated into the world economy, as they have moved from the periphery of the network towards its core. Our results support the idea that the degree of openness matters but it is not enough to characterize economic integration. The number and identity of trade partners, and the specific individual structure of trade for each country, need to be incorporated in order to fully characterize international economic integration. By doing so, it is possible to argue that the integration process of the East Asian countries mirrors their high economic performance, while the lower degree of integration of Latin America can be related to the lack of economic development of the region, even though their degree of openness has increased.

Keywords: network analysis; globalization; trade and integration; Latin America, East Asia

1. Introduction

Over the past four decades, two groups of countries have occupied center stage in the discussion of economic development and, more specifically,

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ISSN 0963-8199 print/ISSN 1469-9559 online

DOI: 10.1080/09638190802521278
http://www.informaworld.com

regarding the economic policies that lead to stable and consistent economic growth. These two groups have been generally referred to as the High Performing Asian Economies (HPAE) and the Latin American Economies (LATAM).[1] The focus of the discussion, comparisons, and conclusions presented in the literature has evolved over time. Yet, two major empirical regularities emerge clearly: first, East Asian countries have posted impressive economic growth rates, on average, compared with the poor ones observed in Latin America; second, East Asian economies have proved to be more stable (despite the financial crisis of the late 1990s) than Latin American ones.

This paper does not focus on specific differences and similarities in economic policies, growth, and stability across these two regions or within the regions. Rather, the present study takes these characteristics as given and instead poses a different question, one related to the relationship that exists between economic development and international integration. The economic literature often portraits HPAE as the textbook example of the benefits of free trade, whereas the poor growth performance of LATAM countries is attributed to the stubborn adoption of import-substitution policies. Yet, after some 15 years of liberalization and increased openness, Latin American performances are not still keeping up with expectations. On the other hand, and more generally, trade openness per se falls short of capturing the peculiarity of the Asian experience, and of explaining why other emerging markets with similar characteristics have been less successful over the last 25 years.

An extensive literature has studied the effects of international trade on economic growth, with Frankel and Romer (1999) being the most well-known example. But more recent studies suggest that development is more related to the specific structure of international trade than to the mere degree of openness (Arora and Vamvakidis 2005; Kali et al. 2007; Hausmann et al. 2007). These contributions claim that the number of trading partners and their characteristics, in terms of size and performance, also matter for economic growth. Clearly, if part of the gains from trade comes from technology spillovers and from the flow of 'ideas', as postulated in the endogenous growth literature, then the number and identity of trading partners play a relevant role in fostering growth. Similarly, a less geographically concentrated trade structure acts as a diversification mechanism that could result in higher and more stable growth rates. These findings suggest that a fuller characterization of the international economic integration process of a given country or region is needed in order to understand the relationship between international economic integration and economic growth.

All this gives us reasons to believe that direct and indirect trading relationships matter, as well as the specific structure of the World Trade Network (WTN), and that the position of a country within the network can be related to its economic performance. Therefore, the present work exploits recently-developed indicators based on weighted-network analysis to provide a better understanding of the meaning of international economic integration by characterizing several dimensions of the structure of international trade. The main advantage of network indicators over standard openness measures such as trade to GDP ratios is the ability to go beyond first-order relationships (bilateral trade measures) and to capture the whole structure of relationships that form the WTN. For example, one can study trade flows between any two (or more) countries that trade with a given one (i.e. trade relationships which are two-steps away) and assess the length of trade chains occurring among a set of countries. This allows us to understand the specific characteristics of the trade linkages characterizing HPAE and LATAM countries. By doing so, it is possible to show that the early efforts towards more liberalized markets in HPAE countries have resulted in a deeper integration into the world economy; moreover, those economies have moved from the peripheral position they occupied in the 1970s towards the core of the WTN, and in some cases can now be considered part of its core. The characterization of international economic integration through the network indicators presents a clearer picture of the differences observed across regions and therefore provides evidence for the argument that the higher and more stable rates of economic growth observed in the HPAE countries can be related to their higher degree of integration within the WTN.

The analysis presented in this study does not include a regression analysis regarding the relationship between economic growth rates and the network indicators, the reason for this being that the adequate econometric specification is not clear from a theoretical perspective. Instead the discussion in the paper evolves around the analysis of the degree of international economic integration of the HPAE and the LATAM regions, and simply suggests that the observed differences in the economic performance of these regions is mirrored by the evolution of their international economic integration process, as characterized from a network perspective. The results presented here suggest that even though the LATAM countries have increased their degree of trade openness, this has not resulted in a higher degree of international economic integration. Therefore, the benefits from integration, like technology spillovers and diversification of economic activity, have not materialized.

It is worth noting that many of the concepts used throughout the paper are not new to the international trade literature. Yet, in the present context they assume quite a different connotation. So, for instance, the network of international trade to which we refer, is not the same developed in the works of Rauch and co-authors (see Rauch 2001; Rauch and Casella 2003). There, the focus is on business and social networks playing a role in alleviating informational asymmetries and contract enforcement problems, thus shaping the structure of international transactions. Here, on the contrary, we exploit network analysis as developed in the physics domain to describe the patterns of aggregate goods trade among countries. Similarly, core countries are not necessarily those where most of productive activities are located as in the New Economic Geography framework, but rather those involved in a large number of trade linkages. Moreover, Baldwin (2003, 2006) has written extensively on the risk of bilateral trade agreements giving rise to a hub-and-spoke system. Here we disregard whether the polarized structure of international trade is the result of preferential trade agreements, market size, or mere chance, and focus on describing this structure using novel and richer techniques.

The paper is organized as follows. First, in Section 2, a brief overview of the different macroeconomic performances observed across the two regions is presented. The following part, Section 3, reviews the literature on complex networks, and is followed by the main body of the paper (Section 4), where the methodology of the study is explained, and results are discussed. Finally, Section 5 summarizes the findings and concludes the paper.

2. Comparative economic performance: HPAE and LATAM

It would be hard to depict an all-inclusive historical perspective for the different experiences observed across the HPAE and the LATAM regions. The literature includes several studies that have undertaken this task and presented detailed discussions regarding the different policies implemented and the outcomes observed for each case.[2] In this section we present a brief overview, from a macroeconomic perspective, of the key characteristics of the HPAE and the LATAM regions, and we refer the reader, to the extent that is deemed necessary, to other existing studies that present a more detailed discussion of the specific attributes of the data.

A strong argument regarding the different paths followed by the two regions can be built by simply examining the evolution of GDP per capita over the last four decades. During the 1970s, the average GDP per capita of LATAM countries was almost four times higher than that observed in the HPAE region: that gap has since closed down to the point that in the year 2000 this ratio was almost equal to one. This is the result of the impressive growth rates observed in the HPAE countries over the last three decades of the past century, annual rates that were close to 10%on average, whereas they reached only 4%in the LATAM region.

In the HPAE region, high rates of growth have been accompanied by a greater macroeconomic stability, as measured by inflation rates. The hyperinflations observed in LATAM can be associated with the mismanagement of the economy by governments that pursued irresponsible and unsustainable macroeconomic policies implemented throughout the late 1970s and the beginning of the 1980s.[3] Contrary to the LATAM countries, the HPAE countries tamed inflation during the 1960s and consistently adopted sound economic policies thereafter.

Trade openness provides another important source of difference across the two regions. While LATAM countries focused on nurturing domestic firms serving local markets, Asian ones pursued outward oriented policies by blocking imports and promoting exports (Baldwin 2006). This, together with an earlier move towards liberalization, allowed Asian firms to adapt to foreign competition, enjoy from technology spillovers, and climb the quality ladder moving towards the production of capital-intensive goods. These divergent trends with respect to openness continued until the late 1980s, when LATAM economies started implementing policy reforms that involved substantial liberalization in both trade and financial flows, accompanied by privatization and deregulation of centralized sectors.

The ratio of total trade (exports plus imports) to GDP is a common measure of trade openness and integration. When comparing this ratio across the two regions – as done in Figure 1 – it is evident that the value for LATAM economies has been (and still is) substantially below that of the HPAE region. Nonetheless, it is also clear that since the liberalization of the late 1980s LATAM countries have increased their openness: in fact, the share of total trade to GDP moved from 25% in 1990 to 50% in 2004.[4]

The rest of the paper analyzes the presence and role of HPAE and LATAM countries in world trade on the basis of the evolution of the structure of the WTN. More specifically, we investigate how the position of the two regions within the WTN has changed over the last 25 years. We will show that, despite the fact that the ratio of total trade to GDP for LATAM countries displays an upward trend after 1990, thus hinting at increased

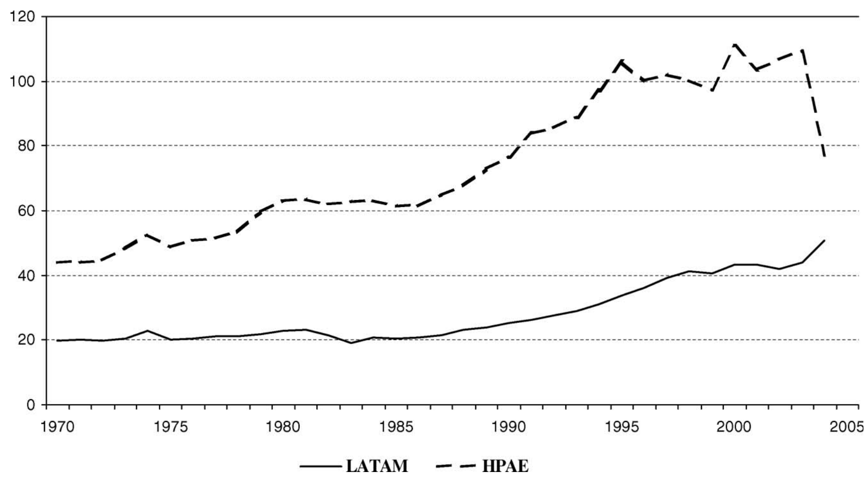

Figure 1. Total trade to GDP ratios.

international integration, measures based on network indicators suggest otherwise. In particular, while the HPAE region has improved its position within the WTN, LATAM countries have clearly failed to do so.

3. Network analysis: a telegraphic introduction

Sociologists and psychologists have employed network analysis for the study of social interactions among people and groups since the beginning of the last century. Pioneering studies in this area include those by Milgram (1967) and Granovetter (1974), who studied the networks of social acquaintances and job market interactions. A number of powerful statistical tools for the analysis of network structures emerged outside the realm of social sciences thanks to the contributions of physicists, mathematicians, and computer scientists. Such methodological advances have then been applied to social analysis in recent studies by Goyal et al. (2006), Kali and Reyes (2007), Hidalgo et al. (2007), and Battiston et al. (2007), where the interactions among academics through co-authorships, trade linkages among countries, networks within the 'product space', credit chains and bankruptcy propagation are analyzed using complex networks.

The use of network analysis to study international trade interactions has been first introduced by sociologists and political scientists. Snyder and Kick (1979) use international trade data and employed network analysis to classify countries into a core-periphery structure. Other studies that explore this 'dependency theory' using aggregated data include Nemeth and Smith (1985) and Smith and White (1992), while some other studies (Breiger 1981; Kim and Shin 2002) use disaggregated trade flows. More recently, in the area of econophysics, a number of papers have focused on the structural and topological properties of the WTN, with little or no emphasis on their economic implications (Serrano and Boguñá 2003, Garlaschelli and Loffredo 2004, 2005). These findings show that the WTN is very symmetric, confirm the presence of a core-periphery structure, suggest the emergence of a 'rich club phenomenon' whereby countries that have higher trade intensities trade a lot among themselves. In addition, Fagiolo et al. (2007) find, somehow surprisingly, that the overall network structure is fairly stationary over time despite the recent wave of globalization. Finally, Kali and Reyes (2007) have used network analysis to explain macroeconomic dynamics such as economic growth and episodes of financial contagion.

As mentioned by Fagiolo et al. (2007), the appeal for using complex network analysis for the study of international economic integration emerges from the fact that a network approach is able to recover the whole structure of the web of trade interactions and by doing so it allows for the exploration of connections, paths, and circuits. When exports and imports to GDP ratios are used to characterize the degree of integration into the world economy of a given country, only first-order trade relationships are captured.[5] Network analysis, on the other hand, accounts for higher-order trade relationships and therefore results in a more in-depth picture of integration. For example, it is possible to specify the countries that have a trading relationship (and their intensities) among themselves but that also trade with another given common country, assess the length of trade chains, and characterize the importance of a given country in the trade network. The study of these properties, as shown by Kali and Reyes (2007), can go beyond the description of stylized facts and can allow one to assess the degree of international economic integration for the overall network. Indeed, the main contribution of this paper is to exploit the deeper characterization of international trade flows offered by network analysis to link international economic integration with growth and development in two specific sets of countries, namely HPAE and LATAM.

4. Methodology, data and results

The data used to carry out the study are extracted from the UN COMTRADE database. We use bilateral trade data for 171 countries over the 1980–2005 period to build the trade matrix for the countries considered in the analysis. In the resulting matrix, columns represent importing countries, while rows denote exporting countries. This matrix is used to build the adjacency (A) and weighted adjacency (W) matrices needed for the computation of the network indicators. The adjacency matrix simply reports the presence of a trade relationship between any two countries, therefore we set the generic entry for the matrix as $a^t_{ij} = 1$ if and only if exports of country i to country j (defined as e^t_{ij}) are strictly positive in year t (and zero otherwise). This binary analysis is then complemented by a weighted approach whereby trade links are scaled by their intensity. Fagiolo et al. (2007) have shown that the network indicators and the network characteristics of the WTN are very robust to different weighting procedures. For example, one can use the actual trade flow as the weight for each link, $w^{t*}_{ij} = e^t_{ij}$, or a scaled measure such as export to GDP, i.e. $w^{t*}_{ij} = e^t_{ij}/GDP^t_i$. For the current study we use the actual trade flows for the benchmark analysis and provide some discussion, for robustness purposes, for the GDP-scaled trade flows.

It should be noted that trade flows generate, by default, a weighted and directed network. We employ a weighted and undirected network (WUN) approach since the WTN is sufficiently symmetric, and this approximation allows us to simplify the analysis quite a bit.[6] Hence, the A matrix is made symmetric by setting $a^t_{ij} = a^t_{jt} = 1$ if any of e^t_{ij} or e^t_{ji} is positive. Similarly, we replace the original weighted entries w^{t*}_{ij} by $w^t_{ij} = \frac{1}{2}(e^t_{ij} + e^t_{ji})$ and then divide all entries by the maximum value in W, which does not introduce any biases in the analysis but ensures that $w^t_{ij} \in [0, 1]$ for all (i,j) and t (see Onnela et al. 2005).

To assess the economic integration of a given country we base the analysis upon three different pillars. We start with first-degree connectivity using node-degree, node-strength, and node-disparity indicators. Clustering and higher-order connectivity measures are then proposed as a second step, while random-walk betweenness centrality represents the highest order indicator considered in the study. In order to keep the exposition of the paper simple and fluent we present a non-technical discussion of these measures in the text and refer the reader to the technical appendix at the end of the paper and to the proper technical papers in the literature of networks where these indicators, their properties, and their derivations are discussed in detail (Fagiolo et al. 2007, and the references therein).

4.1. First degree connectivity

This section explores the extent to which countries are more or less connected in terms of the number of trading partners that each country holds and the intensities of their interactions. The number of connections that a given node has within a network is referred to as node-degree, while the sum of all the valued interactions is referred to as node-strength. Node-degree and node-strength for country i are computed as follows:

$$d_i^t = \sum_j a_{ij}^t \tag{1}$$

$$s_i^t = \sum_j w_{ij}^t \tag{2}$$

Node-degree and node-strength are first dimension indicators since they only exploit the first degree connections of a given country. Node-degree, d_i, would simply represent the number of trading partners that country i has. Additionally, if we define node-disparity among (concentration of) i's weights as follows, it is possible to compute node-disparity for node i as follows:

$$h_i^t = \frac{(N-1)\sum_j \left(\frac{w_{ij}^t}{s_i^t}\right)^2 - 1}{N-2} \tag{3}$$

We compute network indicators for all countries in the sample, and then focus on the HPAE and LATAM regions by calculating group averages that look at the same countries used for the macroeconomic comparison. In addition, when deemed necessary we refine our sample and discuss specific cases; this is done in order to avoid the possibility of generalizing results to the whole region that are only applicable, or driven by, one country.

Table 1 presents the results, in levels and the percent-rank analysis, for all the three indicators while Figures 2–4 show averages across the two regions. It should be noted that for the node-disparity analysis, a lower value is associated with a lower degree of trade concentration, while a higher percent-rank for node-degree and node-strength is associated with a higher degree of connectivity within the network (relative to all the 170 other

Table 1. Results for node-degree, node-strength and node-disparity.

	1980		1990		2000		2005	
Country	level	% rank	level	% rank	level	% rank	level	% rank
Node-degree								
Thailand	139	0.859	155	0.859	169	0.924	170	0.929
Philippines	124	0.818	126	0.788	151	0.788	154	0.765
Malaysia	122	0.812	162	0.912	165	0.865	167	0.876
Korea, Rep.	146	0.876	156	0.865	168	0.888	167	0.876
Indonesia	97	0.718	119	0.759	170	0.953	169	0.906
China	133	0.854	167	0.941	168	0.888	170	0.929
Venezuela	90	0.816	107	0.694	116	0.624	121	0.629
Mexico	128	0.829	147	0.829	149	0.776	154	0.765
Chile	93	0.700	121	0.782	140	0.741	138	0.712
Brazil	152	0.900	160	0.876	163	0.824	168	0.888
Argentina	124	0.818	138	0.812	140	0.741	149	0.753
Node-strength								
Thailand	0.171	0.765	0.266	0.859	0.249	0.871	0.321	0.876
Philippines	0.164	0.753	0.101	0.771	0.165	0.824	0.144	0.782
Malaysia	0.289	0.818	0.282	0.865	0.367	0.900	0.401	0.894
Korea, Rep.	0.447	0.888	0.609	0.929	0.606	0.929	0.787	0.941
Indonesia	0.398	0.871	0.221	0.829	0.192	0.847	0.260	0.824
China	0.320	0.835	0.493	0.906	0.811	0.953	1.948	0.988
Venezuela	0.362	0.853	0.121	0.788	0.090	0.759	0.091	0.729
Mexico	0.463	0.894	0.343	0.882	0.622	0.935	0.614	0.912
Chile	0.118	0.700	0.076	0.741	0.069	0.735	0.106	0.735
Brazil	0.479	0.906	0.251	0.847	0.222	0.859	0.299	0.841
Argentina	0.230	0.794	0.090	0.759	0.098	0.771	0.106	0.741
Node-disparity								
Thailand	0.087	0.265	0.109	0.388	0.087	0.300	0.075	0.229
Philippines	0.143	0.541	0.138	0.547	0.122	0.535	0.091	0.371
Malaysia	0.127	0.465	0.128	0.488	0.116	0.506	0.095	0.406
Korea, Rep.	0.138	0.494	0.156	0.606	0.094	0.376	0.088	0.359
Indonesia	0.241	0.800	0.171	0.647	0.090	0.341	0.092	0.376
China	0.159	0.612	0.162	0.629	0.090	0.324	0.074	0.218
Venezuela	0.151	0.576	0.296	0.894	0.307	0.935	0.311	0.900
Mexico	0.456	0.965	0.502	0.982	0.687	0.994	0.596	0.982
Chile	0.072	0.135	0.079	0.182	0.068	0.147	0.066	0.171
Brazil	0.064	0.065	0.090	0.241	0.090	0.347	0.061	0.124
Argentina	0.067	0.088	0.061	0.071	0.113	0.494	0.094	0.400

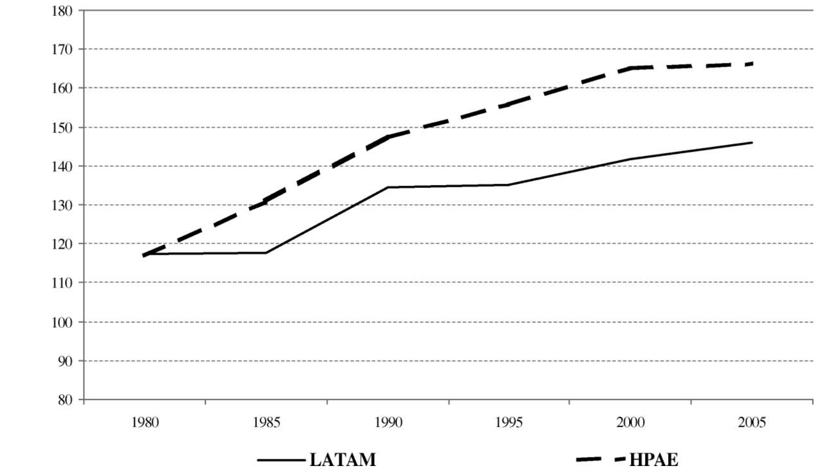

Figure 2. Node-degree (% rank of distribution).

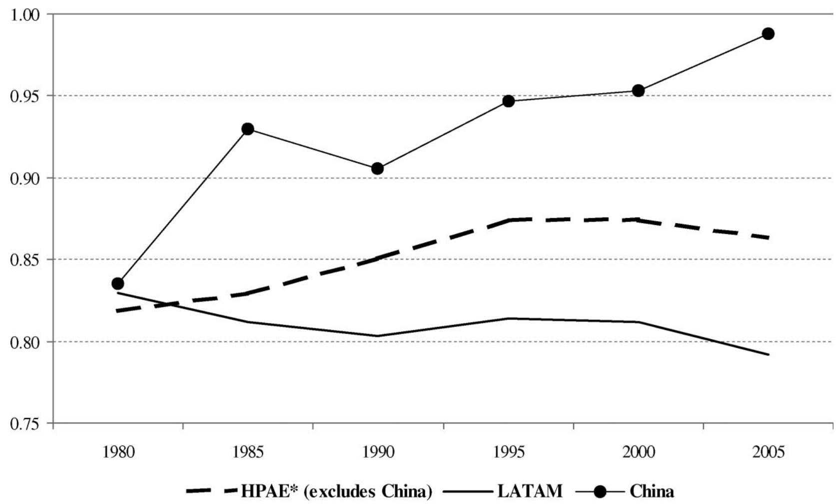

Figure 3. Node-strength (% rank of distribution).

countries in the network) due to a higher number of trading partners and/or a higher intensity in the connections (i.e. trade flows).

The results are clear and can be considered as the first piece of evidence regarding the association of development and integration into the world economy. The HPAE region, even without considering the results for China, rank higher in both node-degree and node-strength distributions and there is a clear increasing pattern, while the results for LATAM show either a

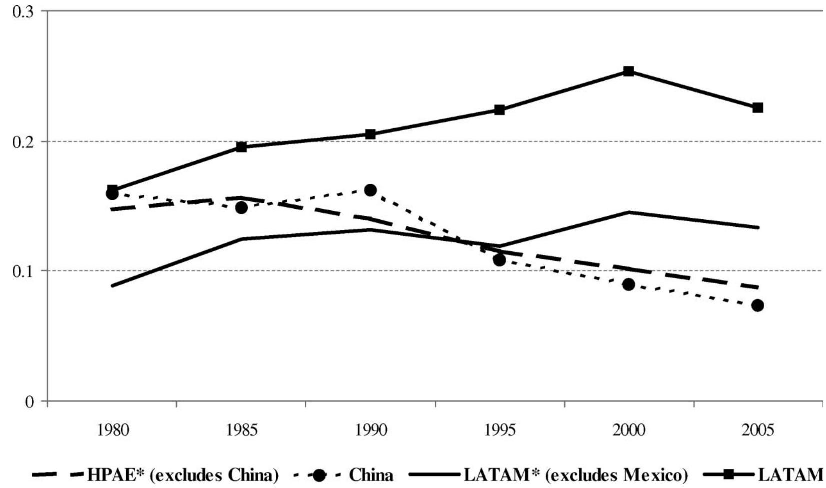

Figure 4. Node-disparity (level).

decline or a constant position within the network. It is possible to conclude that the HPAE countries, relative to the LATAM economies, have observed a consistent increase in the number of trading partners and the intensity of their trade flows. Not surprisingly, the results for node-disparity show a higher degree of trade disparity (trade concentration) for the LATAM region. This is consistent with the argument that the volume of trade has increased for both regions, but for LATAM this increase has been heavily biased towards a few number of trading partners. On the contrary, HPAE have been distributing this increase among a higher number of partners and therefore present a lower level trade concentration, even more so for China than for the rest of the region. The graph in Figure 4 shows that these results hold even when Mexico, a country that concentrates 80% of its international trade with the US, is excluded from the LATAM region. This finding coincides with those reported by Kali et al. (2007), where the authors argue that the positive effects on economic growth of being better connected into the WTN emerge from the expansion of potential markets and competition, as well as the possibility of being exposed to technological spillovers, as the number of trading partners increases.

4.2. *Clustering patterns and connectivity of trading partners*

We now turn to network measures that take into consideration second-degree characteristics present within the network. The first measure we employ is clustering, which like node-strength takes into consideration the strength of the links between nodes i and j but adds the strength of the links between nodes i and h and between nodes j and h to the analysis. In other words it considers the complete triplets within the network and the intensities of the links among them. We follow Onnela et al. (2005) and we compute the weighted clustering coefficient for each country as follows:

$$C_i = \frac{\frac{1}{2}\sum_{j\neq i}\sum_{h\neq(i,j)} w_{ij}^{\frac{1}{3}} w_{ih}^{\frac{1}{3}} w_{jh}^{\frac{1}{3}}}{\frac{1}{2}d_i(d_i - 1)} \tag{4}$$

where (here and in what follows) time superscripts have been removed to simplify the notation.

Clustering allows for the assessment of the degree to which a country tends to build more (number and intensity wise) relationships with countries that themselves trade with each other by taking into consideration the intensity of second-order relationships. The clustering coefficient of country i then depends on the number of triples and on the intensity of the relationships that link them.

The percent-rank results for node-clustering are reported in the first panel of Table 2 and Figure 5 plots the averages for the regions. Once again, there is a clear increasing pattern for the HPAE countries and a flat one for the LATAM region. Furthermore, the correlation between clustering and node-strength (averages) is positive for both regions for the overall period considered for the analysis. In 1980, however, this correlation was 0.77 for LATAM countries and 0.64 for HPAE ones, whereas in the year 2005 the values are 0.96 and 0.98, respectively. These high and positive correlations suggest that in both regions countries with high-intensity trade relationships are typically involved in highly-interconnected triples. And the emergence of these cliques is somehow more recent in the HPAE region since the correlation was lower in the 1970s and values have since then caught up.[7]

Two other second-degree network measures are the weighted average nearest-neighbor degree (WANND) and the average nearest-neighbor strength (ANNS). These two measures allow for the analysis of specific characteristics of the neighbors of a given country and both are related to the so-called assortativity of each node. That is, whether country i trades with countries that themselves are connected to many other countries (i.e. WANND), and/or is it associated with trading partners that themselves have low/high trade intensities. The computation of these indicators is as follows:

$$ANNS_i = d_i^{-1}\sum_j a_{ij}s_j \tag{5}$$

$$WANND_i = s_i^{-1}\sum_j w_{ij}d_j \tag{6}$$

Table 2. Results for node-clustering, node-ANNS and node-WANND.

	1980		1990		2000		2005	
Country	level	% rank	level	% rank	level	% rank	level	% rank
Node-clustering (*Weighted Clustering* * 10^5)								
Thailand	0.157	0.724	0.339	0.859	0.147	0.876	0.220	0.859
Philippines	0.278	0.776	0.100	0.782	0.108	0.853	0.070	0.788
Malaysia	0.524	0.806	0.282	0.847	0.302	0.906	0.332	0.888
Korea, Rep.	1.493	0.894	2.558	0.947	0.994	0.941	1.776	0.941
Indonesia	2.608	0.924	0.431	0.871	0.082	0.841	0.135	0.824
China	1.172	0.865	0.575	0.882	1.478	0.965	6.813	0.988
Venezuela	1.843	0.906	0.139	0.800	0.035	0.782	0.044	0.776
Mexico	1.454	0.888	0.595	0.888	0.935	0.935	1.014	0.929
Chile	0.145	0.712	0.041	0.747	0.013	0.741	0.037	0.753
Brazil	0.879	0.847	0.229	0.835	0.094	0.847	0.163	0.847
Argentina	0.279	0.782	0.023	0.700	0.014	0.747	0.015	0.724
Node Average Nearest-Neighbor Strength (ANNS)								
Thailand	0.304	0.147	0.205	0.147	0.142	0.106	0.176	0.076
Philippines	0.339	0.188	0.253	0.212	0.159	0.218	0.195	0.235
Malaysia	0.343	0.206	0.196	0.094	0.144	0.135	0.179	0.124
Korea, Rep.	0.285	0.129	0.200	0.129	0.140	0.065	0.176	0.094
Indonesia	0.421	0.282	0.266	0.235	0.141	0.082	0.178	0.112
China	0.498	0.418	0.188	0.059	0.139	0.053	0.167	0.012
Venezuela	0.442	0.318	0.296	0.300	0.206	0.376	0.248	0.371
Mexico	0.324	0.176	0.215	0.165	0.158	0.206	0.193	0.218
Chile	0.428	0.306	0.262	0.224	0.172	0.265	0.218	0.294
Brazil	0.276	0.100	0.198	0.118	0.147	0.165	0.178	0.118
Argentina	0.339	0.182	0.231	0.188	0.172	0.259	0.202	0.247
Node Weighted Average Nearest-Neighbor Degree (WANND)								
Thailand	142.94	0.329	155.93	0.441	163.29	0.565	159.84	0.329
Philippines	149.11	0.547	160.57	0.706	167.67	0.947	165.00	0.712
Malaysia	145.25	0.406	150.72	0.218	166.61	0.865	158.89	0.288
Korea, Rep.	144.70	0.400	159.85	0.676	162.85	0.535	161.93	0.435
Indonesia	154.86	0.765	161.40	0.771	164.84	0.682	159.77	0.324
China	154.89	0.771	153.36	0.329	162.63	0.524	161.61	0.400
Venezuela	142.26	0.300	157.56	0.518	156.74	0.235	164.24	0.612
Mexico	155.34	0.776	164.84	0.941	167.89	0.971	167.87	0.959
Chile	144.47	0.394	157.84	0.547	159.75	0.359	163.31	0.524
Brazil	136.40	0.147	152.77	0.306	157.19	0.253	157.54	0.212
Argentina	140.62	0.247	146.63	0.153	158.09	0.288	158.54	0.265

A higher number for both indicators suggests that country *i* is more likely associated with trading partners that themselves are well connected into the WTN, either because of their number of trading partners or for the intensity of their trading relationships. The results for the analysis are presented in Table 2, and for comparison purposes Figures 6 and 7 present the regional averages for ANNS and WANND, respectively.

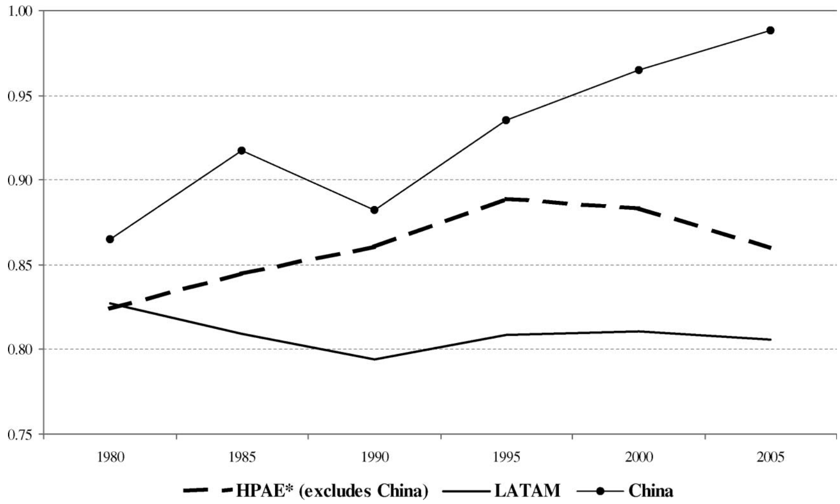

Figure 5. Node-clustering (% rank of distribution).

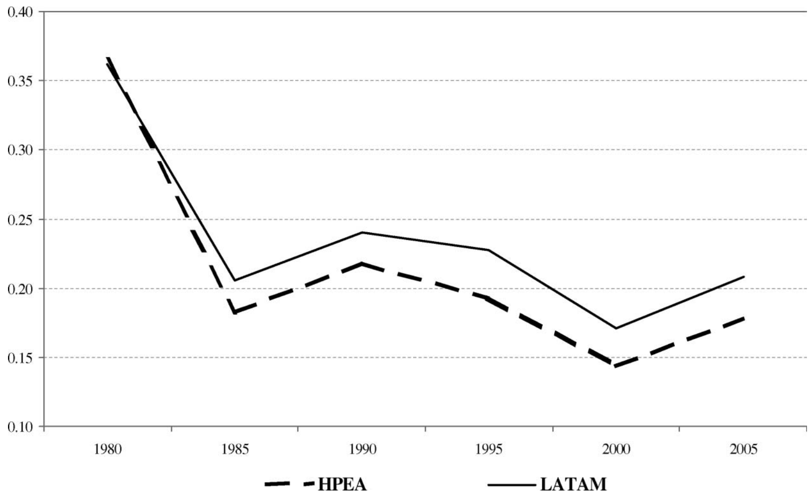

Figure 6. Average Nearest-Neighbor Strength – ANNS (level).

In both cases, the results point in the direction of similar patterns for both regions. The ANNS has been consistently falling, while WANND has been increasing. In essence, both regions have been establishing connections with less intensively connected countries, with respect to trade volumes, but with countries that have a higher number of trading partners. Intuitively this result make sense, since both regions already traded, and did it intensively,

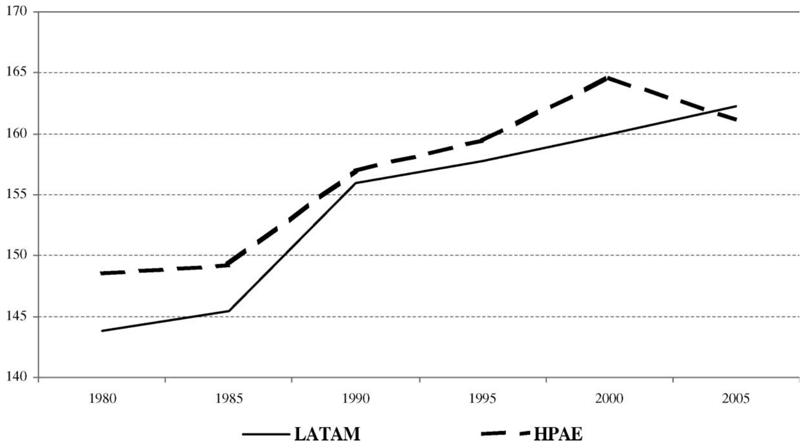

Figure 7. Weighted Average Nearest-Neighbor Degreee – WANND (level).

with the developed economies in the 1970s, but over the past three decades – also in response to the establishment of various regional trade agreements – they have established trading relationships among themselves and with other developing and/or poor countries that tend to have a high number of trading partners.

The correlations between node-strength and ANNS, and node-degree and WANND, have been negative for both regions for the whole sample period. For the case of node-strength versus ANNS, the correlation has been around -0.50 for the past 35 years, while for the HPAE countries has been around -0.60, suggesting that both regions have established trading relationships with similar types of countries (i.e. with countries that have a lower node-strength). Regarding node-degree versus WANND, the correlation is also negative for both regions through the period considered but the correlation coefficient has remained around -0.20 for the LATAM region while for the HPAE economies it has gone from -0.31 to -0.77. This result, in conjunction with the relatively higher node-degree increase observed for HPAE countries, suggests that the countries in this region have not only established more connections than LATAM countries, but these new links connect them to countries that are not so heavily connected into the WTN.

4.3. *Random-walk betweenness centrality*

We now address the position of the two regions within the WTN, and hence the role played by each of them, by means of a measure of centrality. Node-degree and strength provide a rough proxy of this property, but recent studies (Newman 2005; Fisher and Vega-Redondo 2006) have introduced the notion of random-walk betweenness centrality (RWBC), i.e. a measure of centrality that combines the effects of the magnitude of the relationships that a node has with its partners, with the degree of the node in question. Newman (2005) offers an intuitive explanation for RWBC: assume that a source node sends a message to a target node; the message is transmitted initially to a neighboring node and then the message follows an outgoing link from that vertex, chosen randomly, and continues in a similar fashion until it reaches the target node.[8] RWBC exploits (randomly) the whole length of the trade chains present in the network for country *i* and, therefore, is the highest degree measure considered in the analysis.

The RWBC is a measure that allows for the characterization of the core–periphery structure of the WTN and also permits the identification of the countries in the core and the periphery. Using the percent-rank analysis results, the network is divided into core countries (C), inner-periphery countries (I-P), secondary-periphery countries (S-P), and outside of the periphery countries (O). A country is classified as a 'C' country if its RWBC is above the 95th percentile, 'I-P' if it is above the 90th but below the 95th percentiles, 'S-P' if it is above the 85th but below the 90th percentiles, and 'O' otherwise. The results for the HPAE and the LATAM regions, as well as the results for India and the average for the G7 countries are presented and discussed here. The reason to include the G7 and India, a recent globalizer, is for the purpose of comparisons: HPAE countries have attained a higher level of integration within the WTN and it is interesting to analyze their relative position with respect to other countries.

Table 3 presents the evolution using the core–periphery classification while the averages of the percent-rank distribution analysis for India, the G7, the HPAE, and the LATAM countries are reported in Figure 8. The clear picture that emerges is that the gap, according to RWBC, between the G7, the HPAE (with and without China) and India has been closing while that between all these regions and the LATAM economies has remained. It should be noted that when analyzed independently, one country that clearly diverges from the path of the LATAM region is Brazil. The results for this country (Table 3) show that Brazil is clearly among the top countries according to RWBC but it is also true that its initial value in 1980 was already high. Argentina's, Chile's, and Mexico's, RWBC have remained constant, but the result for Venezuela shows that this country is moving away from the core of the WTN. All of the LATAM countries, except for Brazil, are currently at or below the 80th percentile of the distribution, while countries like China and Korea are above the 95th percentile and can be considered as part of the core of the network along with the G7 countries. The only HPAE country that is outside the 80th percentile is the Philippines, and to some extent it can be argued that its degree of integration has stalled. It should be noted that the argument regarding the integration of India into the WTN seems to be well founded, since this country has moved up in the RWBC rankings, consistently.

Table 3. Results for random walk betweenness centrality.

Country	1980			1990			2000			2005		
	level	% rank	location	level	% rank	location	level	% rank	location	level	% rank	location
Thailand	0.0393	0.776	O	0.0651	0.888	S-P	0.0813	0.900	I-P	0.0931	0.900	I-P
Philippines	0.0227	0.671	O	0.0229	0.712	O	0.0289	0.735	O	0.0246	0.700	O
Malaysia	0.0373	0.771	O	0.0439	0.835	O	0.0649	0.882	S-P	0.0692	0.888	S-P
Korea, Rep.	0.0458	0.841	O	0.0811	0.929	I-P	0.1179	0.924	I-P	0.1435	0.959	C
Indonesia	0.0431	0.824	O	0.0386	0.818	O	0.0486	0.835	O	0.0494	0.824	O
China	0.0569	0.855	S-P	0.0941	0.935	I-P	0.1809	0.965	C	0.3252	0.994	C
Venezuela	0.0621	0.888	S-P	0.0391	0.824	O	0.0476	0.824	O	0.0300	0.729	O
Mexico	0.0418	0.812	O	0.0440	0.841	O	0.0569	0.865	S-P	0.0527	0.841	O
Chile	0.0250	0.712	O	0.0241	0.729	O	0.0281	0.729	O	0.0308	0.747	O
Brazil	0.0755	0.912	I-P	0.0650	0.882	S-P	0.0802	0.894	S-P	0.1036	0.912	I-P
Argentina	0.0402	0.794	O	0.0345	0.794	O	0.0423	0.800	O	0.0450	0.818	O
G7 (average)	0.3235	0.976	C	0.3318	0.975	C	0.2885	0.970	C	0.2568	0.966	C
India	0.0215	0.871	S-P	0.0206	0.859	S-P	0.0287	0.912	I-P	0.0345	0.941	I-P

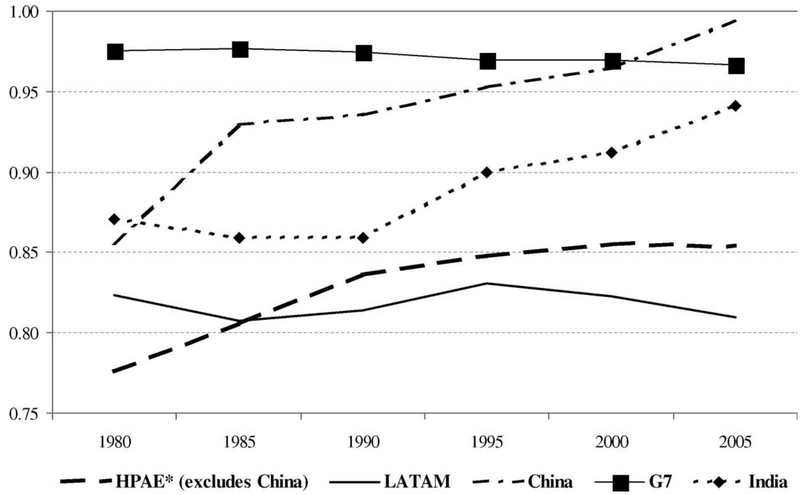

Figure 8. Random Walk Betweenness Centrality – RWBC (% rank of distribution).

4.4. Robustness check and comparison of results

To address the robustness of our results and their plausibility, we can compare the statistics for the overall network with those discussed in Fagiolo et al. (2007, 2008). They use a database provided by Gleditsch (2002) for the 1981–2000 period and comprising 159 countries, and compute a set of network indicators that includes several of the indexes used here as well. Most importantly, they show the robustness of results to different weighting procedures (i.e. the use of actual trade flows rather than trade flows scaled by GDP to build the network): this is the main reason why we do not explicitly address this issue here.[9]

The conclusions we reach with respect to the properties of the overall network are very similar to those reported by Fagiolo et al. (2007, 2008). We find a slightly increasing pattern for node-degree, and a fairly constant level for node-strength (around 0.20) and for the correlation (around 0.50) between these two indicators over time. In addition, both here and in the above-mentioned papers, kernel densities display a bimodal distribution for node-degree, while for node-strength no bimodality appears, and one observes a heavily left-skewed distribution instead (see Figure 9). Similarly, all papers conclude that the WTN is a dissasortative network, given the negative correlation observed between WANND-node-degree, and ANNS-node-strength.

Finally, our centrality results match those reported in Fagiolo et al. (2007), specifically for the patterns observed for China and Korea, two countries that have moved towards the core of the network.

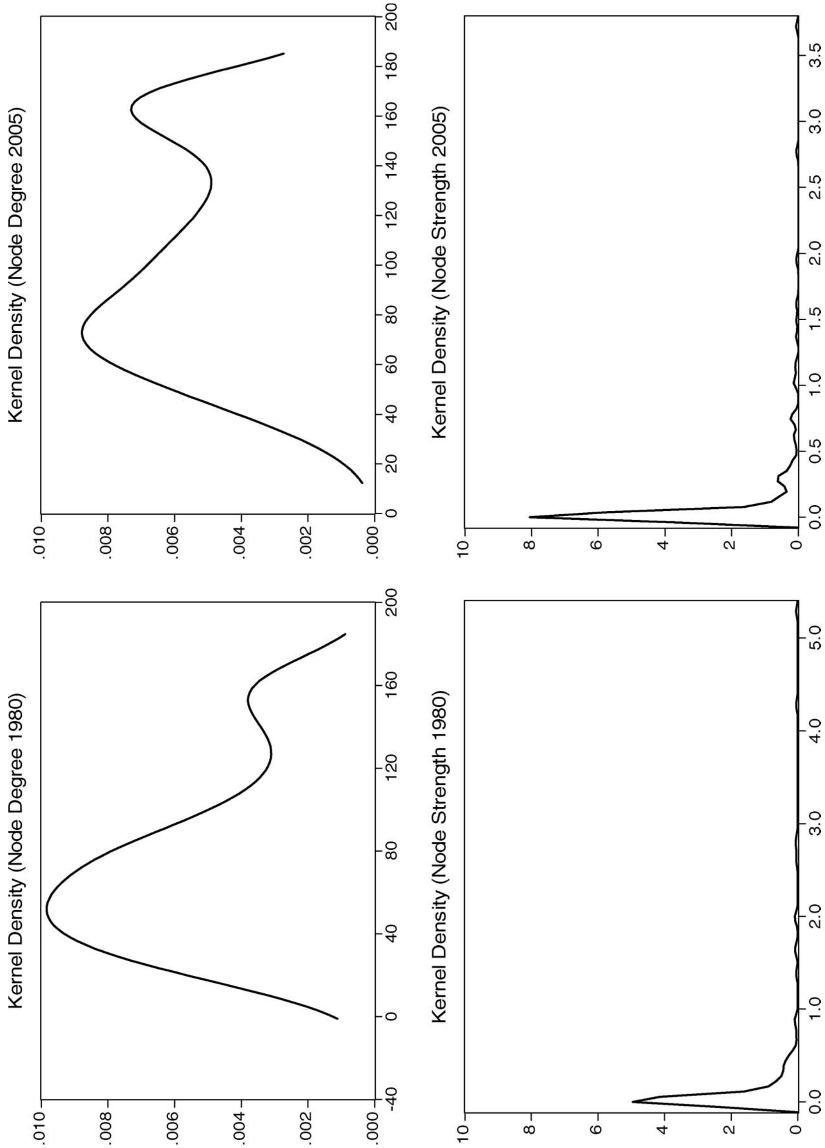

Figure 9. Node-degree and node-strength Kernel densities for the overall network.

5. Conclusions and policy implications

The HPAE and the LATAM regions have been at the center of academic and policy-oriented research and discussions. The development path followed by the HPAE during the last 25 years stands in sharp contrast with the low growth and volatile economic environment that have characterized the LATAM region. The success of the HPAE has been linked to the adoption of a consistent set of policies based on the integration of the region in the world economy. Asian countries have not only increased export participation, but have also benefited from more competition and knowledge spillovers. The LATAM region has followed this example by starting the implementation of market-oriented policies during the mid 1990s. But this move comes after decades of import-substitution policies coupled with large public intervention in the economy.

The aim of the paper has been to assess the degree of international integration enjoyed by countries in the two regions, which results from their respective development strategies. The paper goes beyond the standard measures of openness (exports plus imports to GDP) and uses a complex network approach that provides one with a better understanding of international economic integration since it captures the whole structure of trade relationships.

In fact, while openness has been substantially increasing in both regions over the past 25 years, network indicators point towards a significant difference in the degree of integration and its dynamic. The recurrent pattern emerging throughout the paper is one of rising integration for the HPAE region – a result that is consistent with the increase in the total trade-to-GDP ratio – whereas LATAM economies have not improved their position much within the network. Moreover, at least in the case of Venezuela, there is evidence that this country is moving away from the core of the WTN, a result that contrasts dramatically with the increased ratio of total trade-to-GDP. The HPAE region is involved in both more and stronger trade relationships than the LATAM region, and this has resulted in a higher degree of integration into the WTN. Although we do not explicitly tackle the issue of the potential endogeneity between a country economic development and its role in world trade, our results are consistent with recent contributions that stress the importance of trading partners for economic growth (see for instance Arora and Vamvakidis 2005). Therefore, we claim that at least part of the different development pattern observed for HPAE and LATAM countries can be explained in terms of their respective position within the WTN.

From a more general, and policy-oriented, point of view, our results show quite clearly that it is not only the degree of openness that matters for the economic performance of countries, but also (and above all) their positioning within the network of international trade flows. Such a conclusion is corroborated by the fact that the overall WTN displays a core–periphery setup, so that peripheral countries suffer from a sort of marginalization. Consistently with some recent results in the field of economic geography (see Ottaviano et al. 2002) we interpret our results as suggesting that such a polarized structure is not necessarily the most efficient outcome, and that a more balanced structure of trade relations would allow (developing) countries to exploit more completely the gains from trade.

Moreover, the position of HPAE countries within the WTN has implications that may affect the functioning of international organizations like the WTO. In fact, this rise in economic integration – both in terms of number and intensity of trade relationships – enhances the 'presence' of HPAE economies and this could lead to pressure for changes in international trade policies and in the rules of current and future trade negotiations rounds.

The use of network analysis enables one to uncover interesting patterns, otherwise not identifiable through standard trade openness measures: this suggests a new and fruitful route for the study of international trade that may well go beyond aggregate flows. As a next step it would be interesting to disaggregate trade flows and check the evolution of the place occupied by the two regions in the network of trade flows for different classes of products. This would provide evidence that can be used to support arguments regarding how the HPAE countries have moved, or are moving, to the center of the networks for capital and high-skill labor intensive goods, while the LATAM region – which remains specialized on the production and exports of resource based and low-skill labor intensive goods – may or may not be at the center of the network of such products given that many other countries participate in these markets.

Notes

1. The composition of these groups varies within the literature. In the present work the LATAM sample comprises Argentina, Brazil, Chile, Mexico, and Venezuela, whereas the HPAE considered here are China, Indonesia, South Korea, Malaysia, the Philippines, and Thailand.
2. See Sachs (1985) and Lin (1989) for early comparisons between Latin America and East Asia. More recent studies include Weeks (2000), Krasilshchikov (2006), De Gregorio and Lee (2004), and the references therein.
3. Fischer (1993) argues that high rates of inflation are the summary statistics for mismanagement of the economy, at the macroeconomic level, and the inability of governments to implement sound economic policies.
4. The fact that the gap keeps widening in the 1990s despite the policy change in Latin America corroborates the idea that HPAE economies implemented a more coherent set of industrial policies, which have led to economic stability, increased technological capabilities, and deeper integration (Rodrik, 2004).
5. For instance, Baldwin (2003) develops a measure of 'hubness' that accounts for the appeal of access to country A market by country B firms. Although the concept of hubness refers implicitly to a network structure, the measure remains a bilateral index that abstracts from third countries.

6. Results for a symmetry index computed along the lines of Fagiolo (2006), range between 0.006 (lowest) and 0.013 (highest) for the period 1980 to 2005. This symmetry index ranges (theoretically) from 0 to 1, where zero denotes full symmetry and 1 represents complete asymmetry.
7. This is consistent with the standard accounts of the emergence of 'Factory Asia' (see for instance Baldwin, 2006).
8. In the original measure presented by Newman (2005) the probabilities assigned to outgoing edges are all equal, but in Fisher and Vega-Redondo (2006) these probabilities are determined by the magnitude of the outgoing trading relationships. Hence, links that represent greater magnitude for a trading relationship will be chosen with higher probability.
9. Results obtained using trade over GDP are nevertheless available upon request.

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Data appendix

The bilateral trade data are extracted form the COMTRADE database housed by the United Nations (UN). The database contains more than 200 countries as reporters and more than 250 as partners. After eliminating regional and income aggregations, other classifications (free trade zones, neutral zones and unspecified origin) the database is reduce to the participating countries for the WTN for the period of 1980–2005. Before performing the analysis a decision has to be made with respect to countries that stop existing or began existing after the breakup of a given original country, or because these countries reported their trade flows as one for some of the periods considered (this is the case for Belgium and Luxembourg) – for example, the USSR and Yugoslavia. In this paper, for simplicity, the following groups are considered as one node (reporter and partner):

- **Belgium – Luxembourg:** Belgium and Luxembourg
- **Czechoslovakia**: Czech Republic and Slovak Republic
- **Eritrea – Ethiopia**: Eritrea and Ethiopia
- **Yugoslavia, FR**: Croatia, Macedonia, Yugoslavia, Slovenia, Serbia/Montenegro
- **Russia**: Armenia, Azerbaijan, Belarus, Estonia, Georgia, Kazakhstan, Kyrgyz Republic, Lithuania, Latvia, Moldova, Russian Fed., Tajikistan, Turkmenistan, Ukraine, Soviet Union, and Uzbekistan.

The aggregation of these nodes into one, for every column, is simply to avoid the sudden change in the number of nodes in the network, that could result in structural changes due to number of nodes, even though the trade flows do not change so dramatically. An alternative would be to drop these countries from the analysis, and only consider countries that existed throughout the whole 1980–2005 period, but we believe that this could lead to a greater loss of information than the that which could result from the aggregation. In the end, the trade data for the study includes 171 countries for the 1980–2005 period. Given the stability of the network properties reported in previous studies and confirmed here, we only report results for 1980, 1990, 2000, and 2005.

Technical appendix

Let us assume that the underlying graph is valued and undirected, also let A be the adjacency matrix and W the weighted matrix that define the valued links of the graph. Then the node-degree, strength and disparity for node i are computed as follows:

$$d_i = \sum_j a_{ij} = A_{(i)}1, \tag{A.1}$$

$$s_i = \sum_j w_{ij} = W_{(i)}1. \tag{A.2}$$

$$h_i = \frac{(N-1)\sum_j \left(\frac{w_{ij}}{s_i}\right)^2 - 1}{N-2} = \frac{(N-1)\frac{1}{s_i^2}\sum_j \left(w_{ij}\right)^2 - 1}{N-2} = \frac{(N-1)\frac{W_{(i)}^{[2]}}{\left(W_{(i)}1\right)^2} - 1}{N-2} \tag{A.3}$$

where 1 is an N-vector of ones. Regarding average nearest neighbor strength (ANNS) and weighted average of nearest neighbor degree (WANND) of i, these are as follows:

$$ANNS_i = d_i^{-1}\sum_j a_{ij}s_j = d_i^{-1}\sum_j\sum_h a_{ij}w_{jh} = \frac{A_{(i)}W1}{A_{(i)}1}, \tag{A.4}$$

$$WANND_i = s_i^{-1} \sum_j w_{ij} d_j = s_i^{-1} \sum_j \sum_h w_{ij} a_{jh} = \frac{W_{(i)} A1}{W_{(i)}} \tag{A.5}$$

We follow Onnela et al. (2005) for the computation of the (weighted) clustering coefficient,

$$C_i = \frac{\frac{1}{2} \sum_{j \neq i} \sum_{h \neq (i,j)} w_{ij}^{\frac{1}{3}} w_{ih}^{\frac{1}{3}} w_{jh}^{\frac{1}{3}}}{\frac{1}{2} d_i (d_i - 1)} = \frac{\left(W^{\left[\frac{1}{3}\right]}\right)^3_{ii}}{d_i (d_i - 1)}, \tag{A.6}$$

where $W^{\left[\frac{1}{k}\right]} = w\{w_{ij}^{\frac{1}{k}}\}$,which is the matrix obtained after taking the kth root of each entry. This index ranges in [0,1] and reduces to the clustering coefficient for a binary network when the weights become binary. It takes into consideration all of the edges in a complete triple, while ignoring weights not participating in any triangle, and is invariant to weight permutation for a given triple.

Finally, we follow Newman (2005) and Fisher and Vega-Redondo (2006) for the computation of random walk betweenness centrality, RWBC. Consider a generic node i for which we want to compute the RWBC and an impulse generated from a different node h, that works its way through the network in order to get to target node k. Let $f(h,k)$ be the source vector ($N \times 1$), such that $f_i(h,k) = 1$ if $i = h$, $f_i(h,k) = -1$ if $i = k$, and 0 otherwise. Newman (2005) shows that the Kirchoff's law of current conservation implies that:

$$v(h,k) = [D - W]^{-1} f(h,k), \tag{A.7}$$

where $v(h,k)$ denotes the $N \times 1$ vector of node voltages, $D = diag(s)$ and $[D - W]^{-1}$ is computed using the Moore-Penrose pseudo-inverse. Then, this implies that the intensity of the interaction flowing through node i originated from node h and getting to target node k, is determined by:

$$I_i(h,k) = \frac{1}{2} \sum_j |v_i(h,k) - v_j(h,k)|, \tag{A.8}$$

where $I_h(h,k) = I_k(h,k) = 1$. Therefore RWBC for node i can be computed as:

$$RWBC_i = \frac{\sum_h \sum_{k \neq h} I_i(h,k)}{N(N-1)} \tag{A.9}$$