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Using network analysis to study globalization, regionalization, and multi-polarity—Introduction to special section

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Abstract Q2

In this introduction to the special section on globalization, regionalization, and multi-polarity, we review social network analysis applications to the study of globalization as a complex and multi-dimensional phenomenon and we explore the frontiers of our knowledge about the network properties of global systems. We focus on the global economic (trade and investment), political, and migration systems.

Keywords: *globalization, regionalization, multi-polarity, trade networks, economics*

1 Introduction

Network science has already demonstrated its usefulness in many areas of the social and natural sciences at various levels of aggregation. At the knowledge frontier of this field, we find the exploration of new fields of application very much depend on data availability and the further development of analytical techniques. In this introductory article, we review social network analysis applications to the study of globalization as a complex and multi-dimensional phenomenon and we explore the frontiers of our knowledge about the network properties of global systems. We will thereby focus on the global economic (trade and investment), political, and migration systems. Applications of network research to global systems of connections and flows in other dimensions will thus not be reviewed.[1]

[1] These include applications in the area of global epidemiological networks, global transport networks, and global land acquisition. See e.g., Balcan et al. (2009), Kaluza et al. (2010), and Seaquist et al. (2014).

The globalization concept refers to an underlying hypothesis about the increasingly global scope of relevant flows and interactions. However, competing hypotheses refer to the persistence of regional subsystems, hierarchies in the global systems, North–South and/or center-periphery patterns, and (multi-)polarities. These tensions between globalization, regionalization, and multi-polarity are at the heart of this project, and which has resulted in this special section of *Network Science*.

This introductory article is structured as follows: In Section 2, we start by presenting the problem of measurement of globalization, how indicators have been developed for that purpose, their strengths and weaknesses, and what the possible value added of a network approach could be. In Sections 3–7, we focus on global and regional network features in the following domains: global trade and production (Section 3), global investment (Section 4), global migration (Section 5), trade and investment agreements (Section 6), and the global polity (Section 7). This is followed by concluding remarks and an overview of the papers included in the special section of this issue.

2 The measurement of globalization

In order to establish the value of network analysis for the understanding and measurement of globalization, we briefly review the development of globalization indicators to date. Our purpose is two-fold. First, some of the technical limitations of these indicators can effectively be tackled by a network approach. Second, the work on globalization indicators shows the importance of carefully matching measurement techniques with conceptualizations of globalization.

The experience with globalization indicators can be traced back to the work on indicators of international openness and competitiveness (De Lombaerde & Iapadre, 2011; Martens et al., 2015). This includes the competitiveness indicators of the World Economic Forum published since 1979 (López-Claros et al., 2006), the indicators of economic freedom of Gwartney and Lawson published since 1996 (Gwartney et al., 1996; Gwartney & Lawson, 2006), and the World Market Research Center globalization index (G-index) (Randolph, 2001). The underlying definition of globalization was initially thus clearly unidimensional: globalization was considered as synonymous to economic globalization.

Globalization was defined by Brahmbhatt (1998: 2) as "the increasing freedom and ability of individuals and firms to undertake voluntary economic transactions with residents of other countries, a process entailing a growing contestability of national markets by foreign suppliers." For the World Markets Research Center, globalization shows "the ever closer knitting together of a one-world economy" (Randolph, 2001: 5). And for the OECD, globalization "refers above all to a dynamic and multidimensional process of economic integration whereby national resources become more and more internationally mobile while national economies become increasingly interdependent" (OECD, 2005a: 11).

By the late 1990s, a multi-dimensional conception of globalization came to the fore (Held et al., 1999; Scholte, 2000; Martens et al., 2015) which consequently **Q3** inspired new (multi-dimensional) measurements. For Scholte (2002: 13–14), for example, globalization should be understood "as the spread of transplanetary – and in recent times more particularly supraterritorial – connections between people [. . .]

globalization involves reductions in barriers to transworld contacts. People become more able – physically, legally, culturally, and psychologically – to engage with each other in 'one world' [. . .] globalization refers to a shift in the nature of social space."

This multi-dimensional conception was reflected in the construction of composite globalization indicators such as the well-known A.T. Kearney/Foreign Policy Magazine G-index (A.T. Kearney/Foreign Policy Magazine, 2001-2007). This indicator combined the economic, technological, political, and personal dimensions of globalization.[2] It consists therefore of four components: (i) the degree of integration of its economy into the world economy, (ii) the internationalization of the personal contacts of its citizens, (iii) the use of internet technology, and (iv) the extent of its international political engagement.

Other indicator proposals shared the underlying multi-dimensional conception of globalization (Lockwood, 2001, 2004; Lockwood & Redoano, 2005; Heshmati, 2006).[3] The two most important (and sustained) recent efforts to build globalization indicators are the one built at the University of Maastricht and the one built at KOF (KOF, 2011). In the former case (Zywietz, 2003; Martens & Zywietz, 2004, 2006; Figge & Martens, 2014), the authors adopt a broad definition of globalization: "the intensification of cross-national cultural, economic, political, social and technological interactions that lead to the establishment of transnational structures and the global integration of cultural, economic, environmental, political and social processes on global, supranational, national, regional and local levels" (Rennen & Martens, 2003: 143). Compared to previous indicators, two additional dimensions are added: (i) the global involvement of a country's military-industrial complex and (ii) globalization in the ecological domain.

The globalization concept on which the KOF indicator is based refers to a process of "creating networks of connections among actors at multi-continental distances, mediated through a variety of flows including people, information and ideas, capital, and goods," a process "that erodes national boundaries, integrates national economies, cultures, technologies and governance, and produces complex relations of mutual interdependence" (Dreher, 2006: 3). The KOF indicator distinguishes itself by the expansion of the personal contact and information flow variables, and the incorporation of a cultural convergence variable and economic policy variables.

Although these globalization indicators have shown to be useful in econometric analyses (Potrafke, 2014), there are a number of methodological issues that have been raised. A first is the obvious problem of weighting and aggregation in the construction of the composite indices (Lockwood, 2001; Martens & Zywietz, 2004, 2006; Heshmati, 2006; Martens & Raza, 2008; De Lombaerde & Iapadre, 2008, 2011). In the most recent revision of the KOF index, *de facto* globalization is distinguished from *de jure* globalization (Gygli et al., 2018).[4]

[2] The construction of this globalization index was inspired by the Human Development Index (UNDP, 1998).

[3] For an overview of distinct proposals, their dimensions and variables, see De Lombaerde & Iapadre (2008, 2011) and Dreher et al. (2008). Kluver & Fu (2004) have argued to bring the cultural dimension to the core of the measurement of globalization.

[4] See also, De Lombaerde & Iapadre (2008, 2011) on the need to distinguish between indicators of *de facto* globalization and indicators of globalization policies.

A second issue refers to the fact that the flow variables on which the globalization indicators are based (trade, investment, telecommunications, tourism, etc.) inform us about the *openness* of countries rather than about their *globalization*. Thus, it has been argued that constructed globalization indicators do not necessarily inform about the distribution and reach of international relationships (IRs) of a country, and that alternative indicators are therefore needed (De Lombaerde & Iapadre, 2008, 2011; Vujakovic, 2010). This issue refers also to the question whether the international integration of a country is global or instead, regional. As will be shown in the various contributions to this special section of *Network Science*, social network analysis is an appropriate tool to shed more light on the distribution and reach of IRs in the global system. Network-based measures could constitute a useful complement to the existing globalization indicators.

A third issue refers to *methodological territorialism* which characterizes the quantitative study of globalization (Scholte, 2002). Globalization measures based on alternative groupings of people, alternative *places* (e.g., cities),[5] or even individuals, would also reveal interesting insights in the dynamics of globalization. Network research is well equipped to face this challenge, provided that the necessary data exist.

3 Network analysis of global trade and production patterns

As mentioned before, the recent definitions and conceptualization of globalization emphasize the multi-dimensionality and the complexity of the phenomenon. These aspects are also very evident considering specifically international trade between countries, one of the main manifestations of globalization. The growth of international trade has allowed the integration of national markets and the widespread availability of goods, services, and intermediate inputs produced at far away locations. But this growth did not only imply larger volumes of trade: during the past decades, the number of countries actively involved in international trade increased, while at the same time exchanges across countries expanded from trade in goods to include more services and what is sometimes called *trade in tasks*—tasks are embodied in semi-processed goods crossing borders along the production process.

As the increasing complexity of the observed patterns of international trade suggests, to understand international trade, and its consequences on macroeconomic dynamics, it is not sufficient to look at each single country in isolation, or to the linkages it holds with its direct trade partners. One needs a more holistic perspective, where countries are seen embedded in the whole web of trade relationships. This is precisely what is provided by a network view of international trade. In such a systemic view, countries are characterized not only by how much they trade, but also by whom they trade with, and by their overall connection with the trading system. In this context, the integration or connectivity of a country depends on whether it trades with countries that trade a lot, or if it trades with pairs of countries that are themselves trade partners; if it is embedded in tightly connected groups (or communities) of countries, relatively disconnected to others; and so on. The overall

[5] On city networks, see e.g., Taylor et al. (2002) and Taylor (2004).

structure of relationships will tell whether a country is systemically important (or central) in the whole web of trade system and it will provide information on how exposed its economy is to external shocks.

The relevance of this view has generated recently a number of papers, following the pioneering work by Smith & White (1992) analyzing the characteristics of the world trade network (WTN).[6] From these analyses, some important features of the WTN emerge. The WTN is a dense graph compared to other real-world networks: its density is larger than 0.50, and in the period 1950–2010, the WTN has shown a marked increase in the number of direct linkages and a (weak) positive trend in density (De Benedictis & Tajoli, 2011; Garlaschelli & Loffredo, 2005; De Benedictis et al., 2014). This occurs irrespective of whether or not one factors in any increase in the number of countries in the sample, due (for example) to improvements in data collection or new-born countries. Therefore, trade globalization has not only strengthened the connections among countries that were already trading back in 1950 (increasing the “intensive margin,” as it is called in the international trade literature), but also embedded newcomers in the trade web over the years, inducing a stronger trade integration (increasing the so-called *extensive margin*). Still, it is important to highlight that a density close to 0.6 means that nearly half of all possible bilateral relations are not exploited. In other words, most countries do not trade with all the others, but they rather select their partners.

Another important feature of the WTN is the non-uniform structure of the network. For example, the distribution of the number of export and import partners of each country (i.e., in-degree and out-degree in terms of trade linkages) has become more and more bimodal over time, with a group of highly connected countries co-existing with another group characterized by a smaller number of inward and outward links. Thus, one is not able to talk of a representative country in terms of trade patterns. According to some works, the WTN is disassortative (see Fagiolo, 2010), but this property is not so well established, and results differ when binary or a weighted network data are available.

Despite trade globalization, the WTN is still a strongly modular network. Geography affects trade flows, in spite of the decline in transportation costs, and continental partitions of the WTN display a higher level of cohesion than the whole system. Furthermore, economic and political factors push countries to form over time relatively stable modular patterns of multilateral trade relations, possibly interacting among them, which can be easily identified through network analysis.

Community-detection techniques (Fortunato, 2010) applied to the WTN allow Q4
one to identify several clusters of countries forming tightly connected trade groups
(Barigozzi et al., 2011; Piccardi & Tajoli, 2015). These groups tend to mimic Q5
geographical partitions of the world in macro areas but are less overlapping with existing preferential trade agreements. This confirms previous findings of the trade literature that show the difficulty in assessing the exact impact of trade agreements on trade flows (Baier & Bergstrand, 2007). Many of the identified communities of countries in the WTN appear to have weak “statistical significance” (Piccardi &

[6] See also, Serrano & Boguña (2003), Serrano et al. (2007), and Fagiolo et al. (2007, 2008).

Tajoli, 2012) because inter-community linkages are very relevant, providing support for the WTN as a globalized trading system.

The above-mentioned properties apply to the aggregate WTN; that is, to the network formed by total trade flows between countries. The WTN can also be analyzed by considering separate trade flows of different categories of goods, as done for example, by Barigozzi et al. (2010), De Benedictis and Tajoli (2010), and **Q6** De Benedictis et al., (2014). Results from these analyses show that commodity- **Q7** specific networks are strongly heterogeneous and their properties are statistically different from the aggregate one. Many commodity-specific layers of the WTN are not even fully connected. Nearly full connectivity at the aggregate level is mainly achieved through the presence of specific links that keep commodity-specific networks together.

Another interesting application of network analysis to a specific type of international trade links considers trade flows among countries generated by the so-called global value chains or international production networks (Cingolani et al., 2017, 2018). The analysis of the networks formed by trade links due to trade in intermediate goods to assemble final products and combining the production capacity of different countries allows to better understand how these international production structures are organized and which countries play a more central role in them.

These results add information to the more traditional econometric analysis of the pattern of trade across countries, using mainly the gravity model. The gravity model applied to bilateral trade flows is based in the individual characteristics of the trading country pair, even if the theoretical derivation of the model strongly suggests to take into due consideration the general context of world markets in which the countries are embedded. Empirically, this should be done by introducing the so-called "multilateral resistance" in the econometric specification (Anderson & van Wincoop, 2003), but within the traditional approach finding an appropriate variable to measure this term is not an easy task.

This can be done more explicitly in a network context, as the network allows to examine how countries' structural locations in the global trade network influence their bilateral trade, as it is done, for example, by Zhu and Park (2012). The authors identify a cohesion effect of structural equivalence (the degree to which two nodes have similar ties with other nodes in the network) in global trade: two structurally equivalent countries develop more bilateral trade even after controlling for conventional dyadic factors. Also, Ward et al. (2013) argue that there are theoretical as well as empirical reasons to expect network dependencies in international trade and they should be taken into due account in econometric exercises. Fagiolo (2010) offers an interesting comparative analysis of different empirical approaches to international trade. The paper shows that the residuals of a gravity specification of trade flows, where trade-link weights are depurated from geographical distance, size, border effects, trade agreements, are not at all random, but display marked signs of a complex system. Building on these results, Duenas & Fagiolo (2013) show that the gravity model estimates of trade flows are very poor in replicating the observed binary architecture of the WTN and it is not able to explain higher order statistics that, like clustering, require the knowledge of triadic link-weight topological patterns. These comparisons confirm the contribution of the network analysis to the understanding of trade patterns, and provide useful insights for the theoretical and empirical models of trade.

4 Network analysis of global investment

International production and investment is a domain in which network analysis can play a useful role. The "double network" theory of multinational enterprises (MNEs) is based on the idea that innovation and value creation result from the interaction between the *internal network* connecting headquarters to affiliates and the *external networks* of relationships between each affiliate and its host economy (Cantwell, 1995; Zanfei, 2000). In principle, at the firm level, this approach can be applied to both national and multinational groups; however, it can be particularly useful when studying the specific advantages that MNEs draw from their cross-border network organization. These networks are related to their strategic interactions with other agents, such as trade unions and governments (Ietto-Gillies, 2000).

It has also been observed, however, that the actual geographic scope of the activities of MNEs is not necessarily global; rather, it is often regional. And even if final goods are sold in global markets, most of the manufacturing production is often spread among production locations in countries from the same region (Rugman & Verbeke, 2004; Rugman, 2005, 2008).

Network research has been applied to the study of the internal network of MNEs at the firm level. Vitali et al. (2011) focus on the control network of transnational corporations, to understand how its structure affects market competition and financial stability at the global level. These researchers describe the architecture of the international ownership network, and compute the control held by each global player. Their results allow identifying a giant bow-tie structure, largely controlled by a small core of interconnected financial institutions. In a follow-up paper, Vitali & Battiston (2014) study the community structure of the global corporate network and find that it is strongly influenced by the geographic location of firms. Altomonte & Rungi (2013) explore the structure of national and multinational business groups, conceived as knowledge-based hierarchical networks. The trade-off between knowledge exploitation and communication costs within the group is analyzed through an entropy-like index, which measures the hierarchical complexity of the group.

De Masi et al. (2013) apply complex network analysis to the study of Italian multinationals, in order to identify, at the sector level, the key nodes of the system in terms of investing firms and countries of destination. Joyez (2017) performs a similar analysis on French multinationals, showing the increasing geographic diversification of their location strategies.

A related strand of literature deals with the structure of production networks, in order to understand its macroeconomic effects (see, e.g., Battiston et al., 2007b; Acemoglu et al., 2012). This literature feeds into a more general approach, aimed at representing real and financial markets as a complex evolving system of coupled networks of interacting agents (Doyne Farmer et al., 2012). The properties of this system can allow a better understanding of sudden changes of status and crises.

At the macroeconomic level, aggregating the cross-border control networks of MNEs can lead to build a network of foreign direct investment (FDI) stocks, whose nodes are the home or host countries of investing firms. This can help overcome the problems created by the lack of a comprehensive source of bilateral FDI data, similar to what is available for the international trade network.[7] As in other types of economic networks, geographic distance can prove to be an important factor shaping the structure of FDI networks. Recent research on ownership networks at the firm level seems to support this intuition (see, e.g., Vitali & Battiston, 2011).

Metulini et al. (2017) study the effects of FDI on trade, analyzing the corporate control network, which connects (directly and indirectly) origin and destination countries. They assume that the network's structure is affected by MNEs' attempts to minimize tax burden and coordination costs, as well as to overcome market access barriers.

Economic geography shows that in many cases the specific features of local systems can be more relevant than national factors in explaining the location strategies of MNEs and their effects (Iammarino & McCann, 2013). A promising avenue of further research that can be relevant for FDI is the study of spatially embedded networks. In particular, the degree of local embeddedness of MNEs external networks (Andersson & Forsgren, 1996) as well as the absorption capacity of host economies, have an important influence on control, value creation, and innovation.

In economic geography, network analysis has been used to study the structure of local and trans-local linkages among firms belonging to industrial clusters, distinguishing between buyer–supplier, partnership, and investment linkages (Turkina et al. 2016). Alderson & Beckfield (2004) study the network of global cities on the basis of information about the location of the 500 largest MNEs' subsidiaries. Battiston et al. (2007a) start from data on employment and ownership shares at business level to build the network of inward and outward investment stocks of European regions. Crescenzi et al. (2017) use data on green field investment projects to analyze linkages among European cities, including those in neighboring regions, and identify hierarchical network structures, differentiated by sector and business function.

5 Network analysis of global migration

The fact that there have been very few network analysis applications to the global migration system is due to the fact that only very recently global matrices of bilateral migration stocks (and indirectly, flows) have become available. There is earlier work that applies network approaches to intra-national (i.e., inter-regional and inter-state) migration flows (Maier & Vyborny, 2005). There are also earlier studies on network effects in international migration, but—strictly speaking—these do not rely on a network analysis of the global system. These network effects refer to agglomeration effects in international migration whereby networks of immigrants in specific contexts (destination countries) attract more immigrants from the same origin. This has led to qualitative research in sociology and anthropology, and some quantitative research (Munshi, 2003; World Bank, 2008). In gravity-type models of bilateral migration flows, for example, network effects are proxied by including

[7] In the case of portfolio investment, official bilateral data is available in the IMF Coordinated Portfolio Investment Survey. Song et al. (2009) use this data to study the statistical properties of the world investment network. Joseph et al. (2014) analyze different types of international portfolio investment to identify early-warning network indicators of financial crises. Zhang et al. (2016) build a multi-layer network of the world economy to compare the topology of portfolio investment and trade networks.

migrant stocks in destination countries as an explanatory variable (Bao et al., 2009; Marques, 2010; Jayet et al., 2010). This variable has shown to produce significant effects on the decision-to-migrate.

However, these gravity-type models do not take full benefit of all the information incorporated in the global system of migration flows. This requires a network analysis of the global matrices. In addition, only global bilateral matrices allow to systematically study regional clustering/density and the effects of regional migration policies (Ceccorulli et al., 2011; Deacon et al., 2011) and the changing patterns in North–South and South–South migration (De Lombaerde et al., 2014). The currently available matrices, based on census or population register data on foreign-born population (in combination with data on nationality and estimation techniques), have been developed by the World Bank (Özden et al., 2011) and UNDESA (2008, 2013), and have benefited from pioneering work at the University of Sussex (Parsons et al., 2007). In the 2015 Revision of UNDESA, data are available on a 5-yearly basis from 1990 to 2015.

The information which is available in these matrices is a combination of historical data and estimations. Such information reveals not only the lack of data for a number of countries and years but also a number of conceptual and methodological difficulties, which are largely specific to migration and which will continue to play a role in the foreseeable future. Therefore, network applications in this area will face certain limitations. A first difficulty relates to the fact that national legislations and records on migration and citizenship are very diverse. This diversity has implications for the definition of migrants, their registration, and the comparability of resulting statistics. The UN has tried to harmonize concepts, but this does not completely solve the problem (Bilsborrow et al., 1997; UNSD, 1998; IOM, 2004). In the World Bank project, data were combined for "migrants" according to the place of birth criterion (which is the preferred criterion) and the nationality criterion. In addition, missing data were/are estimated. A second difficulty arises from the growing mobility of people and the multiplication and sophistication of the modalities of that mobility. It is getting more and more difficult to establish a clear distinction between patterns of mobility and migration.

The recent availability of global bilateral migration data has thus led to interesting descriptive work (including the use of network indicators) (Özden et al., 2011; Davis et al., 2013; Abel & Sanders, 2014), which allows observers to have a better (quantified) grasp of the phenomenon; however, the full potential of networks when applied to the global migration system in more (theory-based) analytical work has yet to materialize. How far this analysis will be able to reach, will depend—among other things—on the possibility of obtaining yearly data, disaggregated by categories.

6 Network analysis of trade and investment agreements

The growing array of bilateral and plurilateral agreements aimed at regulating and facilitating international trade and investment stands out as a natural domain for the application of social network analysis.[8]

[8] Network analysis can be applied to the study of any global governance system based on a set of international agreements. For example, Kim (2013) studies multilateral environmental agreements, working on the network of their reciprocal citations.

This is particularly clear if one considers the long standing theoretical and policy debate on the relationship between regional integration agreements and the multilateral trading system (WTO, 2011). One of the main issues under discussion concerns to what extent and under which conditions the growth in the number of preferential agreements might lead to a long-term result, which resembles a complete multilateral liberalization of world trade. In other words, does the network of bilateral agreements become so dense as to turn itself into a fully connected decentralized world network? And if so, how?

Starting from strategic models of social and economic networks (Jackson & Wolinsky, 1996), a strand of literature studies the establishment of trade agreements as a network formation game. Goyal & Joshi (2006) show that a network of bilateral trade agreements among symmetric countries can lead to a stable global free trade equilibrium. Furusawa & Konishi (2007) compare free trade agreements and customs unions, in a view to understand their possible contribution to global trade liberalization. Saggi & Yildiz (2010, 2011) extend this result and explore its limitations. Mauleon et al. (2010) analyze the trade-off between the stability and the efficiency of different outcomes of the network formation game. Zhang et al. (2014) offer a dynamic extension of these models, reinforcing their main conclusion about the tendency toward global free trade. On the other hand, Manger et al. (2012) use longitudinal network analysis techniques to study the formation of preferential trade agreements, showing that there are incentives for the emergence of a hierarchical structure, in which least developed countries tend to remain marginalized.

Most of the above models share the idea that governments are myopic in their decisions about free trade agreements, as they tend to neglect possible future changes in the structure of the network. Departing from this assumption and building on the concept of farsightedly stable networks (Herrings et al., 2009), Zhang et al. (2013) show that global free trade may be the result of a gradual addition of bilateral agreements, even if the process may require the dissolution of some of the already existing ones. However, Lake (2017), starting from the idea that parties in a bilateral agreement may face incentives to exclude third countries from its extension, shows that preferential agreements can reveal to be stumbling blocks against the achievement of global free trade.

Another strand of literature addresses the impact of preferential trade agreements on the structure of the WTN. For example, Reyes et al. (2014) use the techniques of complex network analysis to show that regional integration agreements have exerted an increasing influence on the community partition of the WTN. However, they also find that other factors, such as trade growth in South East Asia, have countered this influence in some periods. Piccardi & Tajoli (2015) show that the effect of preferential agreements on the actual network of trade flows is rather weak, suggesting that forces driving globalization have prevailed, also as a consequence of the gradual erosion of preference margins.

The literature on international investment treaties shows clearly the inadequacy of a dyadic approach to explain their growth (see Jandhyala et al., 2011). Yet, studies using network analysis to understand the formation of bilateral investment treaties (BITs) are still scarce. One example is Saban et al. (2010), who use a dynamic version of complex network analysis to show that a generalized preferential attachment model (Barabàsi et al., 2002) can explain the growth of BITs between 1959 and

2005, and that their network shows signs of saturation. More recently, Rozenas et al. (2017), starting from the observation that the conclusion of a BIT may conceal the underlying asymmetric nature of the relationship between its parties, propose a probabilistic method to identify the unobserved asymmetric network of BITs from the observable network of undirected links between signatory countries.

7 Network analysis of the global polity

The application of network analysis to IRs and politics in the global polity within mainstream IR scholarship is relatively recent (Bonacich, 1987; Beckfield, 2003, 2008; Ingram et al., 2005; Hafner-Burton & Montgomery, 2006; Brams et al., 2006; Maoz et al., 2006; Hughes et al., 2009; Hafner-Burton et al., 2009; Maoz, 2011) and it is argued that a network approach is underused in IR (Hafner-Burton & Montgomery, 2010). Its value has been very well demonstrated by Hafner-Burton (2010), for example, in three cases (research on: joint membership of international organizations and the occurrence of conflict, alliance hierarchy and defense spending, and international trade and labor standards).

Power is the variable which is at the heart of the IR research program, at least in the realist tradition in the field (Morgenthau, 1960). According to neo-realists, power refers to relative material capabilities of states to influence or enforce the behavior of other states (Waltz, 1979; Barnett &Duvall, 2005). Although there is an awareness that a distinction should be made between power potential (material capabilities) and actual exercise of power, empirical analyses usually focus on the former as the capabilities are easier to quantify.[9] In network applications to the global polity, there seems to be a consensus that power is a multi-dimensional phenomenon. Network analysis is therefore often based on combinations of flow data in, for instance, the political, security/military, and economic spheres. In the political sphere, the networks that are mostly analyzed are the ones built on ties showing diplomatic presence/representation and ties showing coinciding memberships of international organizations (Snyder & Kick, 1979). In the security/military sphere, the quantifiable variables show either the presence of a cooperative tie (e.g., existence of an alliance or joint membership of an alliance, weapons trade), a conflictive tie (e.g., existence of conflicts), or the presence of transnational actors (e.g., extraterritorially present military troops, terrorist networks). The fact that also economic flows are covered implies some overlap in the networks that are covered between disciplinary approaches (see above). For instance, political scientists include trade data in their analysis because they claim that the trade patterns can reveal sources of power (Hafner-Burton & Montgomery, 2009). Sometimes these trade flows are filtered and/or expressed as percentages of respective GDPs in order to extract dependency relationships (Van Rossem, 1996).[10] For several of the variables that are used (especially the political ones but also, for example, the presence of foreign troops) turning undirected binary ties into directed ties (“A dependent on

[9] This distinction corresponds with Keohane and Nye’s conceptualization of resource power versus behavioral power (Keohane & Nye 1998: 86).

[10] Compare with the calculation of hubness indicators (Baldwin, 2004). For an application to the analysis of regional centrality of the BRICs, see Chen & De Lombaerde (2014).

B" or "A exercising power over B") is a challenge and ambiguity is not always completely solved. Weighting the ties is similarly problematic for certain variables.

Power is thus not only a matter of relative material capabilities, but it is also related to the position of the states in the global political/economic system. In other words, relative power is acquired by means of the (intensity and structure of) relationships that exist between states and other states. As these feature asymmetries that generate dependencies of one state over another and centralities that increase the prominence of some states over the other, they are a source of power. The application of network measures to the study of power (and influence) in an international context, is therefore related to a distinct understanding of power as *relational power* or *network power*. Thus, network approaches challenge the conventional conception of power; power is defined in terms of social power (connectedness), brokerage, and exit options (Hafner-Burton et al., 2009; Hufner-Burton & Montgomery, 2010). Relational power can be assessed, for example, by calculating centrality indicators. According to Hufner-Burton and Montgomery (2010), centrality measures in this context can be thought of in three classes of measures: *access (*degree and related measures such as eigenvector), *brokerage* (betweenness-related measures), and *efficiency* (closeness-related measures). Disparities in the relative centrality of states can thus lead to conditions of distrust and conflict.

Network-based applications along these lines are connected to the broader recent literature on globalization, multi-polarity/non-polarity (Haass, 2008), and the shifting power balance in favor of the emerging countries, especially from Asia–Pacific and the BRICs. Although there is a tendency to recognize the existence of power shifts (especially regarding China), this literature is not completely conclusive as the empirical results depend heavily on the length of the period of observation and the selected variables. Contrary to certain expectations (e.g., related to the BRICs as emerging economic powers), evidence seems to suggest that it is rather in the political sphere that power is (relatively) shifting toward emerging powers (Beckfield, 2008; Hafner-Burton & Montgomery, 2009).

It should be observed, however, that not only neo-realism is providing a theoretical framework for these network analyses, but that also world-systems analysis has inspired network analyses of the global polity (and economy) (Snyder & Kick, 1979; Breiger, 1981; Nemeth & Smith, 1985; Smith & White, 1992; Van Rossem, 1996; Kick & Davis, 2001; Mahutga, 2006; Clark & Beckfield, 2009; Mahutga & Smith, 2011). For an overview of network applications within the world-system paradigm, we refer to Lloyd et al. (2009). Whereas neo-realists view the international system as anarchic, proponents of the world-systems approach emphasize the core-periphery (hierarchical) structure of the global system and explain the economic logic and long-term dynamics behind it (Wallerstein, 1974; Arrighi, 1998). **Q8**

World-systems analysis has also inspired a specific conceptualization of power as *prominence*. In the global polity, countries are more prominent to the extent that more countries depend (directly or indirectly) on them. Thus, prominence combines centrality with dependence. And dependence is thereby not only based on the nature of bilateral relationships but rather on how countries are connected to the global system as a whole. This hierarchical conception of power has been operationalized by Van Rossem (1996) and Jacobs & Van Rossem (2014a) by applying the triad-census technique (Hummell & Sodeur, 1987). The underlying criterion of the latter is an alternative for the structural equivalence criterion which was used earlier in blockmodeling techniques to detect groups of countries playing similar roles in the global polity (Snyder & Kick, 1979).[11]

Because of its Marxian imprint, this approach tends to emphasize the dominance of economic networks (and sources of power) over political networks (and sources of power). This contrasts with the mainstream approaches where a relative autonomy of the various networks and power dimensions is recognized (Kick & Davis, 2001; Hafner-Burton & Montgomery, 2009). Recent work points to a converging view on this point (Jacobs & Van Rossem, 2014b). This world-systems approach is very much interested in demonstrating the stability of core-periphery patterns over time. Contrary to certain views in mainstream scholarship, the world-systems approach is thus more skeptical about the possibility of vertical mobility in the world polity. The *emerging powers* are conceptualized as a *semi-periphery*. Recent work along these lines on the BRICs questions its validity as an analytical category as these countries occupy very different power positions in the global polity and that these positions are based on different sources of power (Jacobs & Van Rossem, 2014a).

There is still a lot of potential for social network analysis of the global polity, although further development will necessarily be conditioned by the availability of new systematic data on various aspects of IRs and power. The research agenda includes network analysis of soft power networks, differentiation between centrality and autonomy as distinct sources of power, disambiguation of certain dependency relationships, further clarification of the meaning of globalization and its relationship with power dynamics, and linkages between international and intra-national distributional patterns.

8 Conclusions and contributions to this special section

The four papers included in this special section are focused on the global patterns of trade and production. As such, they use a variety of trade datasets to develop new measures, elucidate familiar cases with more depth, and add to the findings of the complex interplay of globalization, regionalism, and multi-polarity in the global system. Two take a more aggregate view (one comparing global value chains across countries while the other interrogates the impact of geographic distance on trade flows), while the other two examine specific sectors more closely (the oil industry and the automotive components industry).

A strong illustration of the tension between regionalism and globalization is evident in "Distance-varying assortativity and clustering of the international trade network," (Angela Abbate, Luca De Benedictis, Giorgio Fagiolo, and Lucia Tajoli). In this work, the authors embed the network of trade flows within geographical space. Using data from the International Trade Network (Subramanian & Wei, 2007) and covering the years of 1970 to 2000, they find that indeed, geographic proximity (not surprisingly) matters for strong trade partnerships, but not in a simple fashion. Using both weighted and unweighted networks, the authors examined the aggregate network, a traditional approach, but also created a series of subnetworks comprised

[11] On blockmodeling techniques, see White et al. (1976), Winship & Mandel (1983), and Wasserman & Faust (1994).

of ties only at certain distances (dividing the international trade network into distance deciles) and examined a number of topological characteristics of networks, node statistics, and some country macroeconomic characteristics.

In the aggregate network, Abbate et al. found the recognized pattern of disassortativity in trade partners. Overall, countries tend to connect to partners who are different than them in measures such as connectivity. However, when considering only near-country trade a different pattern arises: countries located near one another exhibit a more assortative pattern of mixing, which countries with many partners tending to trade with other high-degree partners. This pattern smoothly reverses in considering networks of more distant countries, until the pattern of dissasortative trade showing that highly connected countries showing a strong preference to countries with far fewer ties. Intermediate distance networks showed no tendencies in this matter.

Another network-level measure they consider is the differences in distanced-conditioned clustering coefficients. Previous findings that did not consider distance found evidence of strong clustering among countries and their trade partners, but examining the distance-conditioned networks reveals that this overall tendency is being heavily influenced by short-distance trade relationships. At high distances, the tendency weakens. This effect of distance with both assortative and clustering is somewhat attenuated by considering country-level measures such as GDP. In addition, the authors find that the importance of distance in trade evolves over time—disassortativity has increased for distant partners over time, reflecting increased participation by all countries in the network, just as clustering has also increased for near and far partners.

Geographic distance and the role of networks also changes in importance over time in the case examined in the next paper, which tracks international trade in crude oil from 1995 to 2014. "The evolution of oil trade: A complex network approach" (Andrea Fracasso, Hien T. T. Nguyen, and Stefano Schiavo), considers bilateral trade data from the BACI International Trade Database for crude oil (Gaulier & Zignago, 2010). Examining network-level measures such as density, centralization, community detection (modularity), and changes in geographic distances of trading partners over time, the authors find that the evolution of oil trade over 20 years has seen a broad reduction in traditional powers (such as OPEC), while new emerging importers (China, India) have changed both the community structure and the centralization of the network. Density of ties increases (more trade), while centralization decreases (less singular power). While the network ends as organized in several modular communities (which might argue for increasing regionalism or multi-polarity), the average geographic distance between partners within those communities increases, complicating a simple regionalization argument.

Using the HITS algorithm to examine hubs in import and export combined, Fracasso et al. find that relative importance of exporters is related to (as one would expect) their share of global exports, but also the size of their reserves and the distance they are from the United States. Canada in this measure emerges as an outlier in its hub score as compared to its export size. Russia, on the other hand, is also a much large exporter but has a comparatively low hub score because of its connection to less prominent importers. China, in 2014, the second largest importer, has created a small community of African exporters rather than near neighbors.

Overall, the authors find evidence of an early phase of regionalization, but a more recent turn back to globalization of the oil trade, with a reduction in traditional powers and the emergence of new powers.

Also, considering the emergence of rising powers in a multi-polar global system and its intersection with regionalism, the next paper in this issue, "Automotive international trade networks: A comparative analysis over the last two decades" (Sara Gorgoni, Alessia Amighini, and Matthew Smith), uses bilateral trade statistics on auto parts and components from the UN Comtrade database in 1993, 2003, and 2013. Using highly disaggregated trade data at the product level to create directed, weighted networks for the case of the automotive industry, the authors examine the differences in trade networks of the electrical and electrical components, rubber and metal, and engines. They examine many factors, including size, composition, out-degree (number of export partners), weighted out-degree (value of trade), core-periphery structure of the whole network, centralization, and a weighted and normalized version of the E–I index. They also examine brokerage roles of individual countries within the network.

As Gorgoni et al. found, the networks diverged in patterns by product types, with some regional leaders (Japan and Germany) acting as gatekeepers to strengthening regional networks. Over time, for the electric and electrical parts and rubber and metal (but not for engines), the trade network diversifies as more countries join, but the average value of ties decreases as exporting was spread across more countries. Accordingly, export networks for these products became less centralized. Electric and electrical parts also shifted over time into a slightly more core-periphery model, with China and Eastern European countries playing an increasing role as new suppliers. The engine trade network displayed a large move to the core-periphery model, with a small core of countries increasingly controlling a large amount of engine exports, while the rubber and metal trade network actually became less hierarchical. Specific product spaces connect regions to the international trade networks in different ways, such as through the heterogeneity of patterns over time by product type with respect to regionalization and the divergence of the roles played by traditional players in strengthening regional networks while rising powers (Brazil, Russia, India, and China). This points to a need to carefully attend to the level of aggregation of trade data, so as not to mask patterns.

Instead of import–export flows, the final article in this section, "The similarity of global value chains: A network-based measure" (Zhen Zhu, Greg Morrison, Michelangelo Puliga, Alessandro Chessa, and Massimo Riccaboni), proposes and presents a more refined measure of similarity of countries than traditional export similarity measures by examining international production networks in sectors. They calculate the similarity of countries within sectors in upstream and downstream global value networks constructed from the global multi-regional input–output tables from World Input–Output Database, covering 1995–2011. They use a type of *role equivalence* for their weighted directional networks of countries, which considers the similarities countries have with other countries by their connections to other equivalent countries (but not necessarily the same countries, as would be required with *structural equivalence*). In generating this profile, which also accounts for self-loops and exogenous nodal attributes of the countries, they show that on average, sectors reveal an increasing trend of similarities over time. More variability could be seen in sectors such as services, while manufacturing tended to be more similar. A temporary reduction in the similarities, particularly in the upstream ones, followed the 2008 economic crisis, but did rebound. Zhu et al. warn that increasing similarities point to increased systemic risk in international production networks as there is increasing overlap in trade partners along value chains.

Taken together, these four papers add to the understanding of the heterogeneity of the response to increasing global trade ties. They remind us geography matters not always in a straightforward way (such as with increasing assortativity with increasing distance in the International Trade Network) and that power is not always residing in largest market shares, but is also embedded in relationships (such as with Canada and the United States for oil). They show that the structure of some industrial sectors can be more or less entrenched with strong patterns of dominance by traditional powerful countries (in the case of automobile engine production) and that economic risk can be increased by patterns of similar interactions (such as with global value chains). Network approaches such as these broaden our understanding of globalization, as well as of the complexities of its countervailing forces and alternative explanations.

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