Forest Policy and Economics 86 (2018) 45–66

Contents lists available at ScienceDirect

Forest Policy and Economics

journal homepage: www.elsevier.com/locate/forpol

# Submission of an original research paper: Social network analysis as a tool for the analysis of international trade of wood and non-wood forest products

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ARTICLE INFO

*Keywords:*
Social network analysis
Forest products
International trade
Modelling

ABSTRACT

Countries are almost exclusively seen as the primary unit of analysis in the study of international trade; and analysis of trade in wood and non-wood forest products is no exception to that rule. This paper uses the relationship among countries as the primary unit of analysis and introduces different procedures of social network analysis, where the goal is to demonstrate their applicability to the study of international trade of forest products. Compared to statistical analysis, additional benefit of social network analysis is the fact that the assumption of independence of observations does not hold true; and thus enables a more thorough insight into the structure of the international trade network.

Data on international trade of chemical wood pulp, truffles, and aggregate forest products in the 1988–2006 period is used to demonstrate the applicability of selected network indices as descriptors of economic flows among countries. The analysis covers topics of network visualization, characteristics of the network, grouping of countries, their individual positions and modelling of international trade that includes endogenous effects such as reciprocity, and exogenous effects such as forest certification and contribution of forestry to the gross domestic product.

Results show that many procedures of social network analysis can be used in the field of international trade of forest products, but that great care is needed in their contextual interpretation. Prominent topics of application are the structural trends and impact of different policies, such as the EU Timber Regulation on international trade of wood-based products.

## 1. Introduction

In the context of globalization, even the critics of global market forces (Hirst and Thompson, 2009) mark international trade as one of the main pillars of world's economic structure. On a micro-economic level, international trade not only provides new business opportunities, it significantly increases employment, total shipments and value-added per worker (Bernard et al., 2007), and within-plant productivity (Bernard et al., 2006). Analysis of international trade has been marked in the last decades with the introduction of methods from different areas of economics (Davis and Weinstein, 2001; Feenstra, 2004), and usage of econometric models (Van Bergeijk and Brakman, 2010; De Benedictis and Taglioni, 2011). However, the biggest change in the field is the tremendous growth of collection and diffusion of regional or global-level data bases, such as the Comtrade database of the UN's Department of Economic and Social Affairs (2015), Direction of Trade Statistics database of the International Monetary Fund (2006), World Integrated Trade Solutions of the World Bank (2016) and the Eurostat's (2016) database on international trade in goods.

When looking at the statistical procedures used in analysis of international trade (Bhagwati et al., 1998; Feenstra, 2004; Bowen et al., 2012), it can be stated that they are rooted in a substantivist approach, where the basic unit of analysis is the country. As such, they are adequate to describe and draw inferences about parameters that are focused on single countries, such as import quotas and prices, comparative advantage, economies of scale and exchange rates (Krugman, 2000). This position is contrasted by the relational approach, where the basic unit of analysis is not a country but rather the trade flows between them. For analyzing trade flows structure and the role played by different trade partners, Social network analysis (SNA) has been proposed as a powerful tool. Social network analysis can be defined as "… a comprehensive paradigmatic way of taking social structure seriously by studying directly how patterns of ties allocate resources in a social system" (Wellman, 1988, p. 20). The notion of relation as a fundamental unit of social analysis was later described as the "anti-categorical imperative" by Emirbayer and Goodwin (1994). This puts SNA to

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http://dx.doi.org/10.1016/j.forpol.2017.10.006
Received 2 April 2017; Received in revised form 6 September 2017; Accepted 2 October 2017

close relation with ‘The New York School of Relational Sociology’ and its critique of the dominant ‘substantialist’ approaches to social analysis (Mische, 2011). According to its manifesto (Emirbayer, 1997), SNA is the best way to study social structure from a relational perspective. As such, it is not the preferred way to the study international trade structure from an economists' perspective as based on country-level parameters. International trade is more than a sum of bilateral trade relations, and SNA can be used to describe and draw inferences about its overall structure and development, as reviewed in the following paragraphs.

SNA have been used to ‘map’ international trade since 1943 (Hilgerdt, 1943), not long after Moreno (1934) introduced sociograms to explain why a pandemic of runaway teenage girls emerged at the New York Training School for Girls in Hudson. Network studies of international trade from the sociology field have focused on position and role analysis of the various market players. The seminal article in this vein is Snyder and Kick's (1979) description of world systems as a core, semi-periphery and periphery structure, which is based on trade flows, military interventions, diplomatic relations and conjoint treaty membership. Smith and White (1992) followed the same approach and identified five groups following a core–periphery structure based on three time points. Similar studies were done by Kick and Davis (2001) who used two time points and Nemeth and Smith (1985) who used a single time point. Their work was continued by Clark and Beckfield (2009) who applied Borgatti and Everett's (1999) core–periphery model to describe trichotomous world systems. These procedures were used to assess globalization in international trade by Mahutga (2006) and Kim and Shin (2002). Zhou et al. (2016) focused on the top exporting and importing partners of countries for the 2001–2010 period, and revealed a network focused on the US, China and Germany. They also highlighted a “… need to develop theoretical models explaining, rather than simply describing, the observed networks” (p. 20).

Network studies coming from the fields of economics and physics have concentrated on degree distributions and clustering. Serrano and Boguna (2003) used Comtrade data to map global trade in 2000, and identified features characteristic of large networks: power-law distribution (Barabási and Albert, 1999), small world properties (Milgram, 1967; Watts and Strogatz, 1998) and strong hierarchy (Ravasz and Barabási, 2003). Bhattacharya et al. (2007) assessed symmetrized trade data set against log-normal distribution, and expanded those research directions through dynamical model based on gravity law in Bhattacharya et al. (2008) to show increasing concentration of trade into a few rich countries. Barigozzi et al. (2010) found divergent dynamics between commodity-specific and the aggregate trade network; Barigozzi et al. (2011) assessed the same trade network but focused on the 12 top commodities and found that aggregate networks show globalization trend but the commodity-specific ones do not. De Benedictis and Tajoli (2011) see SNA as complementary to the gravity model, and compared the two on the same dataset and the same relation was also explored by Fagiolo (2010). Hidalgo et al. (2007) assessed the development of nations through their positioning in ‘product space’, i.e. a proximity matrix of complementary products formally based on their trade patterns, with the assumption that complementary products can be produced and exported with the same type of factors of production, technological sophistication and institutional qualities. This line of investigation was further expanded with the economic complexity index (Hidalgo and Hausmann, 2009), which has proved to be a more accurate predictor of GDP per capita than other frequently used indicators such as global competitiveness index or increased exports of natural resources (Hausmann et al., 2014).

In this paper, we present a series of SNA measures and models coming from the social sciences (see Wasserman and Faust, 1994 for overview), and use them to analyze international trade networks of wood and non-wood based products. First we apply different network visualization techniques as a preliminary analysis of trade structure, then we use descriptive SNA indices to explore the overall network structure and the position of the key countries, and finally we study the network dynamics. The purpose of the paper is not to show an overview of SNA procedures, as they are far too numerous for this type of publication and many do not have relevant interpretation in the context of international trade. Instead, we strive to address the role that prominent SNA metrics can have in understanding the structure and the trends of international trade which cannot be gained from ‘classical’ statistics and models. The rationale behind the selection of each visualization and SNA index is explained following its application.

## 2. Materials and methods

The analysis was performed on several trade networks, encompassing different commodities and geographical scales. Network visualization techniques were used on global trade network in 2010 of chemical wood pulp (HS code 470200), for which the data is drawn from Forest Products Trade Flow Database (build on Comtrade data; Rougieux et al., 2015) of the European Forest Institute. Descriptive network analysis, that looks at characteristics of individual countries, their grouping and the overall trade network, was performed on the trade of truffles (HS Code 070952) for the 1988–2006 period. Analysis consisted of different SNA procedures that cover the characteristics of the whole network (all world countries and international trade relations), identification of sub-groups and node-level parameters. Chemical wood pulp and truffles are selected as being significative of many opposing forest product characteristics. Wood pulp is a product based on industrial large-scale mass processing technologies, with limited impact on income generation in rural areas but with well consolidated set of traditional key players operating in the international market. Truffles on the other hand are niche luxury product with dynamic international market that is very much connected with rural income generation and small-scale processing. Non-technical explanation of selected network concepts and measures (based on De Nooy et al., 2005 and Snijders et al., 2010) are presented in Appendix A; for detailed explanations, readers are referred to books authored by Wasserman and Faust (1994) and Borgatti et al. (2013).

Network dynamics was analyzed for the cumulative trade of all forest products within EU-27 (i.e. EU 28 without Croatia) for the 1999–2006 period, where the data were drawn from the EFI-WFSE Forest Products Statistics and Trade Flows Data Base (Michie and Wardle, 2000). Dynamic analysis was performed through application of the Stochastic Actor-Oriented Model (SAOM; Snijders et al., 2010), which was implemented using the SIENA (Simulation Investigation for Empirical Network Analysis; Ripley et al., 2016) computer programme, used through the *R* software environment (R Development Core Team, 2016). As its name suggest, the modelling focus of the SAOM is on the actors (nodes), who control their outgoing ties, where only one tie change can occur at one point in time (called a micro step), and no coordination in the tie change status is allowed. SAOM also assumes that the current state of the network is conditioned by its previous step, but not the ones before it (i.e. the network is a continuous Markov chain). The model also assumes that individual observations of the network are its states and not brief events, and the change between them is gradual (indicated by the Jaccard index, where values higher than 0.3 for two consecutive observations indicate gradual change). How often an actor can change its network state between two network observations (i.e. number of micro-steps) is defined by the rate function. SAOM also has an objective function, in which actors strive towards a network state in which the value of the objective function is higher – by dissolving a tie, making a new one, or choosing to remain in their current state. This function is set up in terms of probabilities, and is defined by a series of network parameters that influence the probability of changing the network state. SIENA provides parameter estimates and their standard errors. These parameters are called effects, and they can be endogenous (e.g. reciprocity) and exogenous (e.g. country's production capacity, corruption perception index, GDP per