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Connectivity to international markets: A multi-layered network approach

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ABSTRACT

Improving connectivity for freight movements between countries is increasingly a topic at the centre of the international trade and transport policy agendas. In spite of this, a method to asses a country's degree of connectivity to its international markets for freight is still missing. To close this gap, this paper proposes a multi-layered network approach that enables the assessment of: (i) the different factors that influence connectivity to international markets; and (ii) the extent to which a country's connections matter for its international trade activities. The international trade network and its 'support network' are analysed using network theory. The approach proposed is applied to the Americas, a region the relevant literature has not specifically focused on yet. It is expected that a comprehensive understanding and assessment of the determinants of connectivity for freight will contribute to guide and design more effective policies to remove barriers to international trade flows.

1. Introduction

In the context of globalization, delocalization of production activities and the emergence of global value chains, enhancing connectivity is becoming critical as a means to overcome barriers to international trade and improve competitiveness (Arvis and Shepherd, 2015). Because of this, research on connectivity as a determinant of international trade flows has seen increasing attention from academia and policy-makers. While most of the available literature refers to a narrow definition of connectivity, with focus on transport services (Marquez-Ramos et al., 2011), a broader perspective on connectivity to international markets endorsed by the studies and programmes commissioned by policy-makers is emerging (ITF, 2012; Calatayud et al., 2016). Aside from transport services, this perspective includes infrastructure and trade facilitation procedures as important elements to assess connectivity to international markets. 'International markets' are defined as the geographic area of demand of commodities located in one or more countries abroad (Salvatore, 2002). Therefore, the term 'connectivity to international markets' refers, in general, to the capability of a given country to connect to countries demanding products from it, therefore ensuring a seamless movement of freight between countries.

Despite increasing interest in this topic, a metric that takes into account the determinants of connectivity as suggested by the broader perspective is still missing. Instead, available connectivity metrics focus on the characteristics of transport services only. In addition, such metrics do not take into account whether and to what extent a country's connections influence the ability of exports to reach their destination markets. In contrast, a country's degree of connectivity is usually assessed in the context of transport networks only. An incomplete understanding on connectivity performance can misguide policy-makers and practitioners in their assessment of a country's degree of connectivity to international markets, the factors hindering it, and the actions needed to overcome any limitations. In this context, the premise proposed in this paper is that an approach that enables a more comprehensive assessment of the factors that influence a country's degree of connectivity, as well as the extent to which those connections matter for its international economic activities, can provide better guidance for policy-makers seeking to improve their country's connectivity to international markets.

The paper is organised as follows: Section 2 presents the literature review; Section 3 presents the methodology; Section 4 presents the results and discusses the implications for academic research and policy-making; and Section 5 presents the conclusions of this research.

2. Literature review

Literature in International and Transport Economics has shown that transport costs are a critical determinant of international trade. For example, Jacks and Pendakur (2010) and Bernhofen et al. (2016) showed that the introduction of containerization reduced transport costs and thus stimulated trade flows. Indeed, while in the past decade preferential agreements, multilateral negotiations, and unilateral trade

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liberalizations all significantly reduced tariff barriers, transport costs emerged as important deterrents to international trade. Given the prevalence of maritime transportation in international trade (UNCTAD, 2013 and 2015), a large part of research focused on estimating the impact of port connectivity on international trade flows as a result of, for example, liner shipping route structure, equipment structure, and service structure (Marquez-Ramos et al., 2011). Available studies suggested that connectivity had a significant effect on transport costs (Wilmsmeier and Martinez-Zarzoso, 2010); that trade routes more centrally located in the maritime liner service network had lower average transport costs and higher trade flows (Marquez-Ramos et al., 2011); and that – together with distance – connectivity was an important variable explaining the geographical patterns of trade flows (Guerrero et al., 2016).

Research on connectivity as a determinant of international trade flows has seen increasing attention not only from academia but also from policy-makers. In the context of globalization, delocalization of production activities and the emergence of global value chains, enhancing connectivity is becoming critical as a means to overcome barriers to international trade and improve competitiveness. For example, in its 2012 Annual Summit, the International Transport Forum (ITF) included among its main recommendations the need to increase "connectivity across borders" by enhancing infrastructure, increasing information sharing and providing the harmonisation and standardisation needed to smooth border crossing and reduce transit time (ITF, 2012, p. 30). National governments and international organisations have supported reports, master plans and programmes aimed at enhancing connectivity to international markets, evidencing policy-makers' growing interest in this subject (APEC, 2010; ASEAN, 2010). According to Calatayud et al. (2016), available literature not always refers to the concept of connectivity with the same meaning. Instead, through a systematic literature review they suggest that, in the context of international trade, connectivity is frequently defined in three different ways: (1) a narrow definition focused on the availability and characteristics of infrastructure and transport services; (2) a broader definition that, apart from infrastructure and transportation, also includes trade facilitation procedures; and (3) a supply chain management definition that refers to the degree of information sharing among supply chain partners. In addition, a body of literature distinguishes between the concepts of connectivity and accessibility. Although tightly related, accessibility can be defined as the ability to be reached by others, measured in terms of cost and time (Salgado and Cea, 2012; Redondi et al., 2013). Instead, connectivity is more related to the configuration and characteristics of infrastructure and transport services, as a result of which nodes obtain different positions within a network and access to other nodes in the network (Mishra et al., 2012).

In line with the different definitions of connectivity present in the literature, a variety of metrics have been developed and applied to assess a country's degree of connectivity. Using Graph and Network metrics, literature in the fields of Transport Economics and Geography has estimated countries' connectivity based on the characteristics of transport networks. Indeed, connectivity is a network metric and can only be understood in the context of a network and its characteristics. In Graph and Network Theories, connectivity is defined as whether and how nodes are connected to one another through the network (Newman, 2003). In other words, connectivity refers to how easy it is to reach the network from a given node and the opportunity for connections (available links) that the node offers (Paleari et al., 2010). The use of network analysis in transportation geography has a long tradition (Garrison, 1960). In the past ten years, the research in this area has been advanced by developments in information technology, which spurred the timeliness and amount of data available, new research questions, and improved theoretical models (Gaile and Willmott, 2004). Together with GIS (Thill, 2000) and modelling (Sheppard, 2000), network analysis is one of the major topics of contemporary transportation geography (Gaile and Willmott, 2004).

Literature in the field of maritime transportation has applied connectivity metrics to explore the characteristics of shipping networks. Ports and ships movements are used to build adjacency matrices and study network topology (Hu and Zhu, 2009). Different network metrics that take into account the quantity – the number – of connections have been used to understand local connectivity (that of a specific port or group of ports) and global connectivity in the network. Among these are degree and degree centrality, network density or beta index, alpha and gamma indices, and betweenness centrality (Ducruet et al., 2010). These metrics have been useful to show that the container shipping network is a 'scale-free' network, where a limited number of nodes are highly connected and links among nodes are distributed according to a power-law distribution (Kaluza et al., 2010). The 'scale-free' characteristic reflects the hub-and-spoke organisation of liners shipping networks. Because of this network configuration, large hubs are important at the global scale for global connectivity, while smaller ports are key for connectivity at the regional level (Ducruet and Zaidi, 2012). More recently, the use of multi-layered networks suggested that nodes could have different positions and connectivity levels in a network according to different criteria or relationships linking them, each criterion represented as a layer in a multi-layer network (Boccaletti et al., 2014). In the case of maritime transportation, Kaluza et al. (2010) and Ducruet (2013) suggested that the global shipping network is a multi-layered structure of three classes of cargo ships that spanned distinct subnetworks, with different ports being critical for global connectivity in each layer. Ducruet (2013) also analysed the interdependencies at stage between the maritime transport network and different commodity flows, and found a very strong influence of commodity diversity on the distribution of maritime traffics among ports.

In addition to the metrics that assess connectivity based on the number of connections or links in the network and/or the number of connections available at a specific node in the network, other connectivity metrics have recently been developed to account for the quality of connections. These metrics assess the strength of the connection between two nodes in a network by looking, among other factors, at the capacity of the connection, the level of competition in a connection, or the feasibility of a connection (Burghouwt and Redondi, 2013). For example, Lam and Yap (2011) combined the number of vessels calling at a certain point with the capacity of such vessels in terms of TEUs. UNCTAD (2016) developed the Liner Shipping Connectivity Index (LSCI), which calculates a country's degree of connectivity based on four components: (i) number of containerships calling at the country's ports; (ii) container carrying capacity; (iii) number of shipping companies, liner services and vessels available in a country; and (iv) average and maximum vessel size. In addition, UNCTAD (2016) has just released the Liner Shipping Bilateral Connectivity Index, which estimates connectivity between pairs of countries and apply a threshold to assess the feasibility of a connection between countries according to a maximum number of transshipments allowed between them.

The estimation of connectivity based on the availability and characteristics of transport services relates to a narrow definition of connectivity present in the literature (Marquez-Ramos et al., 2011). In addition to this definition, a broader perspective is emerging. Aside from transport services, this perspective includes infrastructure and trade facilitation procedures as important elements to assess connectivity to international markets (Arvis and Shepherd, 2015). This broader perspective on connectivity is the one endorsed by the studies and programmes commissioned by policy-makers (ITF, 2012). Indeed, literature in International and Transport Economics has provided evidence that trade flows can be critically affected by not only transport services, but also by infrastructure and trade facilitation performance. For example, Clark et al. (2004) estimated that improving port efficiency from the 25th to the 75th percentile reduced maritime freight rates by 12% and raised bilateral trade by 25%. Wilson et al. (2005)